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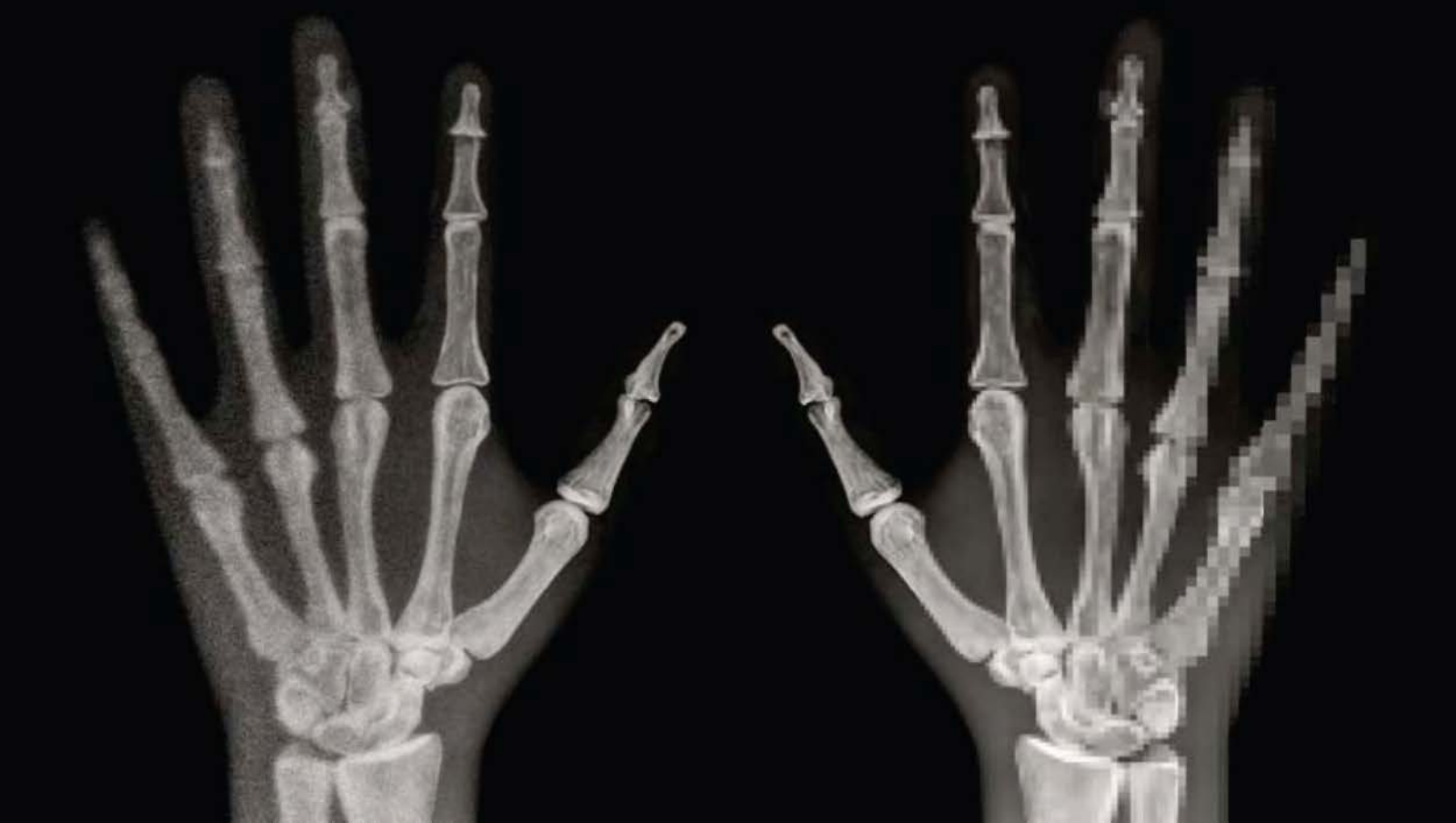
Zbornik predavanj in posterjev kongresa Društva radioloških inženirjev Slovenije

Analogna in digitalna radiološka tehnologija

Ankaran, 18. in 19. maj 2012



PROGRAM 1. KONGRESA RADIOLOŠKIH INŽENIRJEV SLOVENIJE

18.-19. maj 2012, Ankaran

ANALOGNA IN DIGITALNA RADIOLOŠKA TEHNOLOGIJA

Petek, 18.05.2012

9:00 **Registracija udeležencev**

10:00 Otvoritev

10:30 **Prvi sklop predavanj – moderatorja: Valerija Žager, Matjaž Kolar**

10:35 Janez Žibert: Mere kvalitete medicinskih slik, vabljeno predavanje

11:10 Suzana Ljevaja, Boštjan Stražišar, Valerija Žager: Razvoj slikovnih sistemov v radioterapiji

11:30 Odmor

12:00 Marko Zaletelj, Srečko Hlupič: Obsevalne tehnike v radioterapiji danes (IGRT in RapidArc)

12:20 Sponzorsko predavanje: Siemens

12:40 Kosilo

14:40 **Drugi sklop predavanj – moderatorja: Aleš Kukovič, Matevž Čadej**

14:45 Robert Pintarič, Simona Šmigoc: Uporaba računalniško tomografske angiografije in brez kontrastne magnetno resonančne angiografije pri odkrivanju zožitev vratnega ožilja

15:05 Anamarija Kostiov: Vrednosti povprečnih žleznih doz v presejalnem programu Dora in primerjava z vrednostmi povprečnih žleznih doz v tujih presejalnih programih

15:25 Sponzorsko predavanje: FujiFilm

15:45 Odmor

16:20 Brigita Haclar, Katja Podobnik: Manj dodatnih slikanj z digitalno mamografijo?

16:40 Sponzorsko predavanje: Mark Medical

17:00 Elvis Paladin, Aljoša Sabadin, Andrej Lenassi: Prikaz patologije patelofemoralnega sklepa (video predstavitev)

17:10 Zaključek prvega dne

Sobota, 19.05.2012

9:30 **Tretji sklop predavanj – moderatorja: Matej Podsedenšek, Janez Podobnik**

9:35 Michaela Davis: A Cross European Study To Investigate The Ability Of Diagnostic Radiographers In The Republic Of Ireland And Slovenia To Recognise Typical Non Accidental Injury Fractures In Children

9:55 Sabina Steržaj, Adrijana Ravšelj: Prospektivna in retrospektivna računalniško tomografska angiografija koronarnih arterij

10:15 Csaba Vandulek, Zoltan Kovacs, Richard Tokai, Tamas Donko, Zsolt Petrasi, Tamas Foldes Imre Repa: Application Of Radiology In Research And Non-Human Imaging

10:35 Sponzorsko predavanje: Mark Medical

11:00 Odmor

11:30 **Četrti sklop predavanj – moderatorja: Hedvika Šauperl, Zdravko Luketič**

11:35 Dejan Žontar: Digitalizacija v radiološki tehnologiji, vabljeno predavanje

12:05 Dejan Hribar, Nina Djurič, Katarina Šurlan-Popovič: Nizkodozna računalniška tomografija glave pri bolnikih z vstavljeno drenažo

12:25 Barbara Petrinjak, Vesna Muhič: Primerjava analogne in digitalne panoramske ter CBCT slike zob

12:45 Sponzorsko predavanje: Siemens

13:05 **Zaključek kongresa in podelitev nagrad**

13:30 Kosilo

Organizator si pridržuje pravico do spremembe programa zaradi objektivnih okoliščin.

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Popoln vpogled.
Zagotovljen.

Od sistemov za preslikave do povezljivosti radiološke mreže, zagotavljamo več kot le sisteme. Prisluhnemo. Razumemo in s strokovnim znanjem ter dolgoletnimi izkušnjami zagotavljamo pravo in celostno rešitev. Za kakovostne storitve v zdravstvu je potreben popoln vpogled. In mi ga zagotavljamo.

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Analogna in digitalna radiološka tehnologija
Ankaran, 18. in 19. maj 2012

Urednik Biltena:
Nejc Mekiš

Urednik Suplementa:
Gašper Podobnik

Recenzenti:
Gašper Podobnik, Nina Djurić, Janez Podobnik, Aleš Kukovič, Matevž Čadej, Valerija Žager, Matjaž Kolar, Matej Podsedenšek, Hedvika Šauperl, Zdravko Luketič, Tina Starc

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Izdajatelj:
Društvo radioloških inženirjev Slovenije in Zbornica radioloških inženirjev Slovenije

Prevod v angleški jezik:
Jasmina Pelc

Lektura angleškega jezika:
Richard Johnson

Grafično oblikovanje in tisk:
Tisk 24

Naklada:
250

Spoštovane kolegice, spoštovani kolegi,

Veseli nas, da smo uspeli zbrati za objavo v zborniku predavanj in posterjev skoraj vse prispevke, prijavljene za 1. Kongres Društva radioloških inženirjev Slovenije, ki je izšel kot dodatek revije Bilten. Zahvaljujem se vsem avtorjem, ki so pripravili svoje prispevke in tako pomagali oblikovali Zbornik.

Če na vašem oddelku opravljate kakšno raziskavo, uvajate novo metodo dela na področju radiološke tehnologije ali katero koli novost in bi to svoje pridobljeno znanje in izkušnje želeli deliti s kolegi vas vabim, da napišete članek in tako sodelujete pri nastanku naslednjih številk Biltena ali morda zbornikov.

Najlepša hvala in lep pozdrav,

Nejc Mekiš
Urednik Biltena

ERRATA / POPRAVEK

- *V kolofonu je napačno zapisano »Zbornica radiološki …« namesto »Zbornica radioloških inženirjev …«.*
- *V kazalu in v glavah od strani 5 do strani 71, so prispevki pomotoma označeni kot članki.*
- *Znanstveni prispevki na straneh 29, 33 in 46, so pomotoma označeni kot strokovni članki.*

vsebina

ČLANKI

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POVZETKI POSTERJEV

Spoštovani kolegi,

Društvo radioloških inženirjev Slovenije že 58 let deluje na področju povezovanja in izobraževanja svojih članov. To delo sloni na tistih dejavnih članih društva, ki nam je v interesu, da dvignemo strokovno raven našega poklica, ga napravimo bolj prepoznavnega in razvijamo radiološko tehnologijo kot samostojno stroko. Vse to zahteva veliko energije, časa in medsebojnega sodelovanja, vendar se z velikim entuziazmom spopadamo z idejami in načrti, ki jih nato uresničimo.

Z zbornikom predavanj in posterjev 1. Kongresa društva radioloških inženirjev Slovenije, z naslovom Analogna in digitalna radiološka tehnologija društvo razširja in nadgrajuje svoje dosedanje dolgoletno delo na področju izobraževanja radioloških inženirjev.

Želim se zahvaliti vsem, ki aktivno sodelujete v organih društva in tistim, ki ste na kakršen koli način prispevali k organizaciji in izvedbi kongresa.
Vsem pa želim prijetno prebiranje strokovnih člankov ter osebno strokovno rast.

Uroš Gačnik
Predsednik društva radioloških inženirjev Slovenije
Ljubljana, maj 2012

Predgovor

Pred vami so prispevki, predstavljeni na 1. Kongresu radioloških inženirjev Slovenije, na katerem je udeležba mednarodna. Kongres predstavlja še en korak naprej pri razvoju radiološke tehnologije v Sloveniji.

Letos smo prejeli veliko število prijav za aktivno sodelovanje, vendar smo morali, zaradi časovne omejitve med prijavljenimi predavanji izbirati. Izbrali smo predavanja, ki so jih pripravili kolegi iz različnih radioloških oddelkov v Sloveniji ter dve predavanji iz tujine. Izbirali smo tudi tako, da prispevki pokrivajo čim več področij radiološke tehnologije, da so teme raznovrstne.

Lansko leto je profesor Erkki Svedström, predsednik nordijskega združenja radiologov na otvoriti nordijskega kongresa v Mariehamnu na Finskem (kongres je skupen za radiologe in radiološke inženirje) dejal, da si radiologi niso nikoli predstavljali, da bodo radiološki inženirji v tako veliki meri spreminjali stroko na podlagi lastnih strokovnih in znanstvenih raziskav. To je bila potrditev, da radiološki inženirji ne le v Skandinaviji, ampak tudi drugod razvijajo radiološko tehnologijo kot samostojno stroko.

Tudi sam zadnjih nekaj let spremljam strokovne in znanstvene prispevke radioloških inženirjev in opažam velik napredek. Prispevki so tematsko zanimivi, strokovno oblikovani in prinašajo verodostojne rezultate, ki prispevajo k razvoju stroke.

Zato nam je bila vsaka prispela prijava za aktivno sodelovanje na kongresu pomembna. Nekateri še niste vešči pisanja tako, kot zahtevajo pravila (ampak vsak nekje začne in če dela, tudi napreduje), vendar so nam bili malo slabše oblikovani prispevki prav tako dragoceni, ker smo veseli, da sodelujete v čim večjem številu, predvsem tudi tisti, ki so tokrat prvič odločili predstaviti svoje delo. Zato nobene prijave nismo zavrnili, le nekaj tistih, ki so prijavili predavanja, smo prosili, naj jih zaradi časovne omejitve preoblikujejo v plakate. Radiološki inženirji iz vse Slovenije so opravili vlogo recenzentov. Vsi prispevki so bili nato še strokovno lektorirani.

Želim si, da bi zbornik čim večkrat vzeli v roke in ga prelistali. Danes v iskanju strokovnega nasveta, čez leta, ko bo stroka napredovala in bodo ti prispevki zastareli, pa kot lep spomin na prijetno bivanje na slovenski obali spomladi 2012.

Podobnik Gašper
Predsednik strokovne komisije DRI

Strokovni članek

MERE KVALITETE MEDICINSKIH SLIK

Professional Article

ASSESSMENT METRICS FOR MEASURING QUALITY OF MEDICAL IMAGES

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POVZETEK

V prispevku sta predstavljeni dve standardni meri za ocenjevanje kvalitete digitalnih radiografskih slik, funkcija MTF in mera DQE. Funkcija MTF predstavlja amplitudni spekter prevajalne funkcije slikovnega sistema, če ga obravnavamo kot linearni stacionarni sistem, in z njo merimo, kako slikovni sistem spreminja kontrastno razmerje med vhodno in izhodno sliko. Na ta način ocenimo prostorsko ločljivost slikovnega sistema. Z drugo mero, mero DQE, poleg prostorske in kontrastne ločljivosti sistema ocenjujemo kvaliteto slike še ob upoštevanju šuma na slikah. Kontrast, ločljivost in šum na sliki so tudi ključni dejavniki, ki vplivajo na kvaliteto slike. S funkcijama MTF in DQE tako povežemo vse tri količine v skupni meri, s katerima lahko objektivno ocenjujemo in primerjamo kvaliteto različnih slikovnih sistemov in ravno zato se tudi uporabljajo kot standard za kontrolo kvalitete sistemov za zajemanje radiografskih slik.

Ključne besede: mera MTF, funkcija PSF, funkcija LSF, funkcija ESF, razmerje signal/šum, močnostni spekter šuma NPS, mera DQE

ABSTRACT

Paper work presents two standard measures for evaluation of digital x-ray image quality i.e. MTF function and DQE measure. MTF function shows the amplitude spectrum of image system compiling function, if the later is treated as a stationary linear system. The function measures how the imaging system changes the contrast ratio between input and output image. The result is the spatial resolution of the imaging system. The second value i.e. DQE measure enables not only spatial and contrast resolution evaluation but also estimates the quality of images on the basis of noise level. Contrast, resolution and noise are key factors which determine the image quality. MTF and DQE functions combine all three values thus allowing objective comparison of different imaging systems quality. The above functions are therefore standard tools for quality control of radiographic imaging systems.

Key words: modulation transfer function - MTF, point spread function - PSF, edge spread function - ESF, signal to noise ratio - SNR, noise power spectrum - NPS, detective quantum efficiency - DQE.

UVOD

Medicinske slike lahko pridobimo iz različnih slikovnih sistemov, različnih tipov detektorjev in različnih postopkov zajemanja slike. Zato je lahko kvaliteta medicinskih slik različna. Kljub temu pa je včasih potrebno oceniti kvaliteto delovanja posameznih slikovnih sistemov bodisi zaradi primerjave med različnimi sistemi, zagotavljanja učinkovitosti ali pa preverjanja kakovosti delovanja sistemov. Zato je potrebno ovrednotiti kvaliteto slikovnih sistemov z uporabo takšnih postopkov merjenja kvalitete slik, s katerimi lahko objektivno ocenimo kvaliteto posameznih slik in jih lahko uporabimo tudi za medsebojno primerjavo kvalitete med različnimi slikovnimi sistemi.

Ustreznost medicinskih slik lahko ovrednotimo z različnimi parametri. Dve ključni lastnosti, ki vplivata na kvaliteto medicinskih slik, sta prostorska ločljivost slike in šum na slikah (1, 3). Prostorska ločljivost določa velikost najmanjših struktur, ki jih lahko na sliki še vidimo, oziroma določa najmanjši razmik med sosednjimi strukturami na sliki, ki jih lahko še ločimo. Zaznavanje struktur na slikah je odvisno tudi od kontrastnih razlik slikanih objektov in prisotnosti šuma na slikah. Zato mere kvalitete slik vključujejo vse te tri ključne parametre, ki jih lahko na slikah izmerimo.

V nadaljevanju bomo podali teoretične osnove za izpeljavo dveh pomembnih mer kvalitete slik, ki se uporabljajo v digitalni radiografiji, in sicer prevajalne funkcije modulacije (angl. modulation transfer function, MTF), s katero poskušamo ovrednotiti kvaliteto ločljivosti na slikah, in mere DQE (angl. detective quantum efficiency), s katero poskušamo ovrednotiti izkoristek detektorskega sistema glede na kvaliteto pridobljenih slik.

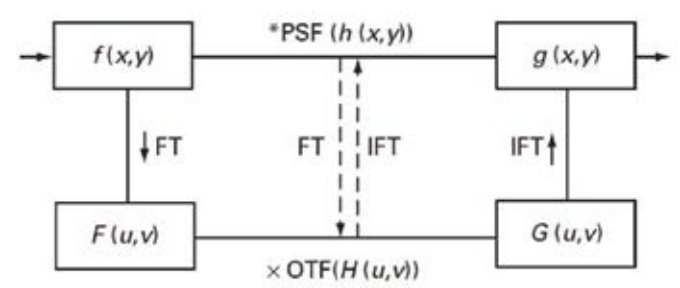
SLIKOVNI SISTEM KOT LINEARNI STACIONARNI SISTEM

Slikovni sistem je sistem, ki na podlagi različnih načinov proizvede sliko slikanega objekta. Tako ga lahko obravnavamo v okviru teorije obdelave signalov kot sistem, ki vhodni signal – slikani objekt – pretvori v izhodni – merjeni – signal, ki v našem primeru predstavlja sliko. To je shematično prikazano na sliki 1.

Slika 1: Slikovni sistem, kot linearni stacionarni sistem, ki vhodni signal f(x,y) pretvori v izhodno sliko g(x,y)

Dvodimenzionalni vhodni signal f(x,y) je slikani objekt, ki ga slikovni sistem pretvori v sliko g(x,y). Zvezo med vhodnim in izhodnim signalom lahko določimo, če predpostavimo linearnost in stacionarnost slikovnega sistema. V tem primeru je zveza med vhodnim in izhodnim signalom podana s konvolucijo s prevajalno funkcijo slikovnega sistema, g(x,y) = f(x,y)*h(x,y), kjer je h(x,y) prevajalna funkcija slikovnega sistema. Prevajalno funkcijo slikovnega sistema imenujemo tudi funkcija razširitve točke (angl. point spread function, PSF), saj predstavlja izhodni signal linearnega stacionarnega sistema (LSS) v primeru, če je vhodna slika sestavljena iz ene same točke, v kateri je zbrana vsa energija vhodnega signala (Barrett in Swindell, 1981). V idealnem primeru, bi bila tudi izhodna slika točka, vendar je to odvisno od samega slikovnega sistema. Običajno se slika točke razmaže in ravno ta razširitev točke vpliva na prostorsko ločljivost slikovnega sistema. Tako funkcija PSF določa prostorsko ločljivosti slik danega slikovnega sistema. Bolj kot se slika točke razmaže, slabša je prostorska ločljivost na sliki. Vendar jo izredno težko neposredno merimo. Za izračun funkcije PSF si tako pomagamo z uporabo Fourierjeve transformacije.

Z uporabo Fourierjeve transformacije se konvolucija med vhodno sliko in funkcijo PSF v sistemu LSS prevede v product med frekvenčnimi predstavitvami slik na naslednji način: G(u,v) = F(u,v).H(u,v), kjer so G, F, H Fourierjeve transformacije slik f, g in h. Tako lahko teoretično izračunamo Fourierjevo transformacijo funkcije PSF, H(u,v), kot kvocient med izhodno in vhodno frekvenčno sliko LSS, torej H(u,v) = G(u,v)/F(u,v). Shematično je to prikazano na sliki 2.

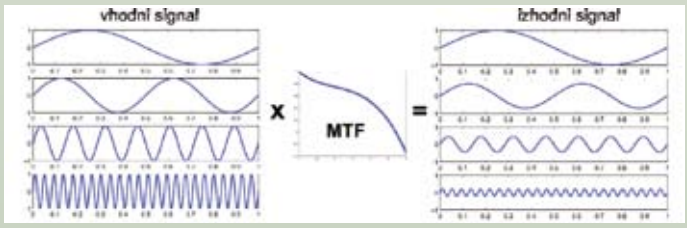


Slika 2: Zveza med vhodno in izhodno sliko LSS z uporabo Fourierjeve transformacije

Z uporabo Fourierjeve transformacije tako lahko izračunamo frekvenčno sliko funkcije PSF, kjer amplitudni spekter funkcije PSF imenujemo prevajalna funkcija modulacije in označimo z MTF. Funkcija MTF tako meri, kako se spreminja amplitudni spekter izhodne slike glede na vhodni amplitudni spekter. Z drugimi besedami, s funkcijo MTF merimo spremembe kontrasta na izhodnih slikah glede na kontrast vhodnega slikanega objekta ob različnih prostorskih frekvencah.

Funkcija MTF

Funkcija MTF predstavlja kvocient izhodnega in vhodnega amplitudnega spektra slik. Na sliki 3 je prikazano delovanje funkcije MTF v primeru enodimenzionalnih signalov.



Slika 3: Prikaz delovanja MTF v eni dimenziji. Funkcija MTF prikazuje spreminjanje amplitude izhodnega signala ob različnih frekvencah (modulacijah) vhodnih signalov

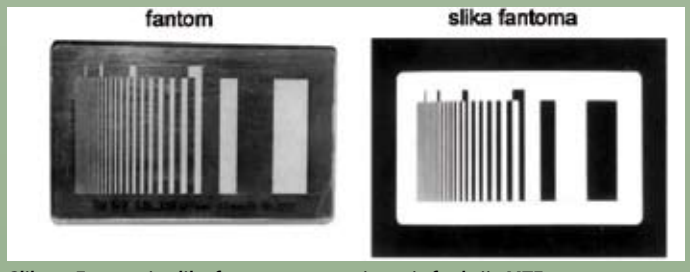
Na sliki 3 so prikazane slike sinusnih sprememb kontrasta v eni dimenziji (v eni smeri na sliki). Vhodni signali imajo enako amplitudo sinusnega valovanja, vendar so se amplitudne izhodnih slik ob različnih frekvencah sinusnih valovanj zaradi narave LSS sistema različno zmanjšale. Pri višjih frekvencah so amplitude izhodnih slik manjše kot pri nižjih. Razmerje med izhodnimi in vhodnimi amplitudami sinusnih valovanj pri različnih frekvencah predstavimo s funkcijo MTF (Giger in Doi, 1984; Dobbins 2000). Vrednosti MTF ležijo na intervalu med 0 in 1.Višje vrednosti funkcije MTF ob določeni frekvenci pomenijo, da slikovni sistem ohranja boljše razmerje med kontrasti vhodne in izhodne slike, kar pomeni boljšo prostorsko ločljivost slik ob tej frekvenci. Višje vrednosti MTF ob višjih frekvencah modulacije tako ustrezajo boljši prostorski ločljivost slikovnih sistemov.

Kot smo že omenili, funkcija MTF predstavlja amplitudni spekter funkcije PSF in torej posredno preko Fourierjeve transformacije opisuje funkcijo PSF. Prednosti ocenjevanja MTF namesto PSF sta predvsem dve: ločljivost slikovnega sistema lahko ocenimo ob različnih prostorskih frekvencah in v primeru, ko je slikovni sistem sestavljen iz različnih komponent (npr. vir energije, detektor energije, analogno-digitalna pretvorba, monitor), se funkcijo MTF celotnega slikovnega sistema lahko določi kot produkt funkcij MTF posameznih komponent.

Postopki določanja MTF

Funkcijo MTF lahko določimo na več načinov (Huang in Hoboken, 2004). Najbolj pogosto se uporabljajo trije postopki določanja MTF: postopek z uporabo slik parov linij na določeno razdaljo, postopek z uporabo slike ene linije in postopek z uporabo slike roba.

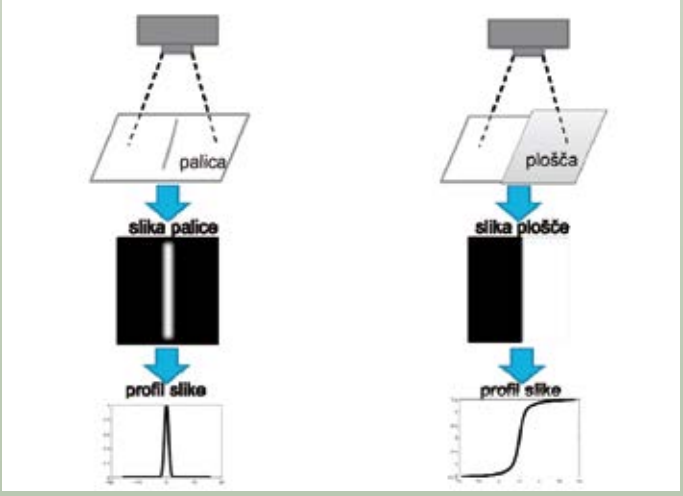
Pri postopku z uporabo parov linij na določeno razdaljo s slikovnim sistemom pridobimo slike parov linij, ki so različno gosto razporejene na vnaprej definirani razdalji. To lahko dosežemo s slikanjem ustreznih fantomov, kot je npr. fantom, ki je prikazan na sliki 4. Nato pa z oceno kontrastnega razmerja na sliki ob različnem številu parov linij na določeno prostorsko enoto ocenimo potek funkcije MTF.



Slika 4: Fantom in slika fantoma za ocenjevanje funkcije MTF

To je razmeroma enostaven postopek za izračun MTF, vendar ocenimo funkcijo MTF samo ob določenih frekvencah, kot so izvedene na slikanem fantomu in ne na vseh možnih frekvencah, kot je to definirano v funkciji MTF.

Druga dva postopka nimata tovrstne omejitve. Postopka z uporabo slike linije in slike roba sta predstavljena na sliki 5.



Slika 5: Levo: postopek ocenjevanja MTF sfunkcijo razširitve linije (LSF). Desno: postopek ocenjevanja MTF sfunkcijo razmazanosti roba (ESF)

Postopek ocenjevanja MTF z uporabo slike ene linije (slika 5, levo) in postopek z uporabo slike roba (slika 5, desno) sta sorodna postopka. Pri postopku ocenjevanja MTF z uporabo slike ene linije slikamo eno palico, ki je vzporedna z eno od osi slikanja in nato opazujemo profil slike palice. Zaradi lastnosti slikovnega sistema se slika linije razširi, zato tako sliko imenujemo tudi funkcija razširitve linije (angl. line spread function, LSF). MTF dobimo, če izvedemo Fourierjevo transformacijo profila slike razširitve točke, torej funkcije LSF. Na ta način lahko ocenimo MTF po celotnem frekvenčnem spektru slikovnega sistema in ne samo za določeno frekvenco, kot je bilo to v prvem postopku.

Podobno ocenimo MTF tudi z uporabo slike roba. V tem primeru slikamo ploščo, ki ima oster rob. Profil slike roba je prikazan na sliki 5, desno spodaj. Tudi slika roba zaradi lastnosti slikovnega sistema ne ustreza stopnici, kot bi morala, ampak se razmaže, zato taki sliki pravimo funkcija razmazanosti roba (angl. edge spread function, ESF). Iz funkcije ESF lahko dobimo funkcijo LSF z odvajanjem funkcije roba, funkcijo MTF pa nato dobimo s Fourierjevo transformacijo funkcije LSF.

Z uporabo zgornjih metod lahko ocenimo MTF samo v eni smeri. Če hočemo oceniti MTF še v drugi smeri (npr. po y-osi), moramo fantome slik iz vseh treh metod ustrezno rotirati in nato ponovno izvesti postopke ocenjevanja MTF.

ŠUM NA SLIKAH

Funkcijo MTF se pogosto uporablja kot mero kvalitete medicinskih slik, saj z njo merimo kvaliteto prostorske ločljivosti slikovnega sistema, vendar na kvaliteto slik vpliva tudi prisotnost šuma na slikah (Dobbins, 200). Šum na sliki predstavlja vsa odstopanja na sliki, ki ne ustrezajo slikanemu objektu. Večja kot so odstopanja od slikanih objektov na sliki, slabša je sposobnost zaznavanja teh objektov na sliki. Proces dodajanja šuma na slike lahko obravnavamo kot naključen proces, ki ni odvisen od slikanih objektov, ampak kvečjemu od slikovnega sistema. Tako lahko obravnavamo šum kot naključni pojav, ki ni odvisen od signala slike.

Tipi šumov na slikah

Na medicinskih slikah se pojavlja več vrst šumov, ki nastanejo zaradi različnih dejavnikov. Na digitalnih radiografskih slikah se največkrat pojavljata dva tipa šumov: kvantni šum, ki je posledica interakcije elektromagnetnega valovanja s snovjo, in šum, ki ga povzročajo elektronske naprave pri zajemu in obdelavi slike.

Kvantni šum je posledica naključnega spreminjanja števila fotonov, ki v času zajemanja slike padejo na izbrani slikovni element. Kvantni šum ima lastnosti Poissonovega procesa, kar pomeni, da je standardni odklon šuma v signalu za vsak slikovni element enak kvadratnemu korenu povprečja signala, ali z drugimi besedami, višina kvantnega šuma je sorazmerna s kvadratnim korenom števila fotonov, ki padejo v danem trenutku na slikovni element. To pa pomeni, da z naraščanjem intenzitete signala narašča tudi šum, vendar počasneje od naraščanja signala (s kvadratnim korenom od intenzitete signala), zato njegov vpliv na kvaliteto slike upada. To pomeni, da se prisotnost šuma glede na signal zmanjša, če povečamo obsevanost pri zajemu radiografske slike.

Elektronske šume modeliramo kot aditivne Gaussove šume. V tem primeru merjeni signal lahko zapišemo kot vsoto osnovnega signala in Gaussovega šuma s povprečjem 0 in konstantno varianco, kar pomeni, da osnovni signal spreminjamo tako, da mu dodajamo vrednosti, ki so normalno porazdeljene okrog povprečja 0. Konstantna varianca nam zagotavlja, da moč šuma ostaja enaka ne glede na moč signala.

Šum, kontrast, ločljivost

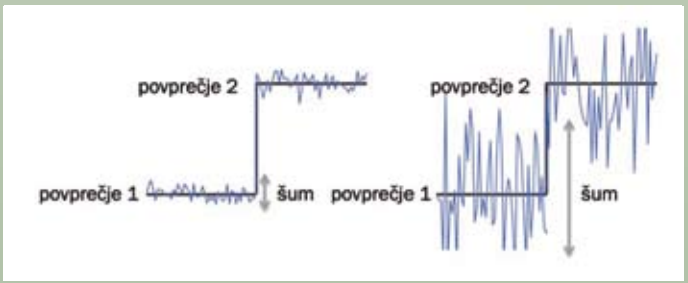
Količino šuma na sliki najpogosteje podajamo z razmerjem signal-šum (angl. signal to noise ratio, SNR) (Bourne, 2010). Razmerje SNR računamo kot kvocient med močjo signala slike in močjo signala šuma. Pri slikah običajno izračunamo razmerje kot kvocient med povprečjem sivinskih nivojev na sliki in standardnim odklonom odstopanj na sliki, ki jih ocenimo iz homogenih področji na sliki. Shematično je to prikazano na sliki 6, kjer signal slike predstavimo s povprečjem, šum pa z varianco (oziroma standardnim odklonom) odstopanj od povprečja signala na področju, kjer se pričakujejo konstantne vrednosti signala.

Slika 6: Osnovni signal na sliki (označen z ravno črto), pošumljeni signal; razmerje SNR se izračuna kot kvocient standardnega odklona šuma in povprečja signal.

Primer razmerja SNR pri kvantnem šumu (Bourne, 2010), ki se porazdeljuje po Poissonovi porazdelitvi, lahko izračunamo na naslednji način. Če je povprečna količina fotonov, ki pade na neko področje, enaka q, potem je standardni odklon količine fotonov na enako velikih področjih po Poissonovi porazdelitvi enak √. Tako lahko razmerje SNR izračunamo kot $SNR = q/\sqrt{q} = \sqrt{q}$.

Večje kot je razmerje SNR, manj šumna je slika. Razmerje SNR lahko povečamo s povečanjem moči signala, kar v radiologiji pomeni, da povečamo obsevanost pacienta, ali pa s povprečenjem več enakih slik (kar tudi pomeni povečano obsevanost zaradi pridobivanja več slik) oziroma z ustreznim filtriranjem slike, s čimer sicer zmanjšujemo prisotnost šuma, vendar običajno zgubimo na ostrini slike.

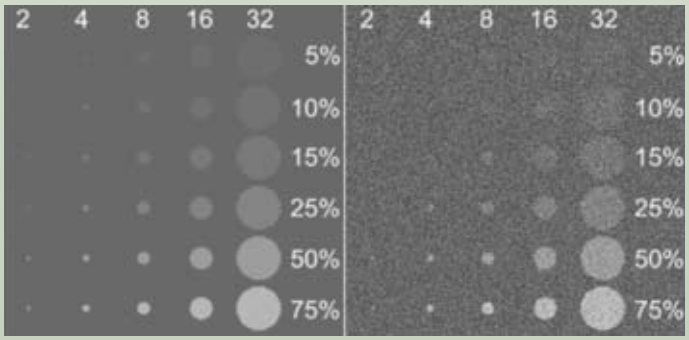
Za razločevanje struktur na sliki je pomembna predvsem razlika v svetlosti med bližnje ležečimi strukturami na sliki. To razliko med signali imenujemo kontrast. Večja kot je razlika med signali sosednjih struktur na sliki, večji je kontrast slike. Vendar šum lahko znatno vpliva na kontrastno ločljivost na sliki. To je shematično prikazano na sliki 7.



Slika 7: Dva primera pošumljenih signalov. Levo je primer, ko je razlika med signaloma 1 in 2 večja, kot so odstopanja zaradi šuma. V tem primeru lahko še vedno ločimo signal 1 in 2. Desno je primer, ko je razlika med signaloma enaka kot v levem primeru, vendar so odstopanja zaradi šuma večja in signalov ne moremo več ločiti

V primeru, ko je razlika med signaloma (povprečjema signalov) večja, kot so odstopanja zaradi šuma (standardni odklon šuma), lahko še ločimo intenziteto obeh signalov na sliki, v primeru, ko pa so odstopanja šuma večja od razlike med signaloma, pa signalov ne moremo več ločiti. To pomeni, da je za kontrastno ločljivost prisotnost šuma zelo pomembna in če je odstopanje šuma večje od razlik med signali to znatno vpliva na zaznavanje elementov na sliki. Zato se pogosto uporablja za mero kvalitete slike namesto razmerja SNR tudi razmerje med kontrastom in šumom na sliki, kar imenujemo razmerje contrast-šum (angl. contrast to noise ratio, CNR) in ga računamo kot kvocient razlike povprečij ozadja in ospredja na sliki (v primeru na sliki 7 kot razliko povprečja1 in povprečja2) in standardnim odklonom šuma, ki ga prav tako kot pri SNR ocenimo iz odstopanj na homogenih delih slike (Bourne, 2010).

Kako so povezani kontrast, prostorska ločljivost in šum na sliki je prikazano na sliki 8.



Slika 8: Slika za testiranje kontrastne in prostorske ločljivosti: levo je nepošumljena slika, desno je pošumljena slika z Gaussovim šumom s standardnim odklonom 15

Na sliki 8 sta prikazani sliki, ki jih uporabljamo za testiranje kontrastne in prostorske ločljivosti. Na desni strani je prikazana leva slika, ki smo jo pošumili z Gaussovim šumom s standardnim odklonom 15 sivinskih nivojev. Kot lahko vidimo, se zaradi šuma zmanjša ločljivost krogov, ki so manjši in kontrastno bližje ozadju slike, kar ustreza naši ugotovitvi, da je zaznavnost strukture na sliki odvisna od prostorske in kontrastne ločljivosti slikanih objektov in prisotnosti šuma na slikah. Zato je potrebno pri meri za kvaliteto slike upoštevati vse te tri količine.

Mera DQE

Da bi v končni meri kvalitete slike zajeli vse tri količine, ki vplivajo na zaznavnost objektov na medicinskih slikah, je potrebno pretvoriti vse te količine v frekvenčni prostor slike. V frekvenčnem prostoru smo že definirali prevajalno funkcijo modulacije MTF, ki v odvisnosti od prostorske frekvence podaja razmerje med detektiranim izhodnim kontrastom (amplitudo) in vhodnim kontrastom, torej meri prostorsko ločljivost s pomočjo kontrasta v frekvenčnem prostoru. Tako moramo predstaviti še šum v frekvenčnem prostoru slike. To se naredi na enak način kot pri MTF, s pretvorbo slike šuma (ponavadi je to kar slika praznega prostora – zraka ali vode, kjer lahko predvidevamo homogeno ozadje) s Fourierjevo transformacijo v frekvenčni prostor slike. Če podobno kot pri MTF vzamemo amplitudni spekter takšne slike, dobimo amplitudni spekter šuma. Ponavadi pa vzamemo kar kvadrat amplitudnega spektra šuma in ga imenujemo močnostni spekter šuma ali NPS (angl. noise power spectrum) (Dobbins, 2000). Tudi NPS je tako odvisen od prostorske frekvence slike.

Tako lahko zapišemo kvadrat razmerja SNR v odvisnosti od frekvence f kot kvocient moči signala na kvadrat, ki ga lahko predstavimo s produktom moči signala S in prostorske ločljivosti MTF(f), ter kvadratom standardnega odklona ali varianco šuma, ki jo predstavimo z NPS(f). S formulo to zapišemo kot SNR2(f) = S2 . MTF2(f)/ NPS(f). Razmerje ima podobno razlago kot prej, če moč signalaS2 (ob enakih ostalih količinah) povečamo, bo razmerje SNR višje, torej bomo imeli manj šumne slike, po drugi strani se bo razmerje manjšalo sorazmerno z manjšanjem vrednosti MTF v odvisnosti od frekvence f ob konstantnem NPS(f). Na drugi strain, če je močnostni spekter šuma velik, pa je ob enakih pogojih detektorja razmerje SNR(f) manjše.

Zato pri merjenju kvalitete slikovnega sistema lahko tudi gledamo, kako se spreminja razmerje SNR izhodnega signala glede na razmerje SNR vhodnega signala ob različnih prostorskih frekvencah. Mero, ki podaja to razmerje v frekvenčnem prostoru, imenujemo DQE (angl. detective quantum efficiency) in jo izračunamo kot $DQE(f) = SNR^2_{out}(f)/SNR^2_{in}(f)$. Pri meri DQE lahko uporabimo podobno razmišljanje kot pri izračunu prevajalne funkcije modulacije MTF, saj gre za izračun prevajalne funkcije sistema LSS v frekvenčnem prostoru, kjer sta vhodni in izhodni signal podana kot razmerje med signalom in šumom. To je shematično prikazano na sliki 9.

Slika 9:Mero DQE izračunamo kot razmerje med izhodnim SNR in vhodnim SNR v frekvenčnem prostoru slike, če slikovni sistem obravnavamo kot LSS

Mera DQE tako pove, koliko se razmerje signal šum poslabša pri prenosu skozi slikovni sistem. Vhodno razmerje SNR^2in lahko obravnavamo tudi kot idealno razmerje, ki ga lahko slikovni sistem bodisi ohrani ali pa poslabša, kar merimo z izhodnim razmerjem SNR^2_{out}. To z drugimi besedami tudi pomeni, da so vrednosti mere DQE vedno na intervalu med 0 in 1, kjer 1 pomeni, da smo vhodno razmerje SNR v celoti ohranili. Manjše vrednosti pomenijo slabšo kvaliteto slikovnega sistema.

Vhodno razmerje SNRin je neodvisno od prostorske frekvence in predstavlja v radiografskih sistemih razmerje med signalom in kvantnim šumom, ki ga modeliramo s Poissonovo porazdelitvijo. To razmerje smo že ocenili v prejšnjem poglavju, kjer smo izračunali $SNR_{in} = \sqrt{q}$, kjer je q povprečno število fotonov, ki pade na določeno površino. Izhodno razmerje signal šum pa podamo s $SNR^2_{out}(f) = S^2MTF(f)/NPS(f)$. Tako lahko mero DQE izračunamo kot (International Electrotechnical Commission, 2003):

$$DQE(f) = \frac{SNR^2_{out}}{SNR^2_{in}} = \frac{S^2 \cdot MTF(f)}{q \cdot NPS(f)}$$

kjer je S2 moč signala, ki ga ocenimo na dovolj velikem področju slike, q je povprečje števila fotonov na določeni površini, ki je lahko že vnaprej podana oziroma določena glede na količino rentgenskega sevanja. Mero MTF ocenjujemo s postopki, ki smo jih opisali v prejšnjem poglavju. Močnostni spekter šuma NPS pa ocenjujemo s povprečenjem močnostnega spektra šuma, ki ga ocenjujemo na prekrivajočih se področjih šumne slike. V ta namen šumno sliko razdelimo na več manjših prekrivajočih se podslik in na vsaki taki podsliki izračunamo močnostni spekter šuma podslike, iz katerih potem izračunamo skupni povprečni močnostni spekter šuma, ki ga uporabljamo za izračun DQE. Tudi tu imamo mero DQE podano za prostorske frekvence v samo eni smeri, vendar je za potrebe ocene kvalitete slik potrebno podati vrednosti DQE tudi v prostorskih frekvencah drugih smeri, kar storimo podobno kot pri oceni MTF.

V splošnem velja, višje kot so vrednosti mere DQE pri različnih prostorskih frekvencah, boljši izkoristek ima slikovni sistem, kar pomeni, da lahko ob manjši količini sevanja pridobimo slike enake kvalitete glede na prostorsko in kontrastno ločljivost.

ZAKLJUČEK

V prispevku smo podali dve osnovni meri za kvaliteto medicinskih slik, ki se uporabljajo v radiologiji in sicer mero MTF in mero DQE. Z mero MTF merimo kvaliteto slikovnega sistema glede na prostorsko in kontrastno ločljivost, z mero DQE pa povežemo ločljivost sistema s prisotnostjo šuma na sliki. Kontrast, ločljivost in šum na sliki so tudi ključni dejavniki, ki vplivajo na kvaliteto slike. S funkcijama MTF in DQE tako povežemo vse tri količine v skupni meri, s katerima lahko objektivno ocenjujemo in primerjamo kvaliteto različnih slikovnih sistemov in ravno zato se tudi uporabljajo kot standard za kontrolo kvalitete sistemov za zajemanje radiografskih slik.

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Strokovni članek

RAZVOJ SLIKOVNIH SISTEMOV V RADIOTERAPIJI

Professional Article

DEVELOPMENT OF IMAGING SYSTEMS IN RADIOTHERAPY

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POVZETEK

Uvod: Za zagotavljanje kakovosti in natančnosti zdravljenja pacientov se v radioterapiji (RT) uporabljajo slikovni sistemi, ki omogočajo določanje lege pacienta in verifikacijo obsevalnih polj. Z razvojem novih obsevalnih tehnik, obsevalnih aparatov in slikovnih sistemov se je kvaliteta obsevanja izboljšala.

Namen: V članku so predstavljeni slikovni sistemi v RT nekoč in danes, njihov razvoj in prispevek k kakovosti dela.

Metode dela: Narejen je bil pregled domače in tuje strokovne literature na področju razvoja slikovnih sistemov v RT ter meritve premikov izocentra s pomočjo portalnih slik (slike zajete na slikovno ploščo) na primeru pacienta z rakom v področju glave in vratu (ORL), na obsevalnem aparatu Clinac (Varian) DBX-SN1058.

Rezultati in razprava: Pri obsevanju s konvencionalno (klasično) tehniko dveh opozitnih polj in verifikacijo obsevalnih polj z radiografskim filmom se je natančnost meje obsevalnega polja lahko določila do približno 5 mm natančno. S prehodom na tridimenzionalno (3D) vrisovanje tarčnih volumnov in tehniko intenzitetno modulirane radioterapije (IMRT), se je tolerančna meja obsevalnega polja zmanjšala na 3 mm. Dobljeni rezultati so med sabo primerljivi, tudi z mednarodno študijo na bostonskem Inštitutu za onkologijo.

Zaključek: Z razvojem digitalnih slikovnih sistemov in obsevalnih tehnik v RT se je znatno izboljšala natančnost obsevanja tumorskega volumna in varovanje zdravega okolnega tkiva. S tem se je dosegla tudi boljša natančnost obsevanja pri ORL pacientih.

Ključne besede: radioterapija, slikovni sistemi, verifikacija, kakovost

ABSTRACT

Introduction: To assure quality and accuracy of patient treatment in radiotherapy, imaging systems are used for determination of patient's position and verification of treatment fields. Quality of radiotherapy treatment has improved due to development of new treatment techniques, treatment devices and imaging systems.

Aim: The following article presents past and present imaging systems used in radiotherapy, their development and contribution to work quality.

Methods: Review of foreign and domestic literature on development of imaging systems used in radiotherapy has been made as well as a case study of a patient with head and neck cancer, treated on a Clinac (Varian) DBX-SN1058 treatment machine, along with measurements of isocenter movements, based on portal images.

Results and discussion: Treatment with conventional technique using two opposite fields followed by verification of treatment fields with radiographic film resulted in 5 mm accuracy of irradiated treatment field. With the transition to three dimensional contouring of target volumes and IMRT (Intensity-Modulated Radiation Therapy) technique, the acceptable tolerance has decreased to 3 mm. The obtained study results are comparable with international study of Boston Institute of Oncology.

Conclusion: With development of digital imaging systems and treatment techniques, the accuracy of treating tumour volume and protecting healthy surrounding tissue in radiotherapy treatment has significantly improved. With these steps, better quality and higher accuracy have been achieved in treatment of head and neck cancer.

Key words: radiotherapy, imaging systems, verification, quality

UVOD

V RT se za določevanje in sledenje lege pacienta in preverjanje načrtovanega in dejanskega položaja obsevalnega polja uporabljajo različni slikovni sistemi. Ti so se razvijali skupaj z razvojem računalniške tehnologije, razvojem obsevalnih naprav in pripadajoče računalniške opreme. V današnjem času se v RT pojavlja vedno večja potreba po geometrični natančnosti obsevalnega polja. Tumorski volumen je potrebno obsevati z največjo dozno obremenitvijo in pri tem ohraniti zdravo okolno tkivo (Kirby

and Glendinning, 2006). Razvijajo se tehnike obsevanja, s katerimi so doseženi boljši končni rezultati zdravljenja. Tradicionalni radiografski film v klasični kaseti in CR (computed radiography) sistem, ki predstavlja prehod med analogno in digitalno tehniko, sta se uporabljala pri obsevanju s tehniko dveh opozitnih polj (Webb, 1993; Langmack, 2001; Haus, 1998; Wilenzick et al.,1987; Scheck et al.,1993). Danes se pri obsevanju z IMRT uporablja preverjanje obsevalnih polj z AMFPI (Active Matrix Flat Panel Imager) detektorjem, ki je del robotske roke in sestavni del linearnega pospeševalnika. V članku bomo predstavili razvoj slikovnih sistemov v RT in na primeru prikazali pomen njihove uporabe. Obsevanje z IMRT tehniko in primerjava izocentra DRR (digitalni rekonstrukcijski radiogram) slike s portalno sliko (slika zajeta na slikovno ploščo) v področju glave in vratu je opisana v številnih študijah. Na podlagi primerjave rezultatov premikov izocentra s portalnimi slikami, ki smo jih naredili na obsevalnem aparatu Clinac (Varian) DBX-SN1058 z rezultati študije Court et al. (Court et al., 2008), so premiki izocentra po kontrolnem portalnem slikanju v anteroposteriorni (AP), infero-superiorni (INF-SUP) ter medialni smeri primerljivi z našimi meritvami in izračuni. Tako je možna tudi primerjava kvalitete delovnih postopkov. Z rezultati bomo dokazali, da je uporaba sodobnih slikovnih sistemov za preverjanje položaja lege pacienta pripomogla k manjšim premikom izocentra pri obsevanju ORL področja v primeru, če so le-ti potrebni.

METODE DELA

Razvoj slikovnih sistemov v RT

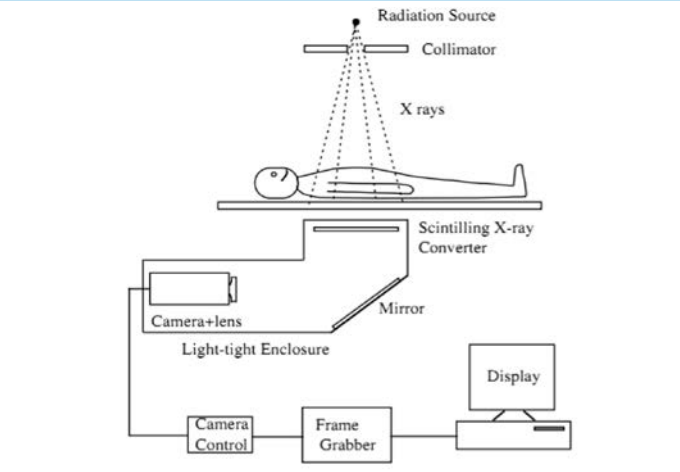
Zgodovina slikovnih sistemov je bila zelo razgibana. Velika mera iznajdljivosti in inovativnosti se je pokazala pri razvoju elektronskih portalnih sistemov, vse od poznih 50-ih let

Tabela 1: Tehnološke različice elektronskih portalnih sistemov (Antonuk, 2002)

Opis sistema	*Žarkovni detektor*	*Organizacija*	*Reference*
Optični sistemi 2D prostorski detektor			
Scintilacijska kamera + ojačevalec rentgenske slike	*Fluorescentni zaslon*	*Chalmers University of Technology*	*(Wallman 1958 po Munro 1995, 1999)*
+ zrcalo in leče	*Fluorescentni zaslon*	*NCI, Bethesda*	*(Andrews 1958 po Webb 1993, Munro 1995, 1999, Herman 2001)*
+ zrcalo in leče	*Kovinska plošča in fluorescentni zaslon*	*University of Goteborg*	*(Benner 1962 po Boyer1992 Webb 1993, Munro 1995,1999)*
+ zmanjševalec slike z optičnimi vlakni	*Kovinska plošča in fluorescentni zaslon*	*Washington University*	*(Wong 1990 po Boyer 1992, Webb1993)*
+ zrcalo + segmentni scintilator	*Kovinska plošča + segmentni kristali CsI(TI)*	*Royal Marsden*	*(Mosleh-Shirazi 1998)*
+ zrcalo + prozorni scintilator	*Prozoren kristal CsI(TI)*	*University of Tennessee*	*(Zemman 1998, Sawant et al., 2002)*
Indirektna detekcija, aktivno matrični ploskovni detektor	*Kovinska plošča + GdO2S2:Tb zaslon*	*University of Michigan*	*(Antonuk 1991a, 1992a, 1998a po Boyer 1992, Munro 1995, 1999, Antonuk 1998b)*
1D prostorski detektor Scintilacijski kristal-fotodiodni detektor	*ZnWO4 kristal*	*Royal Marsden*	*(Morton 1988, Morton 1991 po Boyer 1992, Webb 1993)*
Scintilacijski kristal-fotodiodni detektor	*CsI(TI) kristal*	*Royal Marsden*	*(Symonds-Tayler 1997)*
Neoptični sistemi			
2D prostorski detektor Plinsko elektronska pomnoževalka	*Kovinske plošče*	*Karolinska instituten*	*(Brahme 2000, Ostling 2000, Iacobaeus 2001)*
1D prostorski detektor visokovoltažni usmernik diodni zbiralec	*Pb trak + diode*	*John Hopkins*	*(Taborsky 1982, Lam 1986, 1987 po Boyer 1992, Webb 1993)*
Fotovoltažni detektor	*CdTe diode*	*RMD + MGH*	*(Entine 1992, 1993)*
Matriks z ionizacijkso tekočino	*Kovinska plošča + iso-oktan*	*NKI*	*Meertens 1985, van Herk 1991po Boyer 1992, Herman 2001)*
Kinetični detektor	*cca.100 atm Xe plina*	*University of Tennessee*	*(Meertens 1985, van Herk (DiBianca 1997, Samant 1999)*

prejšnjega stoletja do danes. Povzetek tehnoloških različic je prikazan v tabeli 1. Vidimo lahko razdelitev tehnologij optičnih in ne optičnih sistemov. Za slednje je značilno, da ne proizvajajo svetlobe. Razdelitev je narejena tudi med tehnologijami, ki so istočasno občutljive na celotno obsevalno polje (2D prostorski detektorji) in med linearnimi detektorji. Pri 2D prostorskih detektorjih pretvorba X-žarkov temelji na simultani detekciji in omogoča veliko boljši izkoristek sevanja. Pri teh slikah je v primerjavi z linearnimi sistemi veliko boljša kvaliteta pri enakih ali nižjih dozah (Antonuk, 2002).

Strokovnjaki so razvijali portalne sisteme z različnimi pristopi. Andrews et al. (1958), so predstavili fluorescentni zaslon, ki je bil povezan z Orthicon kamero s kombinacijo ogledalo-leča. Ta tehnološki pristop so kasneje nadgradili s pomembnim dodatkom kovinske plošče pred fluorescentnim zaslonom (Benner et al., 1962), kar je znatno zvišalo zanimanje za optično kombinacijo kovinska plošča/fluorescentni zaslon in kamera/ogledalo-leča. Omenjeni pristop je pomenil uvod v uporabo relativno moderne strojne opreme slikovnih sistemov in je bil nadalje razvit ter izpopolnjen skozi tehnične, teoretične in klinične študije številnih projektnih skupin (Antonuk, 2002). Razvitih je bilo veliko različic osnovnega modela s kamero (slika 1).



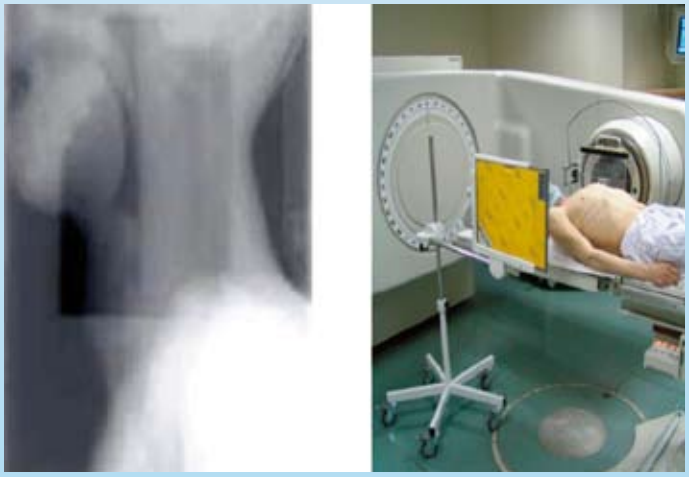
Slika 1: Različica osnovnega modela s kamero (Antonuk, 2002)

V letih, ki so sledila, so raziskave potekale na področju povišanja učinkovitosti detekcije X-žarkov (in posledično kvantne učinkovitosti) pri sistemih, opremljenih s kamero in sicer z nadomeščanjem fluorescentne plošče s pretvorniki kot je npr., CsI (T1) kristal (Zeman et al., 1998, Sawant et al., 1999) ali pa s Cs (T1) kristali (Mosleh-Shirazi et al., 1998a, 1998b).

Leta 1987 so raziskovalci iz Univerze v Michiganu in podjetja XEROX, PARC po vzorcu začetne ideje predstavili komercialno dostopno, alternativno dvo-dimenzionalno optično tehnologijo za portalno slikanje (Antonuk, 2002). Ta tehnologija temelji na tankem sloju filmske elektronike, podobno kot pri aktivni matrici. Zasloni s tekočimi kristali so ponujali mnoge prednosti v primerjavi z obstoječimi komercialnimi EPID (Electronic Portal Imaging Device) sistemi in konvencionalnimi radioterapevtskimi filmskimi sistemi, vključujoč mnogo boljšo kvaliteto slike. Razvoj je bil večinoma usmerjen v optične EPID sisteme. Ne-optični sistemi, ki so bili razviti v zgodnjih osemdesetih letih prejšnjega stoletja, so temeljili na skeniranju linearne palete silikonskih diod (Taborsky et al., 1982, Lam et al., 1986, 1987).

Radiografski film

Radiografski film je bil dolgo časa tradicionalen medij za verifikacijo obsevalnih polj. Najprej so bile slike pridobljenje z industrijskimi, direktno eksponiranimi filmi, ki so bili vstavljeni v kartonski model in so zahtevali posebne tehnike razvijanja v temnici (slika 2). Leta 1974 je podjetje Kodak predstavilo »Kodak Ready-Pack« filme. Slike so bile razmeroma dobre kvalitete. Za izboljšanje kontrastnosti slike so se pričeli uporabljati EC-L sistemi (Kodak), ki namesto elektronov uporabljajo svetlobo za ekspozicijo filma. Sistem je bil zasnovan posebej za radioterapijo (http://carestream.com/ecl_film_system_portal_imaging.html).



Slika 2: Verifikacija obsevalnih polj z radiografskim filmom (Onkološki inštitut, Ljubljana)

CR sistem

CR sistemi so bili prvič predstavljeni v prvi polovici 80-ih let prejšnjega stoletja in predstavljajo prehod med analogno in digitalno tehniko slikanja (slika 3). Film je zamenjala približno

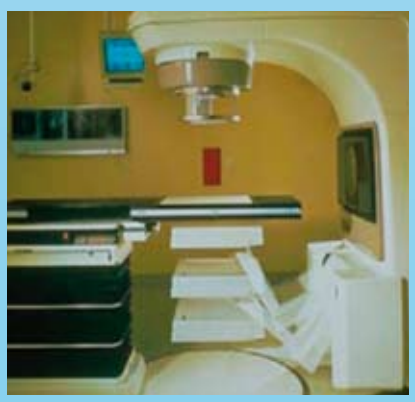
Slika 3: CR sistem (Kodak ACR-2000i, Onkološki inštitut, Ljubljana)

1 mm debela fotostimulacijska fosforescenna plošča (Kirby and Glendinning, 2006). CR sistem se uporablja pri pripravi pacienta na obsevanje na konvencionalnem simulatorju, lokalizaciji, verifikaciji in pri kontroli kvalitete (Žager, 2009). Določanje položaja pacienta in lokalizacijo obsevalnih polj omogoča dobra resolucija slike z velikostjo piksla 0,255 mm. Digitalno pridobljene slike lahko na računalniškem monitorju dodatno obdelujemo, tiskamo ali prenašamo na druge medije.

Elektronski slikovni sistemi

Prvi elektronski slikovni sistemi so bili opremljeni s kamero. Trije od teh sistemov so bili tudi komercialno dostopni, in sicer od proizvajalcev Siemens (»Beamview«), Infimed (»Theraview«) ter Philips/Elekta (»SRI-100/iView) (Kirby and Glendinning, 2006). Princip delovanja je bil podoben kot pri radiografskem filmu. Pretvorba X-žarkov poteka na kovinski plošči (1 - 2 mm bakra, jekla ali medenine), vezani na fluorescentno snov različnih debelin. Pri interakciji z X-žarki na plošči nastajajo visokoenergijski elektroni. Kovinska plošča filtrira tudi nekatere sipane X-žarke in elektrone nizkih energij, ki bi sicer zmanjšali kontrastnost slike. Fluorescentna snov pretvori elektrone visokih energij v svetlobo. Svetloba prehaja skozi fluorescentno snov na kameri in se prezrcali preko serije ogledal v leče kamere. Kamera nato pretvori sliko v video signal, ki se prenese preko elektronike v računalniški sistem (Kirby and Glendinning, 2006). Glavna prednost teh sistemov je hkratni prikaz celotne slike, zelo hitro pridobivanje slike, dobra prostorska ločljivost ter cenovno dostopen sistem, ki je preprost za vzdrževanje. Praktično pomanjkljivost je najprej predstavljala velikost sistema, kar je lahko moteče pri uporabi naprave in pri dodatnih nastavitvah pacienta.

Elektronski slikovni sistem, ki deluje na podlagi matrice z ionizacijsko tekočino so zasnovali in prvič uporabili na Nizozemskem v osemdesetih letih prejšnjega stoletja, v komercialno prodajo pa je prišel v zgodnjih devetdesetih (slika 4). Deluje na principu ionizacijske komore, sestavljene iz dveh delov elektrod, ki sta razmaknjeni za 0,8 mm. Reža med elektrodama je napolnjena z organsko tekočino (2,2,4-trimetilpentan), ki med ekspozicijo deluje kot ionizacijski medij. Ioni, ki nastanejo v tekočini, se zberejo na 256 elektrodah, na vsakem elektrodnem delu. Te elektrode so med seboj razmaknjene za 1,27 mm. Postavitev elektrod je pravokotna in tvori 256^2 matrico. Glavne prednosti tega sistema za komercialno uporabo so bile kompaktnost in praktičnost (Kirby and Glendinning, 2006).



Slika 4: Elektronski slikovni sistem, ki deluje na principu matrice z ionizacijsko tekočino (http://www-naweb.iaea.org/NAHU/DMRP/documents/Chapter12.pdf)

Slikovna plošča z aktivno matrico

AMFPI so leta 1987 razvili znanstveniki z Univerze Michigan, Xerox PARC in tudi drugod po svetu. Indirektna detekcija z AMFPI prikazovalniki predstavlja glavno smer pri razvoju portalnega slikanja, saj omogoča izboljšano kvaliteto slike in predstavlja velik potencial za dozimetrično uporabo. AMFPI sistem spada v drugo generacijo EPID sistemov in je komercialno dostopen od leta 2000 (slika 5, slika 6). Sistem je sestavljen iz številnih manjših podsistemov. Za pretvorbo začetne naključne energije X-žarkov obstajata dve glavni metodi, indirektna in direktna. Danes vsi komercialni AMFPI sistemi uporabljajo indirektno detekcijsko metodo. Pridobivanje slike je hitrejše (do 10 slik v sekundi), njena dinamična vrsta je do 16 bitov, velikost matrike do 1024 x 1024 in velikost slikovnega polja do 41 cm x 41 cm.

Nastanek slike običajno poteka sinhronizirano med delovanjem pospeševalnika. Obdelava slike je podobna kot pri vseh tovrstnih komercialnih napravah. Ker je ta sistem zasnovan kot slikovna plošča, prostorska popačenja v pridobljenih slikah niso prisotna (Kirby and Glendinning, 2006).

Slika 5: AMFPI (Kirby and Glendinning, 2006)

Slika 6: EPID sistem (Varian IAS3, Onkološki inštitut, Ljubljana)

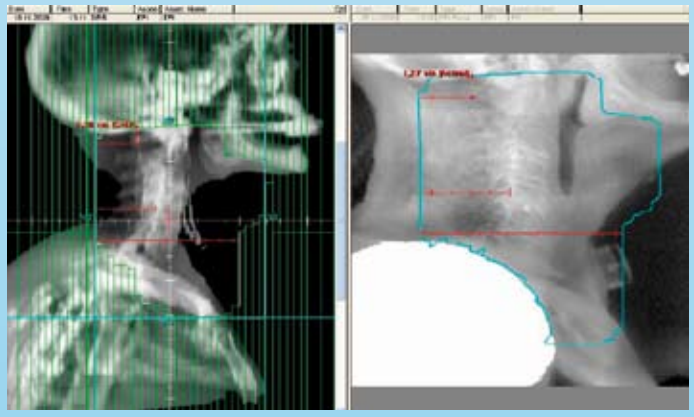
REZULTATI IN RAZPRAVA

V rezultatih bomo predstavili praktični primer, za katerega smo izbrali 15 pacientov, ki so se obsevali z IMRT tehniko v predelu glave in vratu (ORL) na Onkološkem inštitutu v Ljubljani. Obsevanje je potekalo na linearnem pospeševalniku Clinac (Varian) DBX-SN1058 z energijo

6 MV. Skupna tumorska doza (TD) je bila predvidena v 35 frakcijah z dozo 2 Gy na dan. Kot slikovni sistem smo uporabili elektronski slikovni detektorski sistem (Varian IAS3), ki je sestavni del linearnega pospeševalnika. Rezultate smo pridobili z analizo podatkov potrebne poravnave izocentra DRR slike in portalne slike. Vsi pacienti so bili fiksirani z doprsno termoplastično masko (Civco, Sinmed) in standardno podlago za glavo (Civco, Sinmed). Portalno slikanje smo izvajali z AMFPI detektorjem pred prvimi tremi obsevanji, kontrolno portalno slikanje smo opravili enkrat tedensko. Za slikanje smo uporabili 2 MU (monitor units t.i. monitorski enoti) za načrtovano polje in 2 za odprto polje (brez uporabe večlistnega kolimatorskega sistema). Tolerančna meja obsevalnega polja je bila 3 mm (rob PTV- ja meri 3 – 5 mm; PTV = planing target volume). Po vsakem slikanju smo naredili primerjavo med DRR in portalno sliko v računalniškem programu Mosaiq. Ujemanje izocentra smo preverili z metodo merjenja razdalj anatomskih struktur do roba obsevalnega polja. Ta metoda je v tem področju obsevanja med najprimernejšimi (slika 7).

Izmerjena vrednost da morebiten popravek premika poravnave pacienta glede na načrtovani izocenter. Pri primerjavi obeh slik ima pomembno vlogo kvaliteta pridobljenih slik, ki se je izboljšala z novejšimi slikovnimi sistemi in je odvisna tudi od vrste linearnearnega pospeševalnika oziroma od pripadajoče programske opreme.

Dobljene rezultate smo primerjali s podobno študijo, ki so jo opravili na Oddelku za radioterapijo na bostonskem Inštitutu za onkologijo leta 2007 (Court et al., 2008), kjer so naredili analizo rezultatov na podlagi 15 ORL pacientov, vključenih v študijo.



Slika 7: Primerjava DRR (digitalni rekonstrukcijski radiogram) s portalno sliko in prikaz izvajanja meritev (vrednost na sliki pomeni neujemanje kostne strukture in meje obsevalnega polja za 5 mm)

Primerjava rezultatov s študijo (Court et al., 2008)

Pri verifikaciji obsevalnih polj z radiografskim filmom se je natančnost meje obsevalnega polja lahko določila do približno 5 mm. S prehodom na digitalno tehniko verifikacije obsevalnih polj se je tolerančna meja obsevalnega polja zmanjšala na 3 mm, kar pomeni, da boljša kvaliteta slik omogoča manjše premike izocentra. Odstopanja meje obsevalnega polja se lahko določajo tudi do 1 milimetra natančno, z uporabo primernega računalniškega programa (Mosaiq), ki omogoča natančno merjenje. V tabeli 2 so prikazani podatki za 18 premikov pri 15 pacientih. Pri nekaterih pacientih premikov ni bilo, pri nekaterih so bili potrebni premiki v več smereh.

Tabela 2: Premiki na obsevalnem aparatu Clinac DBX-SN1058 pri 15 pacientih (OI, Ljubljana)

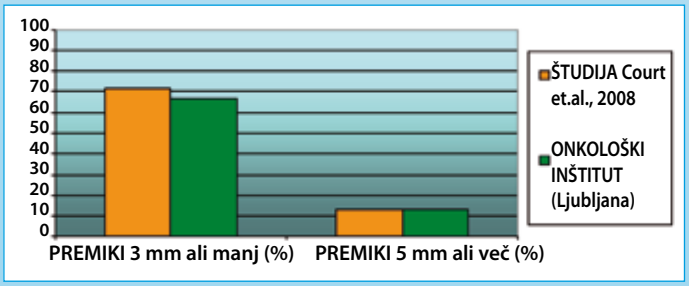
Število pacientov	Brez premikov	Antero-posteriorno	Inferirno-superiorno	Levo-desno
15 (100%)	4 (26,6%)	8 (53,3%)	3 (20%)	3 (20%)

V tabeli 2 je prikazana primerjava premikov v študiji Court et. al., 2008 z rezultati, ki smo jih pridobili na podlagi analize rezultatov na OI Ljubljana.

Tabela 3: Primerjava premikov v študiji Court et.al., 2008 s premiki v študiji na Onkološkem inštitutu

	Skupno število pacientov	Premik 3mm ali manj (%)	Premik 5 mm ali več (%)
Court et al., 2008	15	71,4	13
Onkološki inštitut	15	66,7	13

Pri 66,7% pacientih na OI so bila zabeležena odstopanja v različnih smereh, v študiji Court et.al., 2008 pa v 71,4 %. Iz rezultatov je razvidno, da so odstopanja med našo analizo podatkov in tujo študijo primerljiva. Pri dveh pacientih je bil potreben premik za 5 mm ali več in sicer v anteriorni in desni smeri. Tudi Court et al., 2008 opisujejo premik za 5 ali več mm, vendar v posteriorni in desni smeri. Vsi premiki so prikazani v tabeli 3 ter v grafu 1.



Graf 1: Primerjava zabeleženih premikov v študiji Court et.al., 2008 s premiki na OI Ljubljana

ZAKLJUČEK

Vsaka faza pri pripravi pacienta na obsevanje ima predpisane standarde, katerih se je potrebno držati in jih tudi upoštevati. Izvajati moramo redno kontrolo kakovosti, tako pred obsevanjem kot med njim. Slikovni sistemi omogočajo verifikacijo obsevalnih polj ter lege pacientov. Z razvojem novejših slikovnih sistemov in obsevalnih tehnik v RT se je znatno izboljšala natančnost obsevanja tumorskega volumna in varovanje zdravega okolnega tkiva. Za verifikacijo so se uporabljali različni slikovni sistemi. Na OI se je sprva uporabljal radiografski film, katerega kvaliteta ni dopuščala natančnega določevanja mej obsevalnih polj. Napredek h kvaliteti obsevanja predstavlja CR sistem, z uporabo katerega (primerjava pridobljene CR slike in referenčne slike)

se je natančnost obsevanja še izboljšala, tolerančna meja obsevalnega polja se je zmanjšala na 5 mm.

Vsi sodobni linearni pospeševalniki imajo vgrajen slikovni detektor AMFPI, ki omogoča natančno določanje tolerančne meje obsevalnega polja. To je omogočilo izvajanje novejših, natančnejših tehnik obsevanja. Poleg dosedanjih obsevalnih tehnik se na Onkološkem inštitutu že dobri dve leti izvaja IMRT tehnika.

Študija, ki je bila izvedena v tujini prikaže, da so tolerančna odstopanja obsevalnega polja, glede na anatomske strukture, primerljiva z odstopanji, ki so bila izmerjena na obsevalnem aparatu Clinac (Varian) DBX-SN1058. Z zagotavljanjem natančnosti obsevanja dosegamo boljšo pokritost tumorskega volumna ter ohranjanje zdravega tkiva. Glede na primerjalno študijo in naš praktični primer lahko zaključimo, da je tolerančna meja pri ORL bolnikih zmanjšana na 3 mm, kar omogoča tudi visoko kvalitetna programska oprema slikovnih sistemov. Ti prikažejo boljšo ostrino anatomskih struktur, kar da možnost bolj natančnih meritev.

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Strokovni članek

UPORABA RAČUNALNIŠKO TOMOGRAFSKE ANGIOGRAFIJE IN BREZKONTRASTNE MAGNETNO RESONANČNE ANGIOGRAFIJE PRI ODKRIVANJU ZOŽITEV VRATNEGA OŽILJA

Professional Article

USE OF COMPUTER TOMOGRAPHY ANGIOGRAPHY AND NON CONTRAST MAGNETIC RESONANCE ANGIOGRAPHY IN DETECTING OF VASCULAR STENOSIS IN NECK AREA

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POVZETEK

Uvod in namen: Pri odkrivanju zožitev vratnega ožilja uporabljamo Dopplerjev ultrazvok, računalniško tomografsko angiografijo in magnetno resnonančno angiografijo brez kontrastnega sredstva. Prikazali bomo razlike in podobnosti teh metod in določili kaj je standard, če hočemo zagotoviti pacientu najmanjšo dozo.

Metode dela: Pri opravljanju diagnostike vratnega ožilja začnemo navadno z ultrazvokom, ki ga nato nadgradimo z eno od v uvodu naštetih metod. Pri pacientih, ki izpolnjujejo pogoje za računalniško tomografsko angiografijo, v Univerzitetnem kliničnem centru Maribor predhodno opravimo magnetno resnonančno angiografijo (Inhance 3D Inflow Inversion Recovery) brez kontrastnega sredstva na magnetno resonančnem aparatu 3T. Za raziskavo smo izbrali 29 redno naročenih pacientov, ki smo jim opravili obe preiskavi. Po obdelavi podatkov smo primerjali lumen prikazane žile, polnitvene motnje, razliko izmerjene zožitve, oceno mehkega plaka na računalniško tomografskih in magnetno resonančnih slikah. Podatke smo primerjali in določili katera vrsta preiskave ima večjo diagnostično glede na diagnostični problem.

Rezultati in razprava: Rezultate smo interpretirali s pomočjo podatkov, shranjenih na delovnih postajah. Prišli smo do zaključka da je vsaka od metod uporabna, nedvomno je CTA metoda izbire, pod določenimi predhodnimi diagnostičnimi pogoji pa je MRA primerljiva. Na izbiro metode vpliva zdravnikova odločitev glede na nadaljnje zdravljenje in pacientovo zdravstveno stanje.

Zaključek: CTA ostaja še vedno zlati standard pred zdravljenjem. Pri preiskovancih ki so v istem dnevu opravili obe preiskavi smo dokazali da je MRA (Inhance 3D Inflow Inversion Recovery) po predhodno opravljenim diagnostičnim ultrazvokom enakovreden CTA.

Ključne besede: CTA, MRA (Inhance 3D Inflow Inversion Recovery),vratno žilje, 3T

ABSTRACT

Introduction and aim: The aim of the study was to compare two similar methods for detecting stenosys in neck area. The standard of CTA and MRA (Inhance 3D Inflow Inversion Recovery) procedures will be presented.

Methods: Diagnosis of neck area vessel is usually starting with US and then upgraded with CTA or MRA. With the patients who were appointed for the CTA, we have just performed additional examination i.e. MRA (Inhance 3D Inflow Inversion Recovery) on 3T. Comparing the results we are able to establish adequate method for regular use.

Results and discussion: Interpretation of results was performed on advanced workstations. The aim of interpretation was applicability of both methods for advance endoluminal or surgical treatment. On the basis of above results we have also changed some parts of protocols.

Conclusions: Both methods give good results. The CTA requires the use of iodine contrast agents while the MRA (Inhance 3D Inflow Inversion Recovery) is a more straightforward and non-invasive method; However CTA is still the standard tool for vessel diagnosis and advance treatment in neck area. MRA (Inhance 3D Inflow Inversion Recovery) is comparable to CTA.

Key words: CTA, MRA (Inhance 3D Inflow Inversion Recovery), angiography, 3T.

UVOD

Osnovni namen računalniško tomografske angiografije (CTA) in brezkontrastne magnetno resnonačne angiografije (MRA) preiskav vratnega ožilja je prikazati hemodinamsko pomembne zožitve tega ožilja. V ta namen uporabljamo tudi ultrazvočno preiskavo, ki je zanesljiva, varna in neinvazivna. Pri primarnem preprečevanju žilnih bolezni omogoča oceno stopnje arterioskleroze, pomembnejše mesto pa ima ta preiskava v sekundarni preventivi. Z doplersko UZ diagnostiko operater izmeri pretok v področju stenoze (Tetičkovič in sod. 2001) ter turbulence pred in za njo, kar je ključnega pomena pri načrtovanju endoluminalnega zdravljenja (Flis in sod. 2004).

Bolniki s hemodinamsko pomembno zožitvijo vratnih arterij so zelo ogroženi, vendar imajo po kirurškem ali endovaskularnem posegu ter celo po intenzivnem zdravljenju z zdravili zelo dobro napoved izida bolezni (Poredoš 2003).

Predvidevava, da so rezultati, ki jih dobimo z brezkontrastno MRA primerljivi in prav tako diagnostično uporabni kot tisti, pridobljeni s CTA.

METODE DELA

Po opravljeni UZ diagnostiki, s katero pridobimo podatke o hitrosti pretoka skozi zožitev, na Radiološkem oddelku Univerzitetnega kliničnega centra v Mariboru pacienti opravijo CTA na aparatu Aquilion 64 Toshiba. Z jodovim kontrastnim sredstvom prikažemo pretok krvi po vratnem ožilju. S 3D volumsko obdelavo nato prikažemo lumen žil, ki ga lahko premerimo in interpretiramo s pomočjo različnih programov računalniške obdelave. Na osnovi rezultatov CTA se odločijo za način zdravljenja, ki je lahko endoluminalno ali kirurško.

S predhodno UZ diagnostiko si pri MRA pomagamo pri nastavitvi hitrosti pretoka krvi v ožilju. Na Radiološkem oddelku Univerzitetnega kliničnega centra v Mariboru izvajamo MRA na aparatu Signa Excite HDxt 3T General Electric s pulznim zaporedjem Inhance 3D Inflow IR, ki omogoča prikaz pretoka v arterijah in v venah. Omenjeno pulzno zaporedje je nadgradnja tehnike TOF (Time of flight). Prednost pulznega zaporedja Inhance 3D Inflow IR je, da za prikaz ožilja ne potrebujemo paramagnetnega kontrastnega sredstva. Sledimo pretoku krvi in njeni turbulenci v tistih predelih žil, na katerih so stenoze ali arterosklerotske spremembe, lahko pa jih prikažemo tudi s povečavo (Takei in sod. 2009).

Obe preiskavi smo opravili pri 29 pacientih. Pred CTA smo jim v istem dnevu opravili tudi brezkontrastno MRA. Podatke za MR diagnostiko smo obdelali na delovni postaji ADW 4.4 General Electric, s katero smo prikazali podatke v MIP (prikaz največje intenzitete) in VR (prostorsko upodabljanje) tehniki. CTA obdelavo smo opravili na delovni postaji TeraRecon prav tako z MIP in VR ter CPR (curved planart reformat) tehniko.

Pri zajemanju podatkov lahko na slikah nastanejo artefakti zaradi na primer premikanja pacienta, fiksne zobne protetike ali požiranja sline, kar povzroča težave pri obdelavi podatkov in poslabša kvalitete slik.

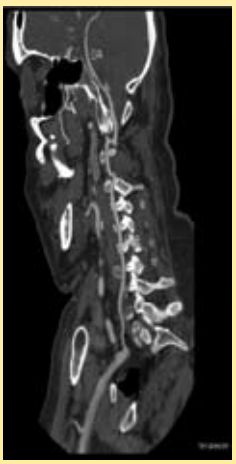
REZULTATI

Obdelane slikovne podatke s CTA in Inhance 3D Inflow IR smo medsebojno primerjali. Pri ocenjevanju obeh metod smo bili pozorni na polni žilni lumen, prikaz stenoz in drugih robnih nepravilnosti, prikaz drobnega žilja in prisotnost artefaktov.

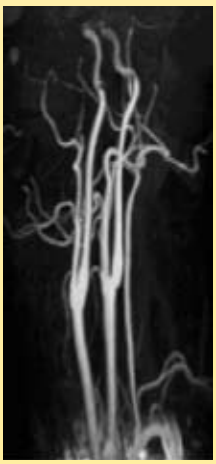
S pomočjo dobljenih rezultatov smo z Inhance 3D Inflow IR v 95% dobili iste rezultate kot s CTA rekonstruiranimi slikami. Primerjava:

- Pri rekonstrukcijah CTA (slika 1) dobimo sliko pretoka kontrastnega sredstva skozi ožilje, Inhance 3D inflow IR pa prikaže pretok spinov (slika 2).
- S CPR obdelavo (slika 3) lahko prikažemo mehke aterosklerotične spremembe, ki so bolje prikazane s CTA kot z MRA.
- S CTA obremenimo preiskovanca s kontrastnim sredstvom in ionizirajočim sevanjem, MRA pa je neinvazivna preiskava, ne uporabljamo kontrastnega sredstva in ne povzroča spazma žilja.

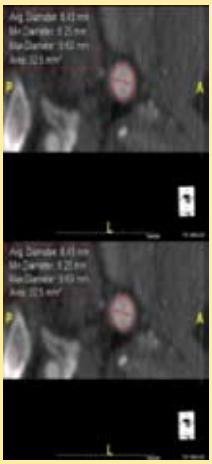
Z MRA glede na izbrano hitrost pretoka spinov bolje ločeno prikažemo arterije in vene, glede na turbulence pa bolje lok aorte in vratne arterije.
CTA nam prikaže vse žile v predelu vratu, vendar zaradi spazma žilja zaradi kontrastnega sredstva lahko neustrezno prikaže drobno žilje.



Slika 1: CTA



Slika 2: Inhance 3D inflow IR



Slika 3: CPR

Slike prikažejo vzroke za hemodinamske probleme, ki so lahko različni: aterosklerotska trombotična masa, stenoza ali artefakt.

CTA je standardna preiskava, s katero lahko hitro in natančno napravimo diagnostiko bolezni vratnih žil. V zakup moramo vzeti da preiskovanec dobi določeno dozo sevanja in količino kontrastnega sredstva. Zaradi aplikacije kontrastnega sredstva sodi med invazivno diagnostiko, ki zahteva predhodno določitev laboratorijsko vrednost kreatinina (delovanja ledvic). CTA je odločilnega pomena za izbiro med kirurškim ali endoluminalnim zdravljenjem, zaradi standarda meritev žilnih opornic. Rezultati CTA bi lahko bili boljši tudi, če kontrastno sredstvo ne bi povzročilo spazma drobnih žil.

Inhance 3D Inflow IR MRA preiskave pacienti s starim osteosintetskim materialom, strahom pred zaprimi prostori in veliko telesno maso ne morejo opraviti. Preiskava ni invazivna in je predvsem primerna za otroke in kontrole že znanih zožitev. Preiskava traja petnajst minut. Slabost pulznega zaporedja Inhance 3D Inflow IR, da moramo zelo natančno nastaviti hitrost pretoka spinov na osnovi predhodnega UZ pregleda, sicer je možno, da so rezultati napačni.

Pulzno zaporedje Inhance 3D inflow IR je primerljivo s CTA in je uporabna metoda s katero lahko kontroliramo napredovanje oženja stenoz. Primerno je tudi za samostojno diagnozo, ni pa uporabno za meritve za žilne opornicev. Zato potrebujemo CTA. Slabost MRA je tudi pri obdelavi podatkov CPR, kjer za ugotavljanje mehkih plakov ne moremo doseči primerljivega rezultata s CTA.

ZAKLJUČEK

CTA je standard, na osnovi katerega izbirajo med endovaskularnim in kirurškim zdravljenjem bolezni vratnih žil. Od postavitve diagnoze do posega s CTA kontroliramo odstotek zožitve lumna žile.

Inhance 3D inflow IR je optimalno pulzno zaporedje za ugotavljanje napredovanja stenoz in drugih hemodinamskih sprememb z magnetno resonanco.

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Strokovni članek

VREDNOSTI POVPREČNIH ŽLEZNIH DOZ V PRESEJALNEM PROGRAMU DORA IN PRIMERJAVA Z VREDNOSTMI POVPREČNIH ŽLEZNIH DOZ V TUJIH PRESEJALNIH PROGRAMIH

Professional Article

VALUES OF MEAN GLANDULAR DOSES IN SLOVENIAN BREAST SCREENING PROGRAMME AND COMPARISON WITH FOREIGN SCREENING PROGRAMMES

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POVZETEK

Uvod: Mamografija je temeljna preiskava za zgodnje odkrivanje raka dojke. Kot vsako rentgensko slikanje tudi mamografija dozno obremeni preiskovanko. Kakovostno organiziran program presejanja je bistven za zgodnje odkrivanje raka dojk in zmanjšanje umrljivosti za to boleznijo. Del vsakega kakovostno organiziranega programa je zagotavljanje najnižje dozne obremenitve preiskovank.

Namen: Namen raziskave je bil izračunati, kakšna je povprečna žlezna dozna obremenitev pacientke pri posamezni projekciji na mobilnih enotah presejalnega programa Dora in primerjati rezultate z vrednostmi povprečnih žleznih doz z dozami drugih presejalnih programov.

Materiali in metode: Mamografa, ki se uporabljata na mobilnih enotah presejalnega programa Dora sta Siemens Inovation. Za izračun povprečne žlezne doze (MGD) je bila uporabljena metoda izračunavanja povprečnih žleznih doz po Dance et al, 2000. V raziskavo je bilo vključenih 2999 preiskovank (11996 projekcij), ki so bile pregledane v mesecu septembru leta 2010 in 2011. Do podatkov, potrebnih za izračun MGD sem prišla preko sistema IMPACS RIS (Agfa Helath care, Belgium). Raziskava je bila retrospektivna. Primerjava naših MGD s tujimi je bila narejena po pregledu strokovne literature.

Rezultati in razprava: Povprečna vrednost MDG na mobilni enoti 1 je bila 1,57 mGy, na mobilni enoti 2 pa 1,83. Vrednosti povprečnih debelin dojke so bile na mobilni enoti 1 56,71 mm, na mobilni enoti 2 pa 57,04 mm. Razlike v povprečnih vrednostih MGD med septembru 2010 in septembrom 2011 so bile na mobilni enoti 1 majhne (manjše od 1%), na mobilni enoti 2 pa nekoliko večje (3%). Povprečna vrednost žlezne doze v mobilnih enotah programa Dora je bila 1,74 mGy, povprečna debelina dojke pa 57 mm. Dozna obremenitev na digitalnih mamografskih aparatih programa Dora je v povprečju za 50% manjša od doze na analognih mamografih, na katerih so bile opravljene tuje študije (Rosberg et al., 2000 in Kruger et al., 2001).

Zaključek: Vrednosti povprečnih žleznih doz se v programu Dora razlikujejo glede na aparat, na katerem je preiskovanka slikana, so pa polovico nižje, kot jih navajajo študije, ki obravnavajo to temo.

Ključne besede: mamografija, povprečna žlezna doza, MGD, presejalni program Dora

ABSTRACT

Introduction: Mammography is a basic examination of early breast cancer detection. Like every x-ray examination mammography has also invasive effect on patients. High quality screening programme is essential for early detection of breast cancer and low mortality due to breast cancer. Part of high quality screening programme is assuring that patients receive the lowest possible dose exposures.

Purpose: Purpose of research was to calculate average dose values in every projection on mobile units of DORA breast screening programme and to compare them to average glandular doses from other studies.

Methods: Mobile units of breast screening programme are equipped with Siemens Inovation Mammograph. Mean glandular doses were calculated by the formula Dance et al., 2000. Research was performed on 2999 patients (11996 projections), examined in September 2010 and September 2011. Data used in calculations were collected within IMPACS RIS system (Agfa Health care, Belgium). Research took place retrospectively. Comparison between our MGD values and values from other studies was performed after the study of correspondent references.

Results: The average MGD value in mobile unit 1 was 1,57 mGy and in mobile unit 2 1,83 mGy. The value of average breast thicknesses in mobile unit 1 is 56,71 mm and on mobile unit 2 57,04 mm. The differences between MGD values in September 2010 and September 2011 on mobile unit 1 were small (less than 1 percent), and on mobile unit 2 the differences were a bit higher (3 percents). Average MGD value in DORA breast screening programme was 1,74 mGy, average thickness was 57 mm. Doses in digital mammographs used in our screening programmes were 50 percent smaller

then the doses on analogue mammographs used in other studies (Rosberg et al., 2000 in Kruger et al., 2001).

Conclusion: MGD values of in DORA breast screening programme depend on the mamograph used in examination. Regarding the above subject, they are half smaller than the values calculated in other studies.

Key words: mammography, average glandular dose, MGD, breast screening programme Dora

UVOD

Program Dora

Na področju celotne države že več kot desetletje poteka neorganizirano presejanje, kar pomeni, da vsaka ženska v starosti 50 do 69 let vsako drugo leto lahko opravi presejalno mamografijo, vendar je od nje odvisno, ali bo to možnost tudi izkoristila.

Tako presejanje ni dalo želenih rezultatov za zmanjševanja pogostnosti raka dojke in odkrivanja njegovih zgodnejših oblik, kar je za preživetje ženske in boljšo kvaliteto njenega življenja v prihodnosti ključno. Zato so bil junija 2004 na Zdravstvenem svetu R Slovenije sprejeli predlog vzpostavitve organiziranega programa zgodnjega odkrivanja raka dojke, namenjen ženskam v starosti 50 do 69 let, katerega nosilec je Onkološki inštitut.

Po pripravah je program Dora v omejenem obsegu začel potekati konec aprila 2008. Omejen obseg izvajanja programa v prvi fazi so predlagali tuji strokovnjaki, ki imajo izkušnje z organiziranjem uspešnih tovrstnih programov in so s svojim znanjem pomagali program vzpostaviti. Namen je lažja zaznava, analiza in seveda sistemska odprava težav, ki se lahko pojavljajo na začetku.

Osnovna organizacijska in funkcionalna enota programa Dora je presejalni center, ki je strokovno in organizacijsko tesno povezan z diagnostičnim in terapevtskim centrom.

Pomemben del organiziranega programa je pisno povabilo na preiskavo vsaki ženski zgoraj omenjene starosti. Odkrivanje zgodnjih oblik raka se izvaja z mamografskim slikanjem dojk vsako drugo leto, kar je tudi priporočilo evropskih smernic za izvajanje presejanja raka dojk. Vse storitve v programu, ki poleg vabila ženskam iz ciljne skupine vključujejo še presejalno mamografijo, dvojno odčitavanje, kontrolo kakovosti ter diagnostično obdelavo vseh žensk, pri katerih je bila najdena sprememba, se krijejo iz obveznega zdravstvenega zavarovanja in so torej za žensko brezplačne.

Program se bo v naslednjih letih razširil na področje celotne države in bo tako postopno zamenjal sedanji oportunistični, neorganiziran sistem presejanja (Uradni list RS, Uradni list RS, št. 19/98, 47/98, 26/00, 67/01, 33/02, 37/03, 117/04, 31/05 in 83/07).
Kakovostno organiziran program presejanja je bistven za zgodnje odkrivanje raka dojk in zmanjšanje umrljivosti (Register raka, 2010).

Del kakovostno organiziranega presejalnega programa je tudi optimizirana dozna obremenitev pacientk, ki v program prihajajo. V mamografiji to obremenitev označujemo kot povprečno žlezno dozo (MGD).

Povprečna žlezna doza pri mamografiji (MGD)

MGD je uveljavljena količina za določitev obsevanosti pri mamografiji. Kot osnovo za izračun MGD uporabljamo absorbirano dozo v zraku (KA) na mestu, kjer sevanje vstopa v dojko. Izmerjeno vrednost KA s pomočjo pretvornih faktorjev pretvorimo v povprečno žlezno dozo MGD (Zdešar et al., 2000).

Povprečna žlezna doza se izmeri v okviru testov mamografskih rentgenskih aparatov, ki jih izvede medicinski fizik. Metoda določanja je povzeta po evropskem protokolu (EC, 1996a).

NAMEN

Namen raziskave je predstaviti povprečno žlezno obremenitev pacientke v programu Dora in ugotoviti ali se povprečna žlezna doza med mobilnima enotama (ME) tega programa razlikuje. Prav tako je namen primerjava povprečne žlezne doze na mobilnih enotah v istih obdobjih dveh zaporednih let in na dveh različnih lokacijah ter primerjava povprečnih vrednosti žleznih doz obeh mobilnih enot z vrednostmi povprečnih žleznih doz tujih presejalnih programov.

MATERIALI IN METODE

Z uporabo metod izračunavanja povprečnih žleznih doz po Dance et al. (2000), lahko brez poseganja v kvaliteto mamograma izračunamo povprečno žlezno dozo za posamezno projekcijo. Izračun sem naredila retrospektivno, uporabila sem program Excel.

$$MGD = KA * g * c * s \ [mGy]$$

Pri izračunu sem uporabila faktorje g, c in s. Poleg teh faktorjev so v izračun vključene tudi vrednosti anodne napetosti (kV), tokovnega sunka (mAs) in debeline dojke (mm), ki se zapišejo v DICOM glavo vsakega mamograma ter dozimetrični parametri (specifična vrednost kerme v zraku) izhodnega snopa rentgenske cevi (Y), ki je izražena v µGy/mAs. Vrednosti izhodnega snopa rentgenske cevi pridobimo iz meritev, opravljenih ob polletnem testu rentgenskega aparata, ki ga opravi medicinski fizik.

Izračun vrednosti KA sem naredila s pomočjo vrednosti Y. Te vrednosti sem pridobila iz poročila polletnega testa aparata. Vrednosti Y se razlikujejo glede na spekter rentgenskih fotonov, uporabljen pri slikanju.

Faktorji g, c in s so tabelirani, spreminjajo se z debelino dojke in vrednostjo razpolovne debeline (HVL). Razpolovna debelina je debelina izbrane snovi (najpogosteje aluminija), ki razpolovi začetno intenziteto sevanja (Terry et al.,

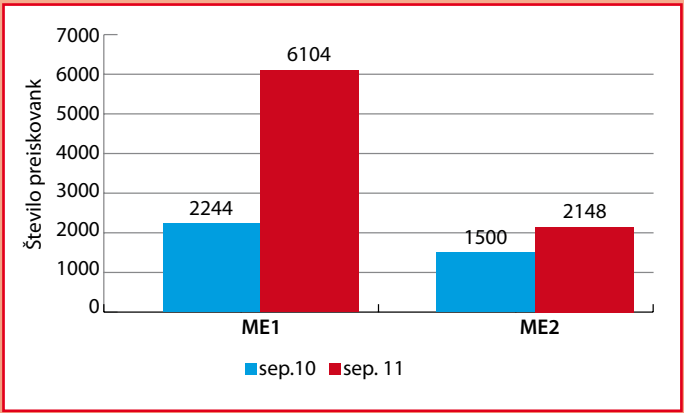
1999). Razpolovno debelino lahko merimo, običajno pa se uporabljajo tabelirane vrednosti. Vrednosti HVL so določene po Dance et al., (2000):
Faktor g je pretvorni faktor, ki KA pretvori v žlezno dozo. Pri tem je privzeta sestava dojke, in sicer 50% žleznega in 50% maščobnega tkiva (Dance et al., 1990).
Faktor c je popravek, s katerim popravimo razliko med sestavo slikane dojke in dojke, sestavljene iz 50% žleznega in 50% maščobnega tkiva (Dance et al., 2000).
Faktor s je popravek, ki upošteva spekter rentgenskih fotonov oziroma kombinacijo anodnega materiala in filtra, ki smo jo uporabili pri slikanju (Dance et al., 2000).

Pri slikanju je bil v vseh primerih izbran avtomatski nadzor ekspozicije. To pomeni, da je mamografski rentgenski aparat za slikanje samodejno izbral material anode in filtra, napetost in anodni tok. Na mobilni enoti 1 (ME1) so uporabljali anodi iz molibdena ali volframa ter filter iz rodija, na mobilni enoti 2 (ME2) pa anodo iz volframa ter filter iz rodija. Povprečna vrednost vseh raziskanih ekspozicij na ME1 je bila 29 kV in 94 mAs, v 73% slikanj je bila izbrana kombinacija materiala anode in filtra volfram-rodij, v 27% pa molibden-rodij. Povprečna vrednost raziskanih ekspozicij na ME2 je bila 29 kV in 132 mAs, izbrana kombinacija materiala anode in filtra je bila volfram-rodij. Na obeh mobilnih enotah je bil uporabljen program avtomatske ekspozicije OPDOSE. Ker mamografov na mobilnih enotah ni umerjal isti aplikator proizvajalca, so bile med ME1 in ME2 razlike v izbiri ekspozicijskih pogojev in materiala anode in filtra.

Primerjavo s tujimi študijami sem naredila po pregledu strokovne literature.

Vzorec podatkov

Obravnavani so mamogrami, narejeni v mesecu septembru leta 2010 in leta 2011 na obeh mobilnih enotah. V raziskavi je bilo zajetih 11996 mamogramov in 2999 preiskovank. Izpis podatkov, potrebnih za izračun povprečne žlezne doze je bil narejen s pomočjo servisnega osebja (Siemens rentgenski aparati), ki je s pomočjo programske opreme iz mamografskega rentgenskega aparata pridobilo tehnične podatke za vsak mamogram.



Graf 1: Število mamogramov, zajetih v raziskavo na obeh mobilnih enotah v mesecu septembru leta 2010 in leta 2011

Graf 1 prikazuje število mamogramov, narejenih v presejalnem programu Dora v septembru 2010 in septembru 2011. ME1 je bila v obeh obdobjih, zajetih v raziskavo, nastanjena pred Onkološkim inštitutom v Ljubljani. V septembru 2011 je delo na njej potekalo dvoizmensko, eno leto prej pa enoizmensko, septembra 2010 je bilo slikanih 561 preiskovank, septembra 2011 pa 1526, kar je vzrok za razliko v številu rentgenogramov, narejenih v obeh obdobjih.

Delo na ME2 je bilo enoizmensko, delala pa je na dveh lokacijah: septembra 2010, ko je bila mobilna enota v Trbovljah, je bilo slikanih 375 preiskovank, septembra 2011 pa je bila v Kamniku, kjer je bilo preiskovank 537. Iz grafa lahko razberemo, da je je bilo zaradi naštetih dejavnikov večje število mamogramov narejenih na ME1.

REZULTATI IN RAZPRAVA

V rezultatih bom predstavila povprečne vrednosti izračunanih MGD, razlike v teh vrednostih in pa povprečne debeline dojk septembra 2010 in septembra 2011 na mobilnih enotah 1 in 2 v programu DORA.

Tabela 1 prikazuje povprečno vrednost MGD v obravnavanem obdobju pri vseh 11996 slikanjih na obeh mobilnih enotah.

Tabela 1: Povprečne vrednosti MGD in povprečne debeline dojk

	Število projekcij	*Povprečna vrednost MGD (mGy)*	*Povprečna debelina dojke (mm)*
MGD	*11996*	*1,74*	*56,88*

Vrednost MGD je v presejalnem programu DORA 30% manjša kot je vrednost, ki jo priporoča evropska komisija (Perry et. al., 2006), ki znaša 2,5mGy, kar pomeni, da so glede dozne obremenitve preiskovank v Dori doseženi dobri rezultati.

Povprečno žlezno dozo in debelino dojk sem nato primerjala med obema mobilnima enotama, primerjava je prikazana v tabeli 2.

Tabela 2: Primerjava povprečnimi vrednosti MGD in povprečnih debelin dojk med mobilnima enotama

	Število projekcij	*Povprečna vrednost MGD (mGy)*	*Povprečna debelina dojke (mm)*	*Razlika med povprečnima vrednostma MGD (mGy)*	*Razlika med povprečnima vrednostma debelin dojk (mm)*
ME 1	*8348*	*1,57*	*56,79*	*0,26*	*0,25*
ME 2	*3648*	*1,83*	*57,04*		

Razliko med povprečnima MGD pripisujem različni avtomatski nastavitvi ekspozicije na enem in drugem aparatu in razliki v povprečni debelini dojk.

Glede na ugotovljeno razliko med povprečnima MGD na obeh mobilnih enotah, sem nato primerjala mesečna pregleda obeh mobilnih enot. Ker se je ME2 v vmesnem času

prestavila iz Trbovelj v Kamnik, sem pri tej enoti primerjala tudi povprečno MGD na obeh lokacijah.

Primerjava rezultatov MGD septembra leta 2010 in 2011 na ME1 je prikazana v tabeli 3.

Tabela 3: Primerjava povprečnih MGD in povprečnih debelin dojk v septembru 2010 in septembru 2011 na mobilni enoti 1

	Povprečna vrednost MGD posamezne projekcije (mGy)	Povprečna debelina dojke (mm)	Razlika med povprečnima vrednostma MGD (mGy)	Razlika med povprečnima vrednostma debelin dojk (mm)
ME1 september 2010 Ljubljana	1,56	57,0	0,01 (0,6%)	0,04 (0,01%)
ME1 september 2011 Ljubljana	1,57	56,6		

Razlika med vrednostma povprečnih MGD in debelin dojk med septembrom 2010 in septembrom 2011 na ME1 je bila minimalna, enako tudi razlika med povprečnima debelinama dojk. Majhne razlike v povprečnih vrednostih MGD pripisujem uporabi enakega programa za avtomatski nadzor ekspozicije, lokacija enote se ni spremenila, populacija zajetih preiskovank je v obeh opazovanih obdobjih približno enaka.

Tudi pri ME2 sem primerjala vrednosti, zabeležene v septembru 2010 in septembru 2011. Septembra 2010 je bila ME2 v Trbovljah, septembra 2011 pa v Kamniku. V tabeli 4 so navedene vrednosti povprečnih debelin dojke in povprečnih žleznih doznih obremenitev v obeh obravnavanih mesecih.

Tabela 4: Primerjava povprečnih MGD in povprečnih debelin dojk v septembru 2010 in septembru 2011 na mobilni enoti 2

	Povprečna vrednost MGD posamezne projekcije (mGy)	Povprečna debelina dojke (mm)	Razlika med povprečnima vrednostma MGD (mGy)	Razlika med povprečnima vrednostma debelin dojk (mm)
ME2 September 2010 Trbovlje	1,87	58	0,08 (4%)	2 (3%)
ME2 September 2011 Kamnik	1,79	56		

Vzrok za večjo razliko med povprečnimi vrednostmi MGD je razlika v povprečni debelini.

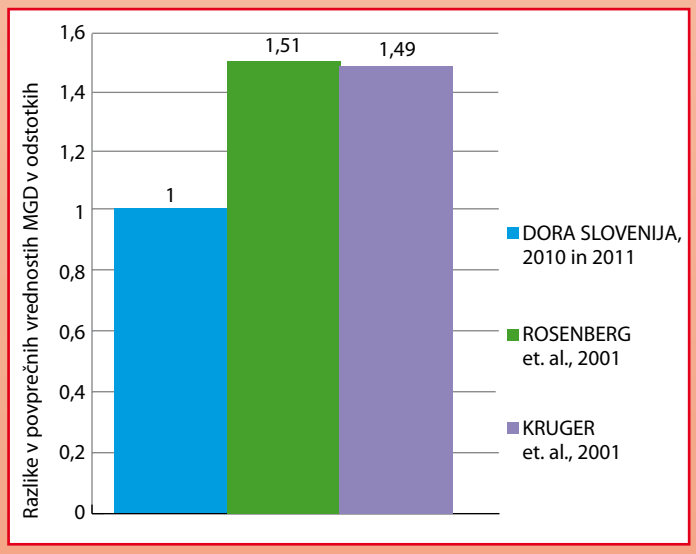
V tabeli 5 so navedene razlike med vrednostmi MGD in povprečnih debelin dojk v presejalnem programu DORA in dveh tujih študijah, opravljenih s klasičnimi slikovnimi sistemih folija-film.

Tabela 5: Primerjava povprečnih MGD in povprečnih debelin dojk na mobilnih enotah Dore in vrednosti tujih raziskav

	Povprečna debelina dojke (mm)	Povprečna vrednost MGD (mGy)
DORA 2011	57	1,74
ROSENBERG et al., 2000	49	2,62 (51%)
KRUGER et al., 2001	51	2,6 (49%)

Študija Rosenberga et al. (2001) je bila opravljena na enem mamografu, v obdobju od novembra 1998 do decembra 1999, v Mehiki. Zajeli so 20705 ekspozicij. V večini primerov so uporabljali molibdenovo anodo in filtracijo snopa ter avtomatsko izbiro anodne napetosti, najpogosteje med 25 in 28 kV. Povprečna debelina dojke je bila 49 mm. Za izračun vrednosti MGD so uporabili enak izračun kot sem ga uporabila jaz. Vrednost povprečne MGD je bila v njihovi raziskavi 2,62 mGy.

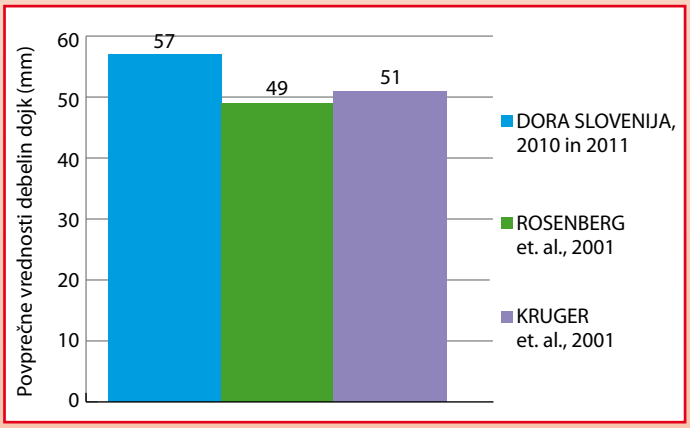
Študija Kruger et al. (2001) so obravnavali 24471 ekspozicij, narejenih na sedmih mamografih v obdobju 4 mesecev v ZDA. V večini primerov so prav tako uporabljali molibdenovo anodo in filtracijo snopa ter avtomatsko izbiro anodne napetosti, med izbranimi napetostmi je bila najpogostejša 25 kV. Povprečna debelina dojke je znašala 51 mm. Za izračun vrednosti MGD so uporabili enak izračun kot sem ga uporabila jaz. Vrednost povprečne MGD je bila v njihovi raziskavi 2,6 mGy.



Graf 2: Razlike med povprečnimi vrednostmi MGD v odstotkih

Razlika med povprečnimi vrednostmi MGD med meritvami v programu Dora in primerjalnima študijama je velika. Prikazana je v grafu 2. Vzrok so različni slikovni sistemi v Dori (digitalni) in obeh primerjanih študijah (analogni). V primerjanih študijah so večinoma uporabljali molibdenovo anodo in filter, v našem programu pa večinoma volframovo anodo in rodijev filter. V primerjavi s študijo v Mehiki (Rosenberg et al., 2001) je bila povprečna MGD pri nas za 51%, v primerjavi s študijo v ZDA (Kruger et al., 2001) pa za 49% manjša. Povprečne debeline dojk so bile v obeh

študijah manjše, kot v naši. Povprečna razlika med MGD v analognih in digitalnih sistemih v moji primerjavi je 50%, v literaturi pa je navedeno, da naj bi uporaba digitalne tehnologije v povprečju zmanjšala dozno obremenitev za 22% (Henrick, Februar 2012 AJR http://www.sciencedaily.com/releases/2010/01/100121135704 .htm).



Graf 3: Razlike med povprečnimi vrednostmi debelin dojke v milimetrih

Študija, narejena v Mehiki je imela najmanjšo povprečno debelino pregledanih dojk, 49 mm, v ZDA je povprečna debelina znašala 51 mm, pri nas pa je bila največja, in sicer 57 mm. Vrednosti povprečnih debelin so prikazane v grafu 3.

ZAKLJUČEK

Pomemben dejavnik v presejevalnih programih je pri slikanju dojk dozna obremenitev (MGD) preiskovanke. Na MGD vpliva več dejavnikov, neposredno tudi debelina dojke.

Povprečna vrednost MGD v mobilni enoti 1, ki je bila septembra 2010 in septembra 2011 na isti lokaciji, je tako rekoč konstantna, razlike med obema obdobjema so minimalne (manj kot 1%). Razlike v povprečni debelini dojke so bile prav tako majhne (manj kot 1%).

Razlika med povprečnimi vrednostmi MGD na mobilni enoti 2 so nekoliko večje (4%), kar pripišemo spremembi lokacije (iz Trbovelj v Kamnik) in nekoliko večji razliki v povprečnih debelinah dojk (3%).

Razliko med povprečnima dozama v mobilnih enotah 1 in 2 pripišemo različnim povprečnim debelinam dojk. Razlika med povprečnima MGD v eni in drugi mobilni enoti je bila 0,25 mGy, razlika v povprečnih debelinah dojk pa 0,25 mm.

Uporaba digitalnih sistemov z novimi programi avtomatskih ekspozicij in uporaba novih materialov pri mamografiji zmanjša dozno obremenitev. Z našo raziskavo smo ugotovili, da je razlika med digitalnim in analognim sistemom v povprečju 50%.

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Strokovni članek

MANJ DODODATNIH SLIKANJ Z DIGITALNO MAMOGRAFIJO?

Professional Article

DIGITAL MAMMOGRAPHY: LESS ADDITIONAL IMAGES?

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POVZETEK

Uvod in namen: Na Onkološkem inštitutu v Ljubljani smo v letu 2007 prešli iz klasične (analogne) mamografije na digitalno. V tem delu želiva predstaviti prednosti digitalne mamografije.

Metode dela: Raziskava zajema 965 analognih in 965 digitalnih mamografij. Osredotočili sva se na število potrebnih dodatnih slikanj pri posamezni tehniki, predvsem naju je zanimalo, za koliko se je njihovo število pri digitalni tehniki zmanjšalo. Med dodatna slikanja sva uvrstili ciljano povečavo, ciljano kompresijo ter ponovno slikanje zaradi neustrezne ekspozicije.

Rezultati: V opazovanem vzorcu je bilo v skupini analognih mamografij narejenih 37,5% povečav, 54,5% ciljanih kompresij in 8% neprimernih ekspozicij, v skupini digitalnih pa 9% povečav, 58% ciljanih kompresij in 1% neprimerno eksponiranih slik.

Razprava: Kljub kakovosti, ki jo nudijo digitalni aparati, je še vedno najpomembnejša vloga radiološkega inženirja, ki mora svoje delo kvalitetno opraviti in se stalno izobraževati.

Zaključek: Rezultati pokažejo, da se je z digitalno mamografijo število vseh dodatnih posnetkov zmanjšalo za 32%. Pri digitalni tehniki je za 28,5% manj povečav, ker se v procesu obdelave slike lahko poljubno spreminjajo kontrastnost, svetlost in povečava. Več napredka v mamografski diagnostiki pričakujeva z vpeljavo tomosinteze, saj se bo odstotek dodatnih slikanj na račun ciljanih kompresij še dodatno zmanjšal.

Ključne besede: digitalna mamografija, analogna mamografija, dodatno slikanje, mikrokalcinacije

ABSTRACT

Purpose: In 2007 the Institute of Oncology Ljubljana has switched from the traditional (analogue) mammography to digital mammography. In this section we will present one of the advantages of digital mammography.

Methods: Our study includes 965 analogue and 965 digital series of mammography. We have focused on the number of additional views of each technique with particular interest in the decreasing percentage of additional views with digital mammogram. Compression spots, magnification views and repeated mammography are included in the study because of inadequate exposure.

Results: Analogue mammography comprised 37.5% magnification views, 54.5% target compressions and 8% inadequate expositions while the digital mammography lead to 9% magnification views, 58% target compressions and 1% inappropriately exposed images.

Discussion: Radiographer still has the most important role to carry out quality work and continuous education; despite the advantages offered by digital mammography sistem.

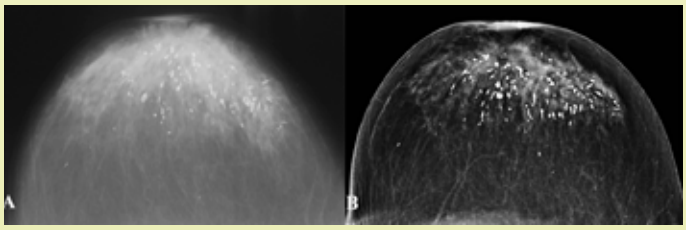
Conclusion: The results of our study indicate that with the digital mammography the number of additional views decreased for 32%. Digital mammography also decreased magnification views for 28.5%, because changing contrast, brightness and screen zoom can be accomplished afterwards. Less target compression in advanced mammographic techniques (tomosynthesis) is also expected.

Keywords: digital mammography, analogue mammography, additional imaging, microcalcification

UVOD IN NAMEN

Rak dojk je v Evropi in v Sloveniji najpogostejši rak pri ženskah. Breme raka dojk se povečuje zaradi večanja vpliva nevarnih dejavnikov, zgodnejšega odkrivanja in staranja prebivalstva (Krajc in sod., 2006). Mamografija je najprimernejša diagnostična metoda za zgodnje odkrivanje raka dojk, saj omogoče prikazovanje drobnih, klinično nezaznavnih spremembe. Je ena izmed najbolj zahtevnih slikovnih metod, zahteve po kakovosti mamografskih posnetkov so večje kot pri drugih rentgenskih posnetkih (Rener in sod., 2001).

Pri analogni mamografiji rentgenski žarki osvetlijo film, ki ga v razvijalni temnici razvijemo v mamografsko sliko. Pri digitalni mamografiji detektorji spreminjajo rentgenske žarke v elektronske signale, ti pa se preko računalniškega sistema pretvorijo v digitalno sliko (slika 1).



Slika 1: Primerjava analogne (A) in digitalne (B) mamografske slike

Prednost digitalne mamografije:

- V treh specifičnih skupinah žensk zazna več tumorjev: pri ženskah, ki so mlajše od 50 let, ter pri zelo gostih in pri zelo tankih dojkah.
- Pri digitalni sliki je mogoče poljubno spreminjati kontrastnost, svetlost in povečavo po že opravljeni mamografiji. Pri analognem mamogramu to ni mogoče in je potrebno preiskovanko ponovno poslikati.
- Preiskava je za preiskovanke krajša, saj ni porebno čakati do konca razvijalnega postopka, slika je prikazana na monitorju skoraj v trenutku.
- Uporaba avtomatske ekspozicije, ki se prilagodi različni debelini in gostoti dojke omogoča, da se izognemo nepravilno eksponiranim slikam (Per Skanne et al., 2003).
- Možnost popravljanja preveč in premalo eksponiranih slik brez ponovnega slikanja.
- Shranjevanje digitalnih slik v računalniškem sistemu (PACS) je preprostejše, arhivi za shranjevanje dokumentacije niso več potrebni.
- Digitalna tehnika omogoča istočasno dvojno odčitavanje slik na dveh delovnih postajah.
- Digitalne slike je mogoče prenesti preko omrežja v druge zdravstvene ustanove.
- CAD, računalniško podprta analiza za detekcijo nepravilnosti, je pri digitalni sliki boljši, saj ne pride do izgube podatkov kot pri klasčnem mamogramu, ki ga je za uporabo CAD sistema potrebno spremeniti v digitalno obliko.

Slaba stran digitalne mamografije je predvsem v ceni, ki je tudi do štirikrat višja od cene analogne.

Raziskovalno vprašanje, ki sva si ga zastavili je ali se s tehničnim napredkom mamografskih aparatov zmanjšuje število dodatnih slikanj na radiološkem oddelku Onkološkega inštituta. Najina hipoteza je, da se s prehodom iz analogne tehnike na digitalno zmanjša število dodatnih slikanj.
Med dodatna slikanja sva uvrstili ciljano povečavo, ciljano kompresijo ter ponovno slikanje zaradi neustrezne ekspozicije.

Ciljano kompresijo in povečavo uporabljamo, kadar želimo razjasniti sumljive nepravilnosti, ki so vidne na osnovnih mamogramih. Tehnika ciljane kompresije omogoča razprtje zgoščenega tkiva. Pripomore tudi k opredelitvi robov tumorja ter pri slikanju retromamilarnega dela, ki je pri osnovni mamografiji slabše komprimiran. S ciljano povečavo je vsaka sumljiva sprememba bolje vidna. Največkrat jo uporabljamo za boljši prikaz mikrokalcinacij: za določitev njihovega števila, razporeditve in oblike. Povečava jasneje prikaže tudi robove in obrise tumorja (Špeh in sod., 2001).
Podobne študije v slovenski in tuji literaturi nisva zasledili.

V vseh delih navajajo le napredek, prednosti in slabosti posamezne tehnike v mamografski diagnostiki.

METODE DELA

V raziskavi sva želeli preučiti odstotek dodatnih slikanj glede na tehniko slikanja: analogna ali digitalna mamografija. Izbrali sva strategijo presečne študije.

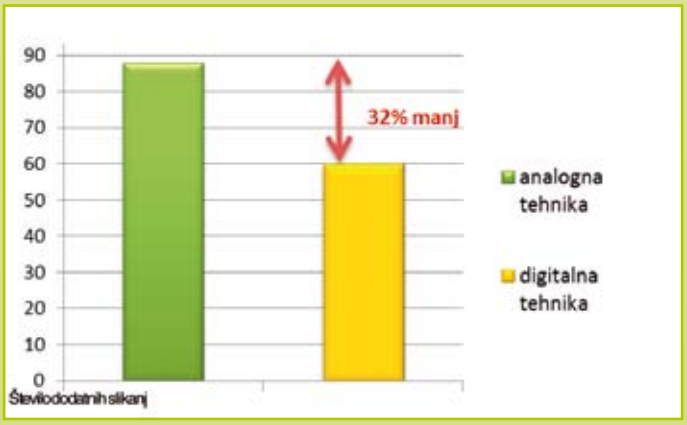
Primerjali sva 965 mamografij, ki so bile narejene v novembru leta 2006 na analognem mamografskem aparatu Lorad M IV in 965 mamografij, ki so bile narejene v novembru leta 2011 na digitalnem aparatu Selenia Hologic. Zanimalo naju je, koliko preiskovank je moralo ponovno priti na dodatno slikanje na posameznem aparatu. Kot dodatno slikanje sva upoštevali ciljano povečavo, ciljano kompresijo, ponovno slikanje zaradi goste oziroma nepregledne dojke ter ponovno slikanje zaradi nepravilno eksponirane slike.

Raziskava je objektivna (nepristranska), saj ni zasnovana na mnenjih in stališčih temveč na sistematični evidenci, število dodatnih slikanj, ki so jih inducirali specialisti radiologi je preverljivo. V prihodnosti bi bilo smotrno raziskavo nadgraditi na nacionalnem nivoju in zajeti večji vzorec; kot zanimivost bi bilo primerjati rezultate z najino raziskavo.

Podatke sva zbrali s pomočjo RIS-a (radiološki informacijski sistem), PACS-a (sistem za arhiviranje in obdelavo slik), Webdoctorja (splošni bolnišnični informacijski sistem) in s pomočjo pregleda vpisne knjige, kamor se vpisujejo vsa dodatna slikanja. V arhivu radiološkega oddelka na Onkološkem inštitutu sva poiskali analogne mamografije in analogna dodatna slikanja, saj v tistem času še nismo imeli radioloških informacijskih sistemov.

REZULTATI

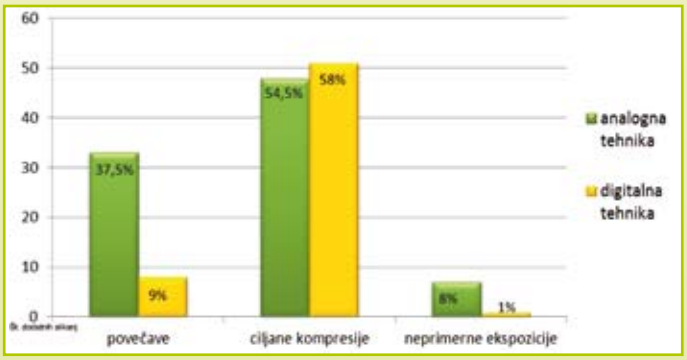
Na analognem aparatu je bilo pri 965 mamografijah narejenih 88 dodatnih slikanj, na digitalnem pa pri istem številu mamografij 60, kar je 32% manj (graf 1).



Graf 1: Število dodatnih slikanj pri dveh vzorcih po 965 mamografij v analogni in digitalni tehniki

Pri podrobnejši analizi sva ugotovili, da je bilo na analognem aparatu od 88 dodatnih slikanj narejenih 33 povečav, 48 ciljanih kompresij in 7 ponovitev slikanja zaradi neprimerne ekspozicije, na digitalnem pa od 60 dodatnih slikanj 8 povečav, število ciljanih kompresij je bilo približno enako,

neprimerno eksponiranih slik zaradi uporabe avtomatske ekspozicije skoraj ni bilo (graf 2).

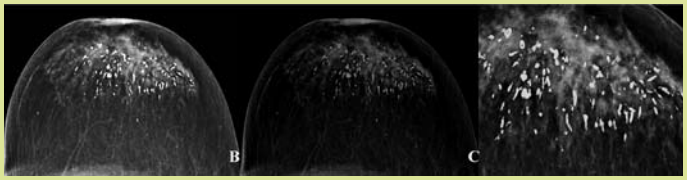


Graf 2: Število dodatnih slikanj glede na vrsto dodatnega slikanja pri dveh vzorcih po 965 mamografij v analogni in digitalni tehniki

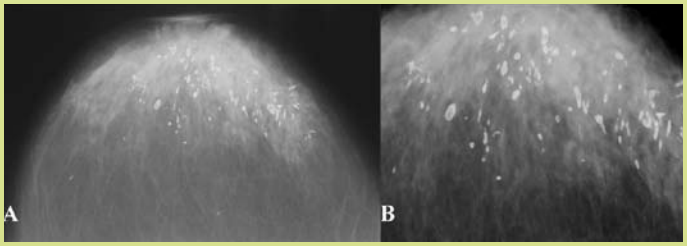
Med dodatna slikanja nisva vključili mamografij, ponovljenih zaradi slabega pozicioniranja, slabe kompresije zaradi bolečine oz. anatomskih ali bolezenskih sprememb pri ženski (npr. poškodovana rama, izbočena prsnica...).

RAZPRAVA

Z uvedbo digitalnega aparata se je število dodatnih slikanj zmanjšalo za 32%. Od tega se je število povečav zmanjšalo za 28,5%, saj lahko pri digitalni tehniki poljubno spreminjamo kontrastnost, svetlost in povečavo v procesu obdelave slike, preiskovanki ni potrebno priti na ponovno slikanje (slika 2). Pri analogni tehnologiji je bilo potrebno opazovani predel naknadno slikati s pomočjo nastavka za povečave (slika 3).



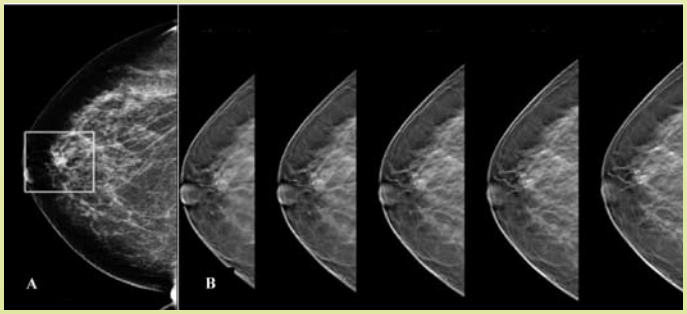
Slika 2: Mamogram, posnet z digitalno tehniko je mogoče poljubno spreminjati: sprememba kontrastnosti (A, B) ter povečava (C) sta mogoča brez ponovnega slikanja



Slika 3: Mamogram, posnet z analogno tehniko (A): za povečavo (B) je bilo potrebno preiskovanko ponovno slikati

Uporaba avtomatske ekspozicije, ki se prilagodi debelini in gostoti dojke, zagotovi pravilno eksponirano sliko, zato nepravilno eksponiranih slik v digitalni tehniki skoraj ni. Takšne slike nastanejo lahko le v primeru silikonskega vsadka, obsevane ali rekonstruirane dojke in tehnične okvare aparata. V najinem vzorcu je bil v skupini mamografij z digitalno tehniko le en primer neprimerno eksponirane mamografije.

Število ciljanih kompresij se pri uporabi digitalnega mamografa ni zmanjšalo, temveč celo povišalo za 3,5%. To minimalno razliko pripisujeva naključno izbranemu vzorcu. Kljub boljši ločljivosti digitalne mamografske slike moramo lezijo v dojki ponovno slikati z manjšim kompresorijem, kar omogoča, da se tkivo bolj razpre. Gur (2007) navaja, da se s tomosintezo zmanjša ne le število ciljanih povečav, temveč tudi ciljanih kompresij. Tomosinteza je serija posnetkov z različnimi nakloni rentgenske cevi, ki omogoča vrsto rezin na različnih globinah dojke. Dobljene presečne slike lahko rekonstruiramo v 3D posnetek. Koncept tomosinteze je preprost: kar je skrito za gostim žleznim tkivom na eni slike je lahko zaradi različnega kota slikanja vidno na drugi (Bakič et al., 2009) (slika 4).
Zaradi napredka mamografske tehnologije se zmanjšuje tudi število invazivnih posegov na dojkah (punkcije dojk).



Slika 4: Prikaz sumljive lezije z digitalnim mamogramom (A) in s tomosintezo (B)

Kljub kakovosti, ki jo nudijo digitalni aparati, je še vedno najbolj pomembna vloga radiološkega inženirja, da svoje delo opravi kvalitetno, se ves čas dodatno izobražuje in spremlja novosti na svojem področju.

Za opravljeno raziskavo preiskovanke niso prejele dodatne doze, saj so bila dodatna slikanja že tako ali tako strokovno indicirana s strani radiologa. Z raziskavo sva dokazali, da se je pri digitalni mamografiji število povečav zmanjšalo, s tem se je posledično zmanjšala dozna obremenitev preiskovankam, ker jih ni bilo potrebno dodatno slikati.

V Sloveniji imamo 22 analognih in 11 digitalnih mamografov. Povprečna žlezna doza se razlikuje glede na vrsto mamografa. Pri analognih mamografih je povprečna žlezna doza 1,59 mGy, pri digitalnih pa 1,42 mGy (podatke posredoval Zdešar, ZVD; december 2011) (tabela 1).

Tabela 1: Število mamografskih aparatov v Sloveniji ter povprečna žlezna doza posamezne mamografije

	Število mamografskih aparatov	*Povprečna žlezna doza (mGy)*
Analogni mamografi	*22*	*1,59*
Digitalni mamografi	*11*	*1,42*

ZAKLJUČEK

Ugotovili sva, da se je število vseh dodatnih slikanj z uporabo digitalne tehnike zmanjšalo za 32%, saj se ciljane povečave skoraj ne izvajajo več, kar pomeni tudi manj dodatne doze za preiskovanke. Več napredka v mamografski diagnostiki pričakujeva z vpeljavo tomosinteze, saj se bo odstotek dodatnih slikanj na račun ciljanih kompresij še dodatno zmanjšal.

Z najino primerjavo sva želeli predstaviti napredek mamografske diagnostike in izvedeti, kaj bi lahko izboljšali v korist vseh izvajalcev in uporabnic na nivoju države. Res je, da novejši mamografski aparat za državo predstavljajo strošek, vendar bi z njimi dolgoročno zmanjšali število dodatnih slikanj, strah preiskovank, dodatno delo, stroške in v nekaterih primerih celo preprečili raka dojk.

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Professional Article

FORENSIC RADIOGRAPHY AND NON ACCIDENTAL INJURIES IN CHILDREN

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ABSTRACT

Aim: This paper explores the role of the diagnostic radiographer from a forensic perspective when imaging children with potential non accidental injuries. The notion of child abuse and non accidental injury specifically is outlined.

Methods: Literature and legislation is presented from both the UK and the Republic of Ireland which have different legal systems.

Results: Practical application is made when exploring the radiographers' role and examples of possible non accidental injury presentations are outlined as well as requirements of witness statements.

Conclusion: Any radiographic examination has the potential to become a forensic case, and as such the radiographer has the possibility of being placed right in the middle of a forensic case. The radiographer has a valuable piece of the child protection jigsaw and as such has vital information to contribute to the evidential chain.

Key words: non-accidental injury, children, radiographer

INTRODUCTION AND AIM

It is important to remember that every radiographic imaging examination undertaken could potentially be or become forensic in nature (IRRT, 2010).

Suspicion and Diagnosis of non accidental injury

Non Accidental falls within the umbrella term of child abuse. This latter term is a large area which includes emotional, physical, sexual abuse and child neglect. Often the abuse will involve two or more of the above. For example emotional abuse may accompany physical abuse or any of the above.

It is first necessary to define the term child abuse, this is: "An intentional act of commission or omission by another person that harms or threatens to harm a child in a significant way" (Department of Health (2001), Birchall and Hallett (1995), Irish Statute Book (1991)).

The key points to note from this definition are the following. The act is an intentional act committed that harms or threatens to harm the child. Alternatively it may be the omission of an act that harms or threatens to harm the child, for example this could be failure to protect a child from a dangerous situation, failure to provide food and water for a child or similar (Barker and Hodes 2004). An equally important factor is that the above harms or threatens to harm the child in a significant way. The term 'significant' is open to professional interpretation and often is the basis of many a child protection discussion and a detailed exploration of the concept is beyond the scope of this paper. Readers are directed to Department of Health 1991, 1999, Irish Statute Book 1998, 2002.

The focus of this paper will be on Non Accidental injury herein referred to as NAI. Speight (1997) stresses the importance of the diagnosis of Non Accidental Injury – " Non accidental injury is one of the most important diagnoses in clinical paediatrics as it can so vitally influence a child's life. At worst it is a matter of life and death for the child and short of death there may still be possible brain damage or handicap" (Speight in Meadows,1997).

NAI may come to the attention of the radiographer in a variety of ways. One way maybe where the radiographer is asked to conduct a skeletal survey to confirm suspicions of NAI (College of Radiographers1995, College of Radiologists 2008). Alternatively it may well be an incidental finding on a radiographic image. For example a radiographer may be asked to conduct a chest radiographic examination for pyrexia of unknown origin, and therefore may give no suspicion of NAI. However on reviewing the image the radiographer may see posterior rib fractures, which would be a potential flag to alert the clinician and certainly warrant further investigation. Alternatively the radiographer may witness a particular event involving the child in the x-ray room or may be a disclosure by the child is made to them, (Davis, 2005).

Children may present at any time to an x-ray department and unless there is a dedicated paediatric hospital to which children are directed to, the local general hospital is often the first point of call following an injury, accidental or otherwise. Therefore any radiographer can potentially encounter a paediatric case, with some radiographers x-raying children on a regular basis (Davis, 2005; Davis and Reeves, 2004). However NAI is brought to the radiographers attention it is prudent to heed the words of Parton et al., 1997.

"Child abuse (and NAI) is identifiable, predictable and preventable via the development and application of scientific research. If only social workers and other professionals familiarised themselves with these research findings and integrated them into their everyday practice, tragedies could be avoided." said Parton et al., 1997.

THE RADIOGRAPHER'S ROLE

As with any radiographic examination, the role of the radiographer is to produce technically correct radiographic images using the lowest possible radiation dose consistent with good image quality (College of Radiographers, 1995; Hogg et al., 1999; Irish Statute Book, 2007; College of Radiologists, 2008; Moore et al., 2012). Previous research by Hogg et al., (1999) referred to the radiographer's role as going beyond the technical acquisition of the radiographic images and further research by Sudberry et al., (1997a, 1997b) referred to the social and emotional role of the radiographer when imaging a child with suspected NAI. This was later highlighted in the Victoria Climbie case (Conway, 2003). Along a similar vein, Davis, 2005 referred to the importance of the radiographer as an evidence collator in the x-ray room during such examinations, and although this was a study published in Ireland, there is similar literature in the UK published by the Department of Health, 1999 regarding protecting children. The principles are transferrable in that the radiographer may be the only person to witness an event, or receive a disclosure which no one else will know unless the radiographer passes that information on. In order to do this the radiographer working under their professional code of conduct (College of Radiographers, 1995; Irish Institute of Radiography and Radiation Therapy, 2010) must understand the significance of the information as discussed Rigney and Davis in their earlier paper of 2004. However Davis and Yielder, 2009 referred to the apathy of radiographers particularly in relation to child protection and suggested various reasons for this.

KEY POINTS IN FORENSIC IMAGING

As the radiographer is producing evidential documents in the form of radiographic images their role is important Sudbery et al., (1997b) highlight the importance of this. The images are also important from a diagnostic and potential treatment point of view and much work has been undertaken regarding potential fracture diagnosis of NAI (Carty, 1997; Royal College of Radiologists, 2008). The radiographic images are part of the forensic process and the chain of evidence (Davis and Reeves, 2009). The Evidential Chain must be maintained and must show continuity of evidence this will be explored in more detail.

The nature of the evidence may be in a variety of formats as outlined below. The evidence may be in the form of Images single or multiple for an unrelated matter, such as in the chest x-ray example above. Alternatively the evidence may be a skeletal survey, together with localised projections of specific areas. It may also be an event that was witnessed by the radiographer or a verbal disclosure. Whatever the nature of the evidence it is important that it is documented by the radiographer. Regarding the earlier point of Image production, it is important that this is conducted in front of a witness, such as Health or Social Care Professional. This witness can then provide a testimony as to what occurred in the x-ray room, this is particularly important regarding the number of projections taken, images produced, the placement of anatomical markers and any bruises or marks that the child may have on their body prior to the radiographic examination.

EVIDENTIAL CHAIN

Throughout any potential or actual NAI case the evidential chain must be maintained. In reality for radiographers this means adherence to particular criteria. For example it is important that there is a record of the child being x-rayed and that the appropriate documentation is completed including witness statements. See Table 2 for an example witness statement. It is important that any notes are made contemporaneously so that a detailed record of all events is recorded and traceable. This forms part of the evidential chain.
It is a sobering thought to remember that any break in the evidential chain may cause the whole chain to collapse. The radiographer may inadvertently break or compromise the evidential chain by their actions or questioning of the child.

All radiographers undertaking forensic examinations should complete a Witness Statement as an accurate and complete record of their involvement in that forensic examination. Such a statement should encompass all aspects of an individual's involvement in a forensic case and should be based on contemporaneous notes (written as you progress through the examination). These detailed contemporaneous notes should be signed and dated and a record kept, as the originals will be given to the investigating officer or passed on at the time of the initial child protection referral. However as the radiographer is imaging the child for suspected NAI, it is important to revisit the indications of this clinical condition.

INDICATIONS OF NAI

Rigney and Davis, 2004 explored radiographers' ability in the Republic of Ireland to recognise NAI and reported that 90% of their sample size was able to detect rib fractures as a positive indicator of NAI. In a later bi cultural study focusing upon paediatric radiographers in Slovenia and the Republic of Ireland conducted by Moore, Davis and Starc, 2012, in which radiographers were presented with a series of radiographic images and asked to rate how confident that they were that the images demonstrated NAI or not, it was interesting to see the radiographers' ability to discern NAI from non NAI images. There are various factors that radiographers need to be aware of when imaging a child that can act as potential indicators of NAI. These are summarised in the table below.

Table 1: Factors to consider when imaging children

History of injury	*Does it change over time? Is it credible? Is it vague?*
Age of the child	*Is the injury consistent with the age and ability of the child?*
Demeanour of child	*How does the child present? What is its general demeanour?*
Interaction between child and parent	*What is the interaction like between the parent and child? Is the parent aggressive to the child? Do they handle the child roughly?*
Frozen awareness	*Does the child exhibit frozen awareness?*
Appearance of child	*What is the appearance of the child? Do they appear unkempt?*

after Rigney and Davis, (2004)

A babygram (the whole child on one image taken using one radiographic exposure) is not appropriate to use during the imaging process as it is undiagnostic (McKinstry, 2001). In cases such as these the radiologist is looking for subtle fracture such as Metaphyseal fractures and epiphyseal fractures including Bucket handle, corner and chip fractures. Consequently a babygram will not show these for a variety of reasons. Firstly the child's bones and joints are not in the correct anatomical position, so there is no true Antero Posterior or Lateral depiction of the joint spaces. Additionally these fractures may be very subtle and so require close scrutiny and occasionally localised projections. Furthermore the babygram gives a large radiation dose to the child and is not admissible as evidence in court. Other fractures which may occur on suspected NAI images are multiple or wide complex skull fractures, rib fractures and fractures in various stages of healing.

GUIDELINES

It is important that radiographers work within the appropriate legal and forensic guidelines according to their country. The Irish Institute of Radiography and Radiotherapy (ISRRT) guidelines are outlined below. If radiographers are unaware or unsure of the guidelines Davis and Reeves (2004) question how do they know they are working within them?

TECHNIQUE

Each anatomical area should be imaged with a separate radiographic exposure to ensure uniform image density and to minimize image unsharpness. This is in preference to the babygram referred to earlier. Additionally every radiographic exposure should demonstrate bony and soft tissue details simultaneously. Furthermore radiographic projections should be obtained at ninety degrees if an abnormality is suspected.

As referred to earlier the technical aspects are only one part of the examination and the radiographer should complete a witness statement. Such a statement may well reduce the likelihood of a court appearance by explaining the events in the x-ray room.

All Radiographers undertaking forensic examinations should complete a Witness Statement as an accurate and complete record of their involvement in that forensic examination. Such a statement should encompass all aspects of an individual's involvement in a forensic case and should be based on contemporaneous notes, written as the radiographer progresses through the examination. These detailed contemporaneous notes are important.

A witness statement should include the following points as outlined overleaf.

Table 2: Witness Statement

All radiographic (X-ray) imaging was performed using the xxxx Digital
Radiography unit in room xxx in xxx Hospital in the presence of witness xxx between 11.00-11.45am on day / month / year.
Others present and their role.
All exposures were made using a X-ray tube focus to detector distance of 100cm and exposure factors of xxx kVp and xxx mAs.
Right and left sided anatomical markers were placed within the collimated field at time of
exposure to allow sides to be identified for all exposures.
A total of x radiographic images were acquired:
List ,using correct terminology in order of actual acquisition
Preliminary Findings:
Name of Radiographer: Signed: Date:
Name of Appropriate Witness: Signed: Date:
xxx Number of images/CDs printed/burnt. These were presented to xxx who
signed to acknowledge receipt of them on day date/ month/year at time.
Name of Representative of Radiology Dept: Signed: Date:
Name of Person who received images/
CD: Signed:

REFERENCE ISRRT (2011)

Imaging Requirements are that each image must have the correct patient identification details, as well as the time and date of the examination inherent on the image. It is not acceptable to write the details on the image at a later late as this will not be admissible in Court as evidence. The name(s) of the Radiographers and the other attending professional must be recorded at the time, ideally upon the image. A single exposure "babygram" must not be performed as it provides sub – optimal image quality; is high radiation dose; and is diagnostically unacceptable to demonstrate anatomy and fractures; and also will not result in true antero-posterior

or lateral positioning (ISRRT, 2011). Several images may well be produced particularly if a full skeletal survey is requested. A typical skeletal survey image series is outlined over the page in Table 3.

Table 3: Standard skeletal survey

Skull *antero-posterior (AP) and lateral projections* *a Townes projection should be obtained for occipital injuries* *skull radiographs should be taken as part of the skeletal survey, even if a CT brain scan has or will be performed, as some skull fractures are not identifiable on CT*
Chest *AP including the clavicles*
Abdomen *AP of the abdomen to include the pelvis and hips*
Spine *lateral cervical spine.* *lateral thoracic spine.* *lateral lumber spine.*
Limbs *AP of both humeri* *AP of both forearms* *AP of both femora* *AP of both tibias/fibulae* *dorsi-plantar (DP) of both hands* *DP of both feet*

Ref ISRRT (2011)

CONCLUSON

Any radiographic examination has the potential to become a forensic case, and as such the radiographer has the possibility of being placed right in the middle of a forensic case, and may be called to a Court of Law to explain their actions, input or what they witnessed during the radiographic examination. Consequently the radiographer provides a valuable role in forensic imaging and especially in relation to NAI. The radiographer has a valuable piece of the child protection jigsaw and as such has vital information to contribute to the evidential chain. It is important that the radiographer does not unwittingly break the evidential chain by their actions as the consequences for the child may be far reaching.

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Professional Article

INVESTIGATING THE ABILITY OF RADIOGRAPHERS TO RECOGNISE TYPICAL NON ACCIDENTAL INJURY FRACTURES IN CHILDREN

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ABSTRACT

Introduction: Child abuse is often underreported by the general population and healthcare professionals for a variety of reasons and, therefore, all avenues to improve the discovery and prevention of child abuse should be explored. Radiographers are well positioned to identify child abuse and in particular Non Accidental Injuries (N.A.I.); having a wealth of experience in image acquisition and visualisation.In the Republic of Ireland Health Care professionals are legally required to report suspicious cases as Designated Officers.

Aim: Our aim was to measure radiographers' ability to recognise non-accidental injury fractures in children comparing radiographers from two different European Countries.

Method: 22 radiographers working in hospitals in the Republic of Ireland and Slovenia viewed 26 plain radiographic images (13 NAI fractures/13 accidental fractures) and rated their confidence on a scale from 1 to 6 that a fracture was either accidental (1-3) or non-accidental (4-6).The images were viewed using ViewDex software on a laptop calibrated to DICOMgreyscale standard display function.Viewing conditions were standardised and optimised. An ROC curve was plotted and sensitivity, specificity and area under the curve (AUC) were calculated for each radiographer.

Results: The results demonstrated a difference in values which AUCwas statistically significant (P=0.0111).
Conclusion: Further research would be beneficial with more images, full skeletal surveys, and paediatric radiologist(s) as a gold standard for comparison.

Key words: non-accidental injury, children, radiographer

INTRODUCTION

Radiographers are well positioned to recognise non-accidental injury in children as they may be the first person to spend time alone with a child who may use this opportunity to confide in them. Radiographers may discover hidden injuries when clothing is removed for imaging, and they are the first to view the diagnostic image of the child which might be the only indication of abuse (Davis and Reeves, 2009, Rigney and Davis, 2004, Hogg et al1999).
The radiographic image is an important aspect of the NAI investigative processas is its interpretation.Research conducted by McNulty et al. (2011) suggests collaboration between radiographers and junior doctors reduces errors in image interpretation.Furthermore, previous research conducted by Brealey et al. (2005) provides evidence that, with appropriate education and training, the accuracy of radiographers in interpreting plain x-ray images is comparable to that of radiologists. The researchers were interested in exploring radiographers' ability to recognisenon-accidental injury in children's radiographs. The aim of our research was to investigate the ability of radiographers in the Republic of Ireland and Slovenia to recognise typical non-accidental injury fractures in children, and compare both groups.

METHODS

Pilot

Before the main study commenced a pilot was performed using academics in one ofthe diagnostic imaging departments as a sample.A number of images were excluded following the pilot due to poor image quality or an unclear fracture site.Some images were tagged with an age to indicate whether the patient was ambulatory, allowing better differentiation between toddlers' fractures and spiral fractures.
For the main study; a random sample of diagnostic radiographers working within paediatric Diagnostic Imaging departments was selected from each country. The sample of 22 radiographers working in hospitals in the Republic of Ireland and Slovenia viewed 26 digital x-ray images of fractures, and rated their confidence on a scale from 1 to 6 that the aetiology of each fracture was either accidental (1-3) or non-accidental (4-6).

Participants

The participants in this study were qualified radiographers who worked in large paediatric referral centres with Accident and Emergency departments in the Republic of Ireland or Slovenia. The inclusion criteria were that all imaged paediatric patients at least once every two days on average. A random selection was utilised based on the sample. The Slovene group had a mean experience of 14.95 years and the Irish group had a mean experience of 12.64 yearsworking as radiographers.

Images

All the images used in the study came from the radiographic teaching file within the Universities and a large paediatric teaching hospital. The participantswere presentedwith 8 previously diagnosed accidental injury images including metaphyseal lesions, rib fractures, occipital compression fractures and spiral fractures of the femur.A further8 images with previously diagnosed non-accidental injury includingColles fractures, greenstick fracture of the radius, clavicle fractures and elbow fractures were also presented. An additional 5 images were selected at random from each group of 8 images and were given minor alterations (that did not alter the fracture site).Each radiographer viewed all of these images.

Image Display Conditions

The images were viewed in random order using ViewDex software(Börjesson et al. 2005) on the same laptop calibrated to DICOMgreyscale standard display function using VeriLum software (Image Smiths, Inc) and luminance pod.Quality checks performed throughout the work with the Society of Motion Picture and Television Engineers test pattern(Society of Motion Picture and Television Engineers 1986) American Association of Physicists in Medicine Task Group 18 findings; and geometry, luminance uniformity, temporal stability, resolution, and veiling glare remained within recommended levels.Ambient lighting was measured using a calibrated photometer to ensure it remained 25-40 luxas suggested by Brennan et al (2006).

Statistical Analysis

The data was inputted into JROCFIT softwareto calculate a range of values for each radiographer including sensitivity, specificity, an ROC curve and an AUCvalue an Az value the area under an ROC curve used as an indicator for performance (Eng, 2006).It was not possible to estimate smooth ROC curves for some of the radiographers due to the presence of asymptotes.Consequently it was difficult, therefore, to generate confidence intervals for these participants.The radiographers were compared on the basis of empirical AUC values using the Mann-Whitney U-Test. We also used ROCKIT software to confirm all the above values were correct and to generate confidence intervals where the raw data allowed (Metz, 2006).

The original intention was to generate a fitted ROC curve, fitted Az values and their confidence intervals; however, the data for a significant minority of the ROC curves was degenerate.This problem was particularly common in the top performers in the Irish sample; the strong confidence they had in their diagnoses coupled with a relatively small number of images and categories on the confidence scale resulted in asymptotes on their ROC curves.The results have shown the fitted Az values and asymmetric confidence intervals where possible, however, the reader should keep in mind that the "degree of non-accidental injury" depicted by the images may not follow a binormal distribution and, consequently the results may be biased (Table 2, Table 3).

By comparing the observers using non-parametric methods, empirical ROC curves and empirical Az values (Table 2,3), we neither had to assume binormal distribution of the images nor was there any degenerate data.However when considering empirical AUC values it is important to remember they tend to underestimate the actual AUC values (Seong, 2004).

The mean Az value of each population sample of radiographers was compared using the non-parametric mean value Mann-Whitney U-Test (Table 1).The mean was for convenience yet is a low measure of central tendency due to the effect of a small number of outliers with low Az values. The Mann-Whitney U-test was used as it is not reasonable to assume the results of the samples followed a normal distribution.

Some images were rated by each radiographer more than once and by comparing the answers, using Kappa with linear weighting, we gained some idea of the consistency/ repeatability of the participants.Linear weighting rather than Cohen's un-weighted Kappa was used as it is appropriate that larger differences in answers would be treated as such (i.e. answering 1 and 5 for the same image is treated as more discordant then answer 1 and 2).A Kappa statistic of 1 is equal to perfect agreement while a score of 0 indicates chance agreement.Participants with high Az values generally had high Kappa statistics, indeed the Kappa statistics were high overall (Table 2, Table 3).

RESULTS

Table 1: The mean values for AUC, sensitivity and specificity.The difference in AUC values compared using a one way mean value Mann-Whitney U Test is statistically significant (U=20, Z=2.54, P=0.0111)

	AUC	*Sensitivity*	*Specificity*
Irish Group $\bar{X}$ =	*0.825 (σ 0.133)*	*70.4%*	*88.2%*
Slovene Group $\bar{X}$ =	*0.698 (σ 0.135)*	*46.9%*	*81.2%*

Table 2: The empirical AUC values, the fitted AUC values with 95 % asymmetric confidence intervals, and linear weighted Kappa statistics with standard errors of the Irish sample

Irish Sample	Empirical AUC	Fitted AUC (Asymmetric 95% Confidence Intervals)	Linear Weighted Kappa (Standard Error)
Radiographer 1	0.849	N/A	0.9211 (0.0797)
Radiographer 2	0.935	0.944 (0.7763 - 0.9921)	0.7568 (0.1469)
Radiographer 3	0.97	N/A	0.7692 (0.1729)
Radiographer 4	0.84	N/A	0.8421 (0.0528)
Radiographer 5	0.825	N/A	0.4 (0.2991)
Radiographer 6	0.82	0.867 (0.657 - 0.966)	0.5333 (0.268)
Radiographer 7	0.787	0.807 (0.590 - 0.934)	1(0)
Radiographer 8	0.488	0.499 (0.272 - 0.726)	0.6154 (0.1938)
Radiographer 9	0.63	0.637 (0.395 - 0.833)	0(0.1863)
Radiographer 10	0.917	N/A	0.8378 (0.1164)
Radiographer 11	0.935	N/A	0.6667 (0.2309)
Radiographer 12	0.873	N/A	0.625 (0.1236)
Radiographer 13	0.861	0.88 (0.69 - 0.968)	0.4857 (0.2623)

Table 3:The empirical AUC values, the fitted AUC values with 95 % asymmetric confidence intervals, and linear weighted Kappa statistics with standard errors of the Slovene sample

Slovene Sample	Empirical AUC	Fitted AUC (Asymmetric 95% Confidence Intervals)	Linear Weighted Kappa
Radiographer 1	0.846	N/A	0.6129 (0.2507)
Radiographer 2	0.754	0.777 (0.547 - 0.92)	0.85 (0.1063)
Radiographer 3	0.814	0.805 (0.547 - 0.945)	0.9143 (0.086)
Radiographer 4	0.76	0.781 (0.556 - 0.921)	0.4783 (0.1324)
Radiographer 5	0.642	0.666 (0.431 - 0.849)	0.5 (0.1932)
Radiographer 6	0.725	0.761 (0.525 -0.913)	0.7857 (0.2047)
Radiographer 7	0.405	0.409 (0.207 - 0.639)	< 0
Radiographer 8	0.743	0.754 (0.515 - 0.91)	0.4706 (0.0928)
Radiographer 9	0.589	0.593	0.85 (0.1063)

DISCUSSION

There was a statistically significant difference between the Irish and Slovene groups.Both groups have a similar level of experience so that does not appear to be an important factor. It appears that with minimal training and involvement in radiography interpretation that radiographers may improve their ability to recognise typical non accidental injury fractures in children.
The 8 week time constraint of this project placed certain limitations of the research.It was not possible to obtain a sufficient number of images to generate a significant AUC value for each radiographer; indeed it remains statistically possible, though unlikely, that the radiographers performed no better than chance.Secondly, the researchers did not utilise a paediatric radiologist to use as a gold standard to compare the radiographers with and consequently cannot comment on the value of radiographer recognition of paediatric fractures in the context of non-accidental injury fractures.

Limitations

With more images it would be possible to produce narrower AUC values and, with additional images and categories on the confidence scale there would probably be much less degenerate data.
The results indicate radiographers can recognise typical non accidental injury fractures better then chance, but it is important to note that these results only apply to the images used in this study.It is debatable whether or not these results can be applied to the radiographer population as a whole because without a paediatric radiologist to use as a gold standard with which to compare our results we have no real notion of how "difficult" the test was.These limitations were an unfortunate consequence of the 8 week time constraint for the completion of the research.

Ability To Recognise Typical Non-Accidental Injury Fractures?

Keeping these limitations in mind the Irish sample seems to have performed rather well.Half the Az values were 0.84 or above, and only two were below 0.787.When these results are considered along with the high Kappa scores there is strong indication that the Irish group can recognise typical non-accidental injury fractures.It is also likely the Slovene sample can distinguish between accidental and non-accidental injury fractures at some level but not to the same extent.

The Effect of Radiographer Experience and Undergraduate /Training

Indeed, there is a statistically significant difference between the Irish and Slovene samples.Both samples have a similar level of experience so it does not appear to be an important factor.The fact that the Irish group works exclusively with children may be a confounding factor yet it seems unlikely to contribute to total the magnitude of the difference.In the opinion of the authors it is reasonable to conclude that

possible undergraduate training and recognition of potential NAI markers in radiography has improved the Irish samples ability to recognise typical non-accidental injury fractures.

In conclusion, there is some indication that radiographers working in the Republic of Ireland can recognise typical non-accidental injury fractures in children; however, further research is needed to confirm or disprove this. The radiographers working in the Republic of Ireland were slightly better at recognising typical non accidental injury fractures then the radiographers working in Slovenia. However it would be useful to repeat this study using a lager sample size.

CONCLUSION

In conclusion the results of this study seem to indicate that radiographers with training and involvement in limited radiographer interpretation can recognise typical non-accidental injury fractures, while those who are not involved in this only performed slightly better than chance.Ashealth care professionals radiographershave a useful contribution to maketo the Multidisciplinaryteam approach regardingthe protection of children.

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Strokovni članek

PROSPEKTIVNA IN RETROSPEKTIVNA RAČUNALNIŠKO TOMOGRAFSKA ANGIOGRAFIJA KORONARNIH ARTERIJ

Professional Article

PROSPECTIVE AND RETROSPECTIVE COMPUTER TOMOGRAPHIC CORONARY ANGIOGRAPHY

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POVZETEK

Uvod in namen: Računalniško tomografska angiografija koronarnih arterij je neinvazivna preiskava za odkrivanje bolezni koronarnih arterij. Zajemanje slike poteka s pomočjo EKG-ja. Na ta način lahko posnamemo srce v fazi njegovega mirovanja. Izognemo se artefaktom zaradi gibanja srca, kar predstavlja velik problem pri klasični spiralni tehniki zajemanja podatkov. Razvoj dual source računalniškega tomografa in zvečanje števila detektorskih vrstic je pripomogel k slikam z boljšo prostorsko in časovno resolucijo. Vse večji pa je problem prejete doze sevanja pri pacientu. Namen članka je predstaviti izboljšave v tehnologiji multidetektorskih računalniških tomografov, ki omogočajo boljše diagnosticiranje bolezni koronarnih arterij ter poiskati odgovor na vprašanje, kdaj uporabiti retrospektivno in kdaj prospektivno zajemanje podatkov.

Metode: Predmet raziskave je bil pregled strokovne literature s področja tehničnih izboljšav, ki jih imajo današnji multidetektorski računalniški tomografi, kot so izboljšanje časovne in prostorske ločljivosti. Pri uporabi EKG – ja sva opisali prospektivno in retrospektivno zajemanje podatkov. Predstavili sva dva protokola za slikanje srca in koronarnih arterij.

Rezultati in razprava: Prospektivno zajemanje podatkov s pomočjo EKG krivulje pokaže podatke v času srčne diastole. Pomembno je, da ima pacient enakomeren srčni utrip. Pri retrospektivnem EKG proženju v času enega vdiha zajamemo podatke celotnega preiskovanega območja. Katero tehniko slikanja bomo uporabili, je predvsem odvisno od pacientovega srčnega utripa in od napotne diagnoze. Avtorji navajajo, da je doza sevanja na pacienta pri računalniško tomografskai angiografiji koronarnih arterij s prospektivno tehniko do 85% manjša, kot pri retrospektivni tehniki. Tudi v naši inštituciji je doza pri retrospektivni tehniki manjša za enak odstotek.

Zaključek: S prospektivnim EKG proženjem dozo v primerjavi z retrospektivnim bistveno zmanjšamo. Kakovost slik pri prospektivnem CT - ju koronarnih arterij bistveno ne odstopa od kakovosti slik pri retrospektivnem.

Ključne besede: koronarna srčna bolezen, prostorska in kontrastna resolucija, časovna ločljivost, prospektivno in retrospektivno EKG proženje

ABSTRACT

Computed tomography angiography (CTA) is a minimal invasive medical examination used to detect possible coronary artery diseases. CT imaging is taken alongside ECG recording. This way a heart can be scanned during its resting phase avoiding the artefact due to heart movement, which is a major problem in the classical spiral data acquisition. The development of the dual-source Computer Tomography (DSCT) and the increased number of detectors improved spatial and temporal image resolution, however increasing the problem of radiation doses received by the patient.

UVOD

Posledica koronarne srčne bolezni je motena oskrba srčne mišice s krvjo. Ta bolezen v zahodnem svetu povzroča visoko obolevnost in smrtnost prebivalstva. V večini primerov je vzrok zanjo ateroskleroza srčnih žil, redko pa je zmanjšana prekrvitev srčne mišice posledica nenadnega krča koronarnih arterij. Srčna mišica mora biti stalno oskrbljena s primerno količino kisika zato ji pri zmanjšani oskrbi s kisikom grozi neke vrste zadušitev, ishemična okvara. K diagnosticiranju koronarne bolezni so pripomogle nove tehnološke izboljšave multi detektorskih računalniških tomografov (MDCT – multiple row detector coputed tomograph), ki omogočajo neinvazivno slikanje srca in oceno koronarne srčne bolezni. Z raziskovanjem slikanja srca in koronarnih arterij z računalniško tomografijo se ukvarjajo že od začetka njenega razvoja, več kot tri desetletja. Zaradi nezadostne hitrosti, slabe prostorske in časovne ločljivosti prejšnjih generacij računalniških tomografov, je bilo natančnejše ocenjevanje koronarnih arterij in funkcije srca do neke meje onemogočeno. Nedavne izboljšave v tehnologiji MDCT, kot so povečanje prostorske ločljivosti, ki je manjša od milimetra (manj kot 0,75 mm), izboljšana časovna ločljivost (80 – 200 ms) in zajemanje podatkov s pomočjo EKG – ja so doprinesle k boljšemu prikazu funkcije srca in njegovih arterij.

V tem prispevku bova predstavili izboljšave v tehnologiji MDCT. Glavni izziv slikanja hitro utripajočega srca je

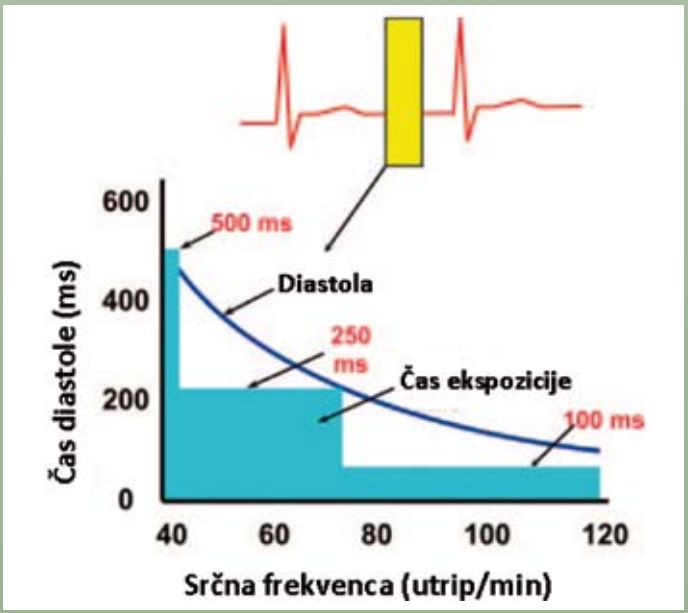
zagotoviti zadostno časovno ločljivost. Srce najbolj miruje v času diastole, koronarne arterije pa so v tej fazi optimalno polnjene s krvjo, zato je najprimernejše slikanje v tej fazi. Pri prospektivni tehniki slikanja snemamo srčni cikel v fazi diastole, pri retrospektivni tehniki pa srce snemamo v celotnem ciklusu. Avtorji študij navajajo, da je pri CTA koronarnih arterij povprečni odmerek efektivne doze pri retrospektivni tehniki med 18 in 26 mSv. Z uporabo prospektivne tehnike pa lahko zmanjšamo dozo sevanja tudi od 67% do 83 % (Earls et al., Shuman et al., Hirai et al. in Arnoldi et al.). EKG beleženje se med slikanjem izvaja zato, da sta zajemanje in rekonstrukcija sinhronizirana z bitjem srca. Najino vprašanje je, kdaj uporabiti prospektivno in kdaj retrospektivno zajemanje podatkov?

METODE

Predstavili bova protokol za slikanje srca in koronarnih arterij. Osredotočili se bova na opis tehničnih izboljšav, ki jih imajo današnji MDCT-ji, kot so izboljšanje časovne in prostorske ločljivosti. Pri uporabi EKG-ja bova opisali prospektivno in retrospektivno zajemanje podatkov.

Časovna ločljivost

Da bi bolje demonstrirali in razumeli potrebo po visoki časovni ločljivosti, slika 1. prikazuje, kako se dolžina (v času) diastolične faze v času spreminja glede na frekvenco srčnih utripov. Z naraščanjem srčne frekvence se diastolična faza skrajša do takšne stopnje, da mora biti časovna ločljivost manjša od 100 ms, da objekt slikanja ustrezno prikažemo. Želena časovna ločljivost za frekvenco, višjo od 70 utripov na minuto je 250 ms in 150 ms za frekvence, višje od 100. Idealno slikanje brez premikanja za vse faze zahteva časovno ločljivost okrog 50 ms. Zlati standard za primerjavo časovne ločljivosti, dobljene z MDCT je klasična radiologija, kjer pri ekspozicijah, dolgih od 1 do 10 ms gibanje srca ne vpliva na prostorsko ločljivost slike. Zato želje po visoki časovni ločljivosti zahtevajo kratke slikovne čase, da dobimo ustrezne podatke za rekonstrukcijo slike.



Slika 1: Shematični prikaz dolžine diastol glede na frekvenco srca (Mahesh and Cody , 2007)

Na časovno ločljivost pri MDCT vplivajo številni dejavniki. Med njimi so ključni čas vrtenja cevi, način zajemanja podatkov, vrsta rekonstrukcije in pitch (Euclid, 2009):

Čas vrtenja cevi: Čas vrtenja cevi je definiran kot čas, ki je potreben za eno rotacijo (360°) cevi okrog objekta. Običajni čas vrtenja cevi je 750 ms, napredek v tehnologiji ga je močno skrajšal, na 330 – 370 ms. Najugodnejša časovna ločljivost pri slikanju srca je omejena s časom vrtenja cevi. Hitreje kot se cev vrti, boljša je. Z naraščanjem hitrosti obratov se veča tudi obremenitev aparata, ker hitro vrtenje težkih komponent mehanizma, ki sestavljajo tomograf, predstavlja večje sile gravitacije, ki otežujejo kasnejše upočasnjevanje časa rotacije. Tudi majhna izboljšava inkrementa (korak prekrivanja) predstavlja velik konstruktorski zalogaj za čas vrtenja cevi. V preteklosti je bil najmanjši čas rotacije večji od 2 s, v zadnjih nekaj letih pa se je počasi zmanjševala na manj kot 400 ms. Ker s trenutnim časom rotacije ne dobimo zadostne časovne ločljivosti, so se razvile različne metode za rešitev tega problema, na primer različne vrste pridobivanja podatkov ali rekonstrukcije slik za nadaljnjo izboljšavo časovne ločljivosti (Euclid, 2009).

Način in protokol pridobivanja podatkov: Slikanje srca zahteva da so prikazani podatki dobljeni v najkrajšem času, da gibanje srca ne vpliva na prostorsko ločljivost. To lahko dosežemo s MDCT s prospektivnim ali retrospektivnim EKG zajemanjem. Protokol opisan v tabelah 1 in 2 uporabljamo na Kliničnem inštitutu za radiologijo Univerzitetnega kliničnega centra v Ljubljani. Preiskava poteka na 64-reznem računalniškem tomografu, proizvajalca Siemens (Dual Source CT Somatom Definition).

Tabela 1: Protokol pri retrospektivni tehniki slikanja

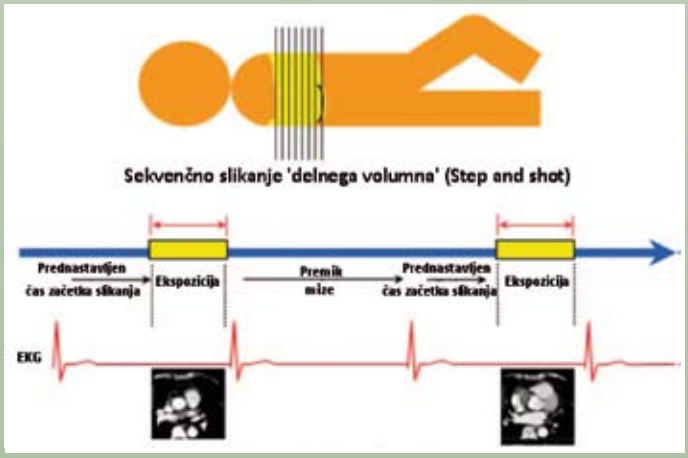
2 TOPOGRAMA	AP (512 mm) in str (512 mm)	
napetost (kV)	120	
tok (mAs)	35	
SCAN	rtg cev A	rtg cev B
napetost (kV)	120	120
tok (mAs)	380 - 430	430
debelina reza (mm)	0,6	
kolimacija (mm)	64 x 0,6	
čas rotacije (s)	0,33	
čas zakasnitve (s)	glede na čas, ki ga izračuna test bolus	
čas skeniranja (s)	odvisno od pacientove frekvence srca	
CTDI (mGy)	35,95	
pitch	odvisno od pacientove frekvence srca	
REKONSTRUKCIJA		
rekonstrukcijski algoritmi	B26f, B30f, B70f	
debeline rekonstruiranih rezov (mm)	0,6; 1,00; 3,00	
rek. inkrement (mm)	0,3 – 0,7	
širina okna	700	
center okna	80	
območje skeniranja	od arkusa aorte do nekaj cm pod trebušno prepono	
smer skeniranja	kranio – kavdalno	
AEC (CARE Dose)	vklopljen	

Tabela 2: Protokol pri prospektivni tehniki slikanja

2 TOPOGRAMA	AP (512 mm) in str (512 mm)	
napetost (kV)	120	
tok (mAs)	35	
SCAN	rtg cev A	rtg cev B
napetost (kV)	120	120
tok (mAs)	430	430
debelina reza (mm)	0,6	
kolimacija (mm)	64 x 0,6	
čas rotacije (s)	0,38	
čas zakasnitve (s)	glede na čas, ki ga izračuna test bolus	
čas skeniranja (s)	odvisno od pacientove frekvence srca	
CTDI (mGy)	4,26	
pitch	/	
REKONSTRUKCIJA		
rekonstrukcijski algoritmi	B26f, B30f, B70f	
debeline rekonstruiranih rezov (mm)	0,6; 1,00; 3,00	
rek. inkrement (mm)	0,3 – 0,7	
območje skeniranja	od arkusa aorte do nekaj cm pod trebušno prepono	
smer skeniranja	kranio – kavdano	
AEC (CARE Dose)	vklopljen	

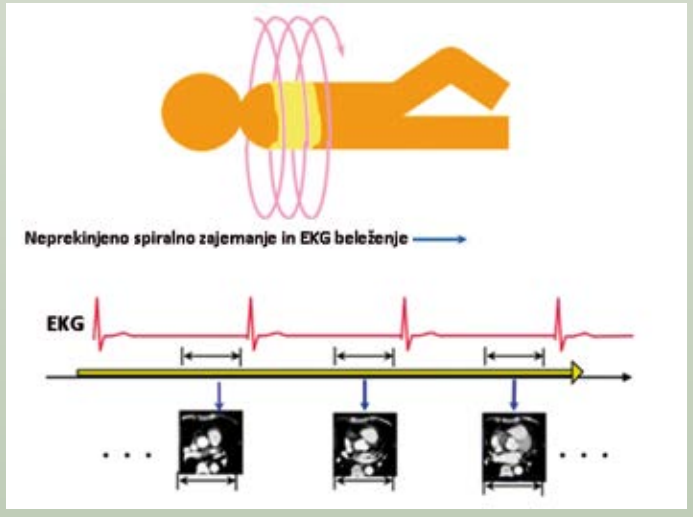
Prospektivno EKG zajemanje: Prospektivno zajemanje je podobno sekvenčni CT metodi, imenovani tudi »step and shoot«. Med slikanjem EKG beleži funkcije pacientovega srca (slika 2). Protokol slikanja je odvisen od EKG krivulje. Sestavljen je tako, da začetek slikanja nastavimo na želeni dolžini med dvema R zobcema, npr.: na 60% ali 70% R – R intervala, običajno v diastoli. Računalniški tomograf je usklajen s pacientovim pulzom, zajemanje podatkov se začne na prej nastavljenem mestu R – R intervala. Prikazani podatki so pridobljeni samo iz dela celotne rotacije cevi, kar imenujemo delni volumen. Za rekonstrukcijo celotne CT slike je potrebno pridobiti podatke iz 180° in pahljačast kot detektorjev v transverzalni ravnini. Zato je čas, ki ga potrebujemo za pridobitev podatkov odvisen od časa vrtenja cevi. Najboljša časovna ločljivost, ki jo lahko dobimo z metodo delnega slikanja je nekoliko višja od polovičnega časa vrtenja cevi. Ko pridobimo želene podatke se miza premakne na naslednje mesto in ko srce preide v ustrezno

fazo mirovanja zajamemo naslednje slike. Ta cikel se ponavlja, dokler ni zajeto celotno preiskovalno področje (Euclid, 2009). Pri večrezinskih računalniških tomografih večje število detektorjev v z smeri omogoča, da v eni rotaciji zajamemo večji volumen srca. To je velika prednost pri zmanjševanju časa, ko mora pacient zadržati dih, tako zmanjšamo artefakte zaradi dihanja. Ena izmed prednosti prospektivnega zajemanja je zmanjšana doza, ker dobimo podatke iz kratkih časovnih intervalov in ne iz celotnega srčnega cikla. Časovna ločljivost v tem primeru znaša od 200 do 250 ms. Ta tehnika je tudi uporabna za ti. ocenjevanje stopnje kalcinacije koronarnih arterij. V tem primeru lahko tok rentgenske cevi precej zmanjšamo, saj je kalcij sam po sebi precej kontrasten in je zaradi visokega CT števila dobro viden. Vsi podatki so običajno dobljeni v fazi diastole (Euclid, 2009). Širina okna, v katerem zajemamo podatke je 10%, s tem dobimo ustrezen prikaz leve in desne polovice srca (Steigner et al 2009).



Slika 2: Shematski prikaz prospektivnega zajemanja podatkov (Mahesh and Cody, 2007)

Retrospektivno EKG zajemanje: Je najpogosteje uporabljena tehnika zajemanja podatkov pri slikanju srca. Pri tem načinu se pacientu snema EKG ves čas, simultano pa se izvaja spiralno slikanje (slika 3). Informacija o preiskovančevem srčnem ciklu se uporabi med rekonstrukcijo, ki jo izvedemo retrospektivno. Rekonstrukcija slike je izvedena s podatki iz delnega volumna ali iz podatkov segmentiranih rekonstrukcij. Pri segmentiranih rekonstrukcijah so izbrani podatki iz različnih delov srčnega cikla tako, da je vsota segmentov enaka najmanjšemu podatku delnega volumna, ki je potreben za rekonstrukcijo slike. S tem dodatno izboljšamo časovno ločljivost, ki znaša od 80 do 250 ms (Euclid, 2009).



Slika 3: Shematski prikaz pri retrospektivnem zajemanju podatkov (Mahesh and Cody, 2007)

Prostorska ločljivost

Prav tako je za kvaliteto slike pomembna velika prostorska ločljivost. Omogoča prikaz koronarnih, ki potekajo v vseh smereh in imajo vedno manjši premer, od nekaj mm do manj kot 1 mm. Za prikaz manjših struktur potrebujemo majhne volumske enote. Prostorska ločljivost je izražena v parih črt/cm oz. milimeter (lp/cm ali lp/mm). Tudi tukaj je zlati standard klasična radiologija, kjer je prostorska ločljivost manjša od 0,2 mm (Mahadevappa, 2006). Zato je glavni cilj razvoja MDCT tehnologije dobiti podobno prostorsko ločljivost v vseh smereh, pogosto jo imenujemo izotropična prostorska ločljivost.

Na prostorsko ločljivost vplivajo tudi: velikost detektorjev v longitudinalni smeri, rekonstrukcijski algoritmi in premikanje pacienta.

Vpliv velikosti detektorja: Velikost detektorja v z smeri ima velik vpliv na prostorsko ločljivost, kar je bilo gonilo razvoja MDCT. Velik razpon področja, pokritega s tankimi rezinami zahteva številčnejše detektorje v z smeri, kar pa predstavlja zaščitni znak MDCT tehnologije. Transverzalna prostorska resolucija je bila že od začetka zadostna, saj je odvisna od matrice in velikosti prikazanega področja (FOV – field of view). Longitudinalna resolucija pa je odvisna od debeline rezov.

Rekonstrukcijski interval: Določa stopnjo prekrivanja rekonstruiranih slik. Je neodvisen od kolimacije ali debeline rezov in ne vpliva na čas preiskave in na dozo sevanja. S prekrivanjem slik izboljšujemo resolucijo v z smeri, kar pride prav pri 3D prikazu in multi planarni rekonstrukcijah MPR (maximum intensy projection). Kadar se slike ocenjujejo le iz transverzalnih slik, prekrivanje nima pomena, vendar pogosto uporabljamo različne MPR, curved MPR in VRT (volume rendering technique) prikaze. Za rutinsko slikanje je zadostno 30% prekrivanje, pri slikanju srca pa je zaželeno 50% prekrivanje. S prekomernim prekrivanjem dobimo veliko število slik, kar podaljšuje čas rekonstrukcije, čas interpretacije, težave s shranjevanjem in pošiljanjem

podatkov, tako da je prekrivanje smiselno le do neke razumne meje.

Metode rekonstrukcije

Rekonstrukcija delnega volumna: je najbolj praktična metoda rekonstrukcije slike. Uporablja se pri obeh metodah zajemanja podatkov. Najmanjša količina podatkov, ki jih potrebujemo za rekonstrukcijo je vsaj 180° in pahljačast kot detektorjev podatkov v transverzalni ravnini. To določa čas zajemanja za pridobitev podatkov, ki jih potrebujemo za rekonstrukcijo delnega volumna, omejuje pa časovno ločljivost, ki jo lahko pridobimo iz zajemanja. CT detektorji v transverzalni ravnini zajemanja se raztezajo v loku, ki pokriva vsaj 30 do 60% pahljačastega kota. Če je čas rotacije cevi 500 ms, je čas, ki ga potrebujemo, da dobimo minimalno število slikovnih podatkov nekoliko večji kot polovica časa vrtenja cevi, kar je najmanjša možna časovna ločljivost, ki jo lahko dobimo z rekonstrukcijo delnega volumna. Zato proizvajalci težijo k vedno hitrejšim rotacijam cevi. Danes je v komercialne namene možno dobiti računalniški tomograf s časom vrtenja cevi 330 ms. Zaradi zahtev po boljši časovni resoluciji pa so se razvili dual source sistemi (DSCT) (Euclid, 2009). Dva detektorska sistema, ki sta postavljena pod kotom 90° istočasno zajemata podatke v isti fazi srčnega cikla in na istem anatomskem področju. S tem dobimo konstantno časovno resolucijo, ki je enaka četrtini rotacije cevi, ne glede na pulz. To močno poveča diagnostično vrednost dobljenih slik (Seidensticker et al., 2008).

Več segmentna rekonstrukcija: Da bi lahko dosegli še boljšo časovno ločljivost, so razvili več segmentno rekonstrukcijo (Flohr et al, 2005). Pri tem načinu izberemo različne sekvence srčnega cikla, namesto iz enega dobimo podatke za rekonstrukcijo iz delnega volumna. To je možno le z retrospektivno tehniko in pri pacientih z rednim srčnim ritmom. Prikazani podatki se pridobivajo v različnih delih srčnega cikla. Ta metoda izbere male dele prikazanih podatkov, ki so dobljeni v različnih delih srčnega cikla, ko pa so sestavljeni, dobimo dovolj podatkov za rekonstrukcijo delnega volumna. Dobra lastnost več segmentne rekonstrukcije je boljša časovna ločljivost, slabost je slabša prostorska ločljivost, ker so prikazani podatki dobljeni iz različnih delov srčnega cikla in zaradi hitrega premikanja dobimo slabši prostorski prikaz.

Časovna ločljivost pri slikanju srca je odvisna od hitrosti rotacije cevi. Čas rotacije med 330 in 500 ms je mogoč pri MDCT s 16 do 64 vrsticami detektorjev. S takim časom vrtenja cevi je mogoče doseči časovno ločljivost 8 ms, z več segmentno rekonstrukcijo ali rekonstrukcijo delnega volumna. Oba tipa rekonstrukcije zahtevata v času vrtenja med zajemanjem podatkov zadostno število projekcij, kar določeno s pitchem. Navadno znaša pitch za slikanje srca med 0,25 do 0,5.

REZULTATI IN RAZPRAVA

Prospektivno zajemanje podatkov s pomočjo EKG krivulje pokaže podatke v času srčne diastole. Pri tej vrsti proženja je pomembno, da ima pacient enakomeren srčni utrip. Pri retrospektivnem EKG proženju v času enega vdiha zajamemo podatke celotnega preiskovanega območja. Katero tehniko slikanja bomo uporabili, je predvsem odvisno od pacientovega srčnega utripa in od napotne diagnoze. Iz slik, ki jih dobimo pri retrospektivnem zajemanju podatkov lahko napravimo rekonstrukcije slik iz podatkov, zajetih v sredi ali proti koncu diastolične faze, ko je gibanje srca najmanjše.

Na našem inštitutu po predhodnem znižanju srčne frekvence na manj kot 60 utripov/min z intravenozno aplikacijo β blokatorjev uporabljamo prospektivno zajemanje podatkov, pri pacientih, pri katerih je pomembna čim manjša doza (otroci, mladostniki) ali kadar je bistven le podatek o poteku koronarnih arterij (izključitev malignega poteka). V teh primerih lahko dodatno zmanjšamo dozo sevanja, tudi s povečanjem kolimacije detektorjev. V ostalih primerih zaradi pogostosti artefaktov zaradi premikanja, peristaltike ali dihanja uporabljamo retrospektivno tehniko, ki omogoča oceno področja kjer je v diastoli prisoten artefakt. Retrospektivno slikanje tako omogoča oceno segmentov, ki jih v diastoli zaradi različnih artefaktov ni mogoče oceniti. Dozo sevanja bi lahko zmanjšali tudi z individualnim prilagajanjem toka na rentgenski cevi, glede na pacientov ITM (indeks telesne mase). Dozo na ta način lahko zmanjšamo tudi za 21% (Jung et al., 2003).

Avtorji navajajo, da je doza sevanja na pacienta pri CTA koronarnih arterij s prospektivno tehniko do 85% manjša, kot pri retrospektivni tehniki. Tudi v naši inštituciji je doza pri retrospektivni tehniki manjša za enak odstotek. Slaba lastnost retrospektivnega zajemanja je večja doza, ker podatke dobivamo skozi celoten srčni cikel, za končno rekonstrukcijo pa uporabimo le del teh podatkov. Doza sevanja je velika tudi zaradi spiralnega slikanja in majhnega pitcha, zaradi katerega dobimo precejšnje prekrivanje med slikanjem. Male vrednosti pitcha in pretirano prekrivanje pa potrebujemo, da dobimo minimalne razmike med dobljenimi podatki.

ZAKLJUČEK

Slikanje srca je zelo zahtevna aplikacija MDCT, ki mora biti opravljena s poudarkom na zmanjševanju doze sevanja. Informacije iz EKG–ja uporabimo za kontrolo toka v cevi in s tem zmanjšamo dozo pri preiskavi. S prospektivnim EKG proženjem dozo v primerjavi z retrospektivnim bistveno zmanjšamo. Kakovost slik pri prospektivnem CT - ju koronarnih arterij bistveno ne odstopa od kakovosti slik pri retrospektivnem.

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Strokovni članek

DIGITALIZACIJA V RADIOLOŠKI TEHNOLOGIJI

Professional Article

DIGITALIZATION IN RADIOGRAPHY

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POVZETEK

Uvod: Tako kot na vsa področja sodobnega življenja digitalizacija prodira tudi na področje rentgenske diagnostike.

Metode: V prispevku so opisane osnove delovanja digitalnih sistemov, ki se uporabljajo v klasični rentgenski diagnostiki in sicer sistemov za računalniško radiografijo (digitalne slikovne plošče) ter sistemov za digitalno radiografijo. Na kratko so opisane tehnologije, na katerih temeljijo detektorski sistemi.

Rezultati in razprava: Predstavljene so njihove glavne značilnosti s poudarkom na razlikah glede na kombinacijo film-folija ter ključni parametri, ki vplivajo na kvaliteto slike. Prispevek se konča s kratko primerjavo prednosti ter slabosti digitalnih sistemov v primerjavi s klasičnimi rentgenskimi filmi.

Ključne besede: digitalni sistemi, detektorski sistemi, radiološka tehnologija

ABSTRACT

Introduction: Digitalization is present in all fields of modern life and x-Ray diagnostics is no exception.

Methods: The present paper describes basic principles of digital systems used in classic x-ray diagnostics i.e. computer radiography systems (digital image plates) and digital radiography systems. Short description of detector system technologies is included.

Results and Discussion: The description of main characteristics is completed with the review of differences between film-foil combinations and key parameters which affect the image quality. Article concludes with advantages and disadvantages of digital systems in comparison with classic x-ray films.

Key words: digital systems; detector systems, radiography

UVOD

Digitalni sistemi se v rentgenski diagnostiki uporabljajo že desetletja. Tako je zajem podatkov v digitalni obliki, ki omogoča 3D rekonstrukcijo slike, osnova vseh 3D slikovnih načinov (CT, SPECT, PET, MRI, …). A tudi na področju klasične rentgenske diagnostike so se prvi digitalni sistemi na osnovi slikovnih plošč pojavili že sredi osemdesetih let prejšnjega stoletja. Vendar so digitalni sistemi začeli intenzivno nadomeščati sisteme film-folija šele v zadnjem času. Digitalni sistem, ki naj nadomesti klasične rentgenske filme, mora namreč izpolnjevati več zahtev:

- dobljena slika mora zadoščati za diagnostične namene,
- celoten postopek mora trajati enako ali manj časa kot pri filmu,
- potrebna doza mora biti enaka ali manjša kot pri uporabi filma,
- uporabljene tehnike morajo biti primerljive tehnikam pri uporabi filmov in
- podatki morajo biti shranjeni v standardnem formatu.

Čeprav ni potrebno, da so vse lastnosti slike, dobljene z digitalnim detektorjem, v vseh pogledih enake lastnostim slike na filmu, pa morajo zadoščati kriterijem za diagnostično uporabno sliko.

Zahteve za lastnosti slike kot so ločljivost, kontrast in velikost so odvisne od slikanega področja in diagnostičnega vprašanja. Pri tem je dosegljiva kakovost slike, dobljene z digitalnim sistemom, močno odvisna od lastnosti detektorja, te pa od uporabljene tehnologije in podrobnosti tehnične izvedbe.

Sistemi za računalniško radiografijo

Računalniška radiografija (CR - Computed Radiography) temelji na uporabi fosfornih plošč (PSP - Photosimulable phosphor). Tako kot pri ojačevalnih folijah, ki se uporabljajo v sistemu film-folija, tudi pri fosfornih ploščah, ki se uporabljajo v CR sistemih, fotoni rentgenske svetlobe vzbudijo elektrone v fosfornih ploščah v vzbujeno stanje. Le ti nato del prejete energije izsevajo kot vidno svetlobo. Vendar je pri fosforjih, ki se uporabljajo v CR sistemih, ta proces bistveno počasnejši kot v ojačevalnih folijah in lahko traja ure ali več. Tako po obsevanju fosforne plošče z rentgensko svetlobo na njej ostane latentna slika, ki jo odčitamo v CR čitalcih.

Fizično je sistem za računalniško radiografijo precej podoben sistemu z rentgenskimi filmi, pa tudi pri delovnem procesu ni velikih razlik. Fosforne plošče se nahajajo v kasetah, podobnim kasetam s kombinacijo film-folija, tako da ob aparatu delo s kaseto ostaja praktično enako. Po ekspoziciji se CR kaseto vstavi v CR čitalec. Tam se fosforna plošča odstrani iz kasete, nato pa se celotno ploščo, točko po točko prečeše z laserskim žarkom. Osvetlitev fosforja z laserskim žarkom ustrezne valovne dolžine spodbudi izsevanje dela energije, shranjene v obsevani točki, v obliki vidne svetlobe. Pri tem je količina izsevane vidne svetlobe sorazmerna s

količino rentgenske svetlobe, ki je med ekspozicijo padla na to točko. Izsevano svetlobo se po optičnih vlaknih vodi do fotopomnoževalk ali fotodiod, kjer se pretvori v električni signal in nato digitalizira. Za vsako točko tako dobimo določeno vrednost signala, ki je sorazmerna s količino vpadle rentgenske svetlobe. Vrednost za vsako odčitano točko se shrani v obliki matrike, ki predstavlja rentgensko sliko v digitalni obliki. Vendar se zaradi omejenega časa odčitavanja pri osvetljevanju z laserjem ne odda vsa shranjena energija. Zato je po končanem odčitavanju potrebno celo ploščo osvetli z močno svetlobo, s čimer se izbriše še preostala latentna slika. Nato se fosforna plošča vrne v kaseto, pripravljena za ponovno uporabo.

Količina izsevane svetlobe predstavlja signal iz izbrane točke in vpliva na razmerje signal/šum na zajeti sliki. Povečamo jo lahko z daljšim časom osvetljevanja z laserskim žarkom ali s povečanjem velikosti posamezne točke (t.j. preseka laserskega žarka). Z daljšim časom osvetljevanja tako sicer izboljšamo razmerje signal/šum, vendar na račun daljšega časa odčitavanja CR plošče. Presek laserskega snopa pa vpliva na velikost točk, iz katerih je sestavljena slika in s tem na prostorsko ločljivost. Kot pri ojačevalnih folijah pa je prostorska ločljivost omejena tudi z disperzijo svetlobe in je odvisna od debeline fosforne plasti. Zato tudi pri CR sistemih večja debelina fosforne plošče omogoča boljši izkoristek a na račun slabše prostorske ločljivosti.

Zaradi napak oziroma okvar fosforne plošče ali CR čitalca se lahko pri uporabi CR sistemov na slikah pojavljajo različni artefakti. Le ti so lahko posledica slabše kakovosti fosforne plošče zaradi staranja ali vlage ali pa njenih poškodb (npr. prask). Artefakti lahko nastanejo tudi zaradi napak CR čitalca, bodisi mehanskih (umazani ali poškodovani optični vodniki, slabi električni kontakti itd.) ali električnih oziroma programskih (npr. napake pri digitalizaciji ali obdelavi slike).

Sistemi za digitalno radiografijo

Za razliko od računalniške radiografije sistemi za digitalno radiografijo (DR) odziv na vpadlo rentgensko svetlobo podajo neposredno kot električni signal. Pri tem se uporabljata dva različna pristopa

- indirektni digitalni detektorji in
- direktni digitalni detektorji.

Indirektni digitalni detektorji tako kot sistemi film-folija uporabljajo fosforne plošče (oziroma scintilatorje), v katerih se vpadna rentgenska svetloba spremeni v vidno. Da bi izboljšali prostorsko ločljivost pa se pri digitalnih detektorjih pogosto uporabljajo fosforji z iglično strukturo, ki delujejo kot optični vodniki in tako zmanjšajo disperzijo. Namesto na rentgenski film nastala vidna svetloba pade na detektorsko plast iz amorfnega silicija (a-Si), v kateri povzroči nastanek električnega signala. Pri tem je detektorska plast sestavljena iz številnih drobnih fotodetektorjev. Signal vsakega fotodetektorja je sorazmeren s količino vpadle vidne (in posledično rentgenske) svetlobe, njegov položaj pa določa, katero točko na sliki predstavlja. Za detektorsko plast se najpogosteje uporabljajo ploski (flat panel) detektorji na osnovi tehnologije TFT ali pa detektorji na osnovi CCD.

Pri ***direktnih digitalnih detektorjih*** pa uporaba ojačevalne plasti ni potrebna. Namesto fosforja se nad detektorsko plastjo nahaja plast amorfnega selena (a-Se), ki ima bistveno višje vrstno število kot silicij in zato precej boljši izkoristek za absorpcijo rentgenske svetlobe (Z(Se)= 34, Z(Si)=14). Tako se selen lahko uporablja za neposredno detekcijo rentgenske svetlobe. Ta v selenu povzroči nastanek električnega signala (parov elektron-vrzel), ki pod vplivom električnega polja odteče do detektorske plasti. Za detektorsko plast se običajno uporabljajo ploski detektorji na osnovi tehnologije TFT, enako kot pri indirektnih sistemih.

Ne glede na tehnologijo se električni signal odčita iz detektorske plasti, ojača in digitalizira ter nato kot pri CR sistemih shrani v obliki matrike. Vendar uporabljena tehnologija pomembno vpliva na povezavo med izkoristkom in prostorsko ločljivostjo detektorja. Tako pri indirektnih kot pri direktnih detektorjih je najboljša dosegljiva prostorska ločljivost omejena z velikostjo detektorskih elementov. Pri indirektnih detektorjih pa je prostorska ločljivost zaradi disperzije svetlobe v ojačevalni plasti odvisna tudi od njene debeline in tako povezana z izkoristkom detektorja. Nasprotno pa je pri direktnih detektorjih zaradi usmerjanja električnega signala z električnim poljem disperzija zanemarljiva, zato lahko debelino plasti amorfnega selena poljubno povečamo in tako dosežemo zelo dober izkoristek. Direktni digitalni sistemi zato omogočajo zelo dobro prostorsko ločljivost in hkrati visok izkoristek, zaradi česar predstavljajo prevladujočo tehnologijo v digitalnih mamografskih sistemih.

Digitalni detektorji zaradi precej zapletene strukture nimajo povsem homogenega odziva, kar pomeni, da se na enako količino vpadne rentgenske svetlobe različni detektorski elementi odzovejo z različno močnim signalom. Ker bi to močno poslabšalo kakovost slike, se v praksi surova slika (raw image) avtomatsko matematično obdela, pri čemer se upoštevajo popravki zaradi napak detektorja. Informacije, potrebne za izračun teh popravkov, so rezultat kalibracije detektorjev, ki jo v okviru rednih testov običajno izvajajo radiološki inženirji. Napake pri kalibraciji vodijo do neustreznih popravkov in poslabšajo kakovost vseh nadaljnjih slik, zato je izjemno pomembno, da kalibracija poteka natančno po navodilih proizvajalca.

Lastnosti digitalnih sistemov

Ne glede na uporabljeno tehnologijo imajo digitalni sistemi številne skupne lastnosti. Najbolj očitna je seveda ta, da dobimo sliko v digitalni obliki, ki jo lahko prenašamo, kopiramo in shranjujemo v elektronski obliki ter s programi za obdelavo slike prilagajamo njen prikaz. Pomembna prednost digitalnih sistemov pa je tudi njihov velik dinamični obseg. Za razliko od sistemov film-folija, pri katerih dobimo dober kontrast le v relativno ozkem področju optimalne ekspozicije (doze), imajo digitalni sistem linearen odziv preko zelo širokega območja. To pomeni, da se bo latentni kontrast dobro prenesel na sliko tudi pri obsevanju z dozo, ki je občutno nižja ali višja od optimalne. Vendar to žal ne pomeni, da digitalni sistemi omogočajo visoko kvaliteto slike pri poljubno nizkih dozah. Namesto slabšega prenosa kontrasta

se pri digitalnih sistemih ob nižanju doze slabša razmerje signal/šum (in s tem veča zrnatost slike), kar navzdol omejuje sprejemljivo dozo.

Žal pa pri digitalnih sistemih ne obstaja naravna zaščita pred previsokimi dozami. Medtem ko pri sistemih film-folija slikanje s previsoko dozo vodi do izgube kontrasta zaradi pretemne slike, pri digitalnih sistemih s poviševanjem doze kvaliteta slike narašča, saj se izboljšuje razmerje signal/šum, prenos kontrasta pa ostaja nespremenjen. Previsoka doza se zaradi obdelave slike kot na primer spreminjanje okna (»windowing«) običajno tudi ne odraža ko temnejša slika in pogosto ostane neopažena. Tako pri prehodu na digitalne sisteme obstaja velika nevarnost neupravičenega naraščanja obsevanosti pacientov. Da bi uporabniku omogočili povratno informacijo o uporabljeni dozi, večina proizvajalcev uporablja indikatorje ekspozicije. Ti so povezani z obsevanostjo detektorja in kažejo, ali je bila uporabljena doza primerna ali pa morda prenizka ali previsoka. Žal pa proizvajalci ne uporabljajo enotnega sistema, ampak se indikatorji ekspozicije med proizvajalci močno razlikujejo (S, EI, AL, lgM, …), kar povzroča zmedo ter otežuje njihovo uporabo in primerjavo med napravami.

Pomembna lastnost vsakega slikovnega sistema je njegova prostorska ločljivost, saj določa velikost najmanjših struktur, ki bodo na sliki še vidne, oziroma najmanjši razmik med strukturami, pri katerem bodo te na sliki še razločljive. Vendar pa sta mejna velikost oziroma razmik odvisna tudi od tega, kako kontrastni so slikani objekti, kar pomeni, da sta prostorska ločljivost in kontrast medsebojno povezana. Pri digitalnih sistemih zato sposobnost slikovnega sistema za prenos majhnih struktur opisujemo s funkcijo MTF (Modulation Transfer Function). Ta pove, za koliko se poslabša kontrast drobnih struktur v primerjavi s kontrastom velikih. Zato si želimo slikovni sistem, ki bo imel čim višjo vrednost funkcije MTF. Ker pa je le ta odvisna od prostorske frekvence (merjene v številu parov linij na milimeter, lp/mm) in običajno ni absolutnega zmagovalca, moramo pri izbiri slikovnega sistema upoštevati, čemu bo namenjen in s tem, kakšno prostorsko ločljivost potrebujemo. Za večino digitalnih sistemov podatke o vrednost funkcije MTF podajajo proizvajalci.

Pomembna lastnost detektorskega sistema je tudi njegov izkoristek, saj določa, s kolikšno dozo moramo obsevati detektor, da bomo dobili sliko ustrezne kakovosti. V splošnem velja, da so CR sistemi običajno primerljivi s kombinacijo film-folija, DR sistemi pa običajno potrebujejo nižje doze. Za medsebojno primerjavo digitalnih detektorjev se pogosto uporablja funkcija DQE (Detective Quantum Efficiency). Pri tem načeloma velja, da bo sistem z 10% višjo vrednostjo DQE omogočil enako razmerje signal šum že pri 10% nižji dozi. Tako kot v primeru MTF je tudi DQE odvisen od prostorske frekvence, s stališča varstva pred sevanji pa je seveda boljši sistem z višjo vrednostjo DQE.

ZAKLJUČEK

Digitalni sistemi vztrajno nadomeščajo rentgenske filme na vseh področjih rentgenske diagnostike. To je v veliki meri posledica številnih prednosti, ki jih prinaša njihova uporaba, med katerimi so:

- Ni potrebe po filmih (za enkratno uporabo) in kemičnem razvijanju.
- Preprostejši in hitrejši delovni proces.
- Preprostejše (in cenejše) shranjevanje in prenos.
- Večji dinamični obseg kot klasični filmi:
  - manj pogosto ponavljanje slikanja zaradi previsoke ali prenizke ekspozicije,
  - eno slikanje lahko nadomesti več klasičnih slik s filmi različnih občutljivosti.
- Digitalna obdelava slik.
- Sliki se avtomatično dodajo podatki o posegu

Seveda pa digitalni sistemi niso brez pomanjkljivosti in najpomembnejše med njimi so sledeče:

- Previsoka ekspozicija težko opazna!!!
- Preprosto delo lahko vodi do nepotrebnih dodatnih slik.
- Preprosto brisanje slabih slik.
- Rokovanje kasete s filmom omogoča večjo fleksibilnost (ne velja pri slikovnih ploščah in prenosnih ploskih detektorjih).

Popolnoma pa lahko prednosti, ki jih ponujajo digitalni sistemi za rentgensko diagnostiko, izkoristimo šele, če na delo s slikami v digitalni obliki preide ves radiološki oddelek ali celo celotna institucija (npr. bolnišnica). Šele v tem primeru se bo slika v digitalni obliki uporabljala v celotnem procesu, od zajema in prenosa do shranjevanja in prikaza, rentgenske slike v fizični obliki pa lahko skoraj povsem izginejo.

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Strokovni članek

NIZKODOZNA RAČUNALNIŠKA TOMOGRAFIJA GLAVE PRI BOLNIKIH Z VSTAVLJENO DRENAŽO

ZNIŽANJE DOZE IN VPLIV NA KVALITETO SLIKE

Professional Article

LOW-DOSE HEAD CT IN PATIENTS WITH EXTERNAL VENTRICULAR DRAINAGE

DOSE REDUCTION AND EFFECT ON IMAGE QUALITY

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POVZETEK

Uvod: Pri bolnikih z vstavljeno zunanjo ventrikularno drenažo je med hospitalizacijo pogosto potrebno večkratno slikanje glave z računalniško tomografijo. Vsaka preiskava predstavlja dozno obremenitev za bolnika, kar povečuje dolgoročno tveganje za nastanek raka zaradi učinkov ionizirajočega sevanja.

Namen: Namen raziskave je ugotoviti, ali lahko pri bolnikih, ki zaradi bolezni potrebujejo večkratno slikanje glave, uporabimo nizko dozni protokol slikanja in s tem bistveno zmanjšamo dozno obremenitev bolnika, toda brez pomembnega vpliva na diagnostično uporabnost slik.

Metode dela: V raziskavo je bilo vključenih 10 bolnikov, ki so bili po vstavitvi zunanje ventrikularne drenaže napoteni na kontrolno slikanje. Vsi bolniki so bili slikani na 40-rezinskem računalniškem tomografu. Pri prvem slikanju je bil uporabljen standardni protokol slikanja glave (280 mAs, 120 kV, debelina rekonstruiranih slik 3 mm). Pri kontrolnem slikanju pa nizko dozni protokol (180 mAs, 120 kV, debelina rekonstruiranih slik 3 mm). Diagnostično uporabnost slik je pri obeh protokolih naključno ocenjeval nevroradiolog s pomočjo ocenjevalnega lista.

Rezultati: Z uporabo nizko doznega protokola je bila doza v povprečju nižja za 38%. Uporaba le tega ni vplivala na diagnostično sprejemljivost slik (P=0,564). Med standardnim in nizko doznim protokolom ni bilo statistično značilne razlike v prikazu sive in bele možganovine (P=0,47 in P=0,932). Povprečna vednost šuma na področju sive in bele možganovine je bila na slikah, pridobljenih z nizkodoznim protokolom signifikantno višja (P=0,0001 in P=0,001). Razmerje kontrast šum je bilo pri nizkodoznem protokolu za 35% manjše.

Razprava: Podobno kot pri drugih raziskavah, rezultati raziskave kažejo na to, da so pri uporabi nizko doznega protokola dobljene slike kljub slabši kvaliteti diagnostično uporabne. Doza, ki jo prejme bolnik je bistveno manjša, kot če uporabimo standardni protokol.
Zaključek: Pri bolnikih z vstavljeno zunanjo ventrikularno drenažo lahko pri kontrolnem slikanju uporabimo nizkodozni protokol slikanja glave in s tem pomembno zmanjšamo prejeto dozo, toda brez pomembnega vpliva na diagnostično sprejemljivost slik.

Ključne besede: CT glave, nizko dozni protokol, efektivna doza, kakovost slik.

ABSTRACT

Introduction: Patients with external ventricular drainage often undergo multiple follow-up head CT scans during hospitalisation. Each scan increases the risk of long-term effects caused by ionizing radiation.

Purpose: The purpose of our study was to assess whether the use of repeated low-dose head CT protocol importantly decrease the effective dose received by patients who need multiple head CT scans and still provide images with acceptable quality and diagnostic information.

Methods: 10 patients were included in the study. Patients were referred for a non-enhanced head CT scan, after insertion of external ventricular drainage. Studies were performed on a 40-slice multi detector CT (Siemens Somatom Sensation Open). For the baseline CT study the standard protocol was used (280 mAs, 120 kV, slice thickness 3 mm). Follow-up scans were performed using low dose protocol (180 mAs, 120 kV, slice thickness 3 mm). Radiologist evaluated and graded both low-dose and standard-dose studies of each patient.

Results: With the use of low-dose protocol the effective dose was decreased by 38% in average. Diagnostic acceptability of low-dose studies was not affected (P=0.564). There was no statistically significant difference in visualisation of white matter (WM) and grey matter (GM) between low-dose and standard-dose studies (P=0.47 and P=0.932). The mean GM and WM noise levels were significantly higher in low-dose studies (P=0.0001 and P=0.001). Contrast to noise ratio was approximately 35% smaller at low-dose studies.

Discussion: Similar to other studies, results show that quality of images with use of low-dose protocol is lower but still diagnostic acceptable. Dose received by patients is significantly lower than when using standard protocol.

Conclusion: The use of low-dose head CT protocol in patients with inserted external ventricular drainage for follow-up scans importantly reduce effective dose without reducing the diagnostic acceptability of images.

Keywords: head CT, low-dose protocol, effective dose, image quality.

UVOD

Pri bolnikih po možganskih operacijah je med hospitalizacijo pogosto potrebno večkrat opraviti slikanje glave z računalniško tomografijo. S kontrolnim slikanjem spremljamo položaj vstavljenih drenaž, vstavljenih elektrod za merjenje možganskega pritiska, krvavitve ali nastanek hidrocefalusa.

Prejete doze pri računalniški tomografiji so med najvišjimi pri uporabi virov sevanj v diagnostične namene in tako vsako slikanje predstavlja veliko dozno obremenitev za bolnika, kar povečuje dolgoročno tveganje za nastanek raka zaradi učinkov ionizirajočega sevanja (Mullins et al., 2004). Na področju zmanjšanja prejete doze zaradi sevanja pri CT preiskavah je bilo narejenih že nekaj raziskav. Zmanjšanje doze sevanja pri CT preiskavi vodi sicer v zmanjšano kakovost slik in znižanje razmerja kontrast-šum, vendar do neke vrednosti ne vpliva pomembno na diagnostično uporabnost slik (Mulkens et al., 2004).

Udayasankar et al. (2008) so ugotovili, da lahko pri kontrolnem CT slikanju glave otrok, pri katerih so spremljali stanje prirojenega hidrocefalusa, zmanjšamo dozo za 63% in še vedno lahko zanesljivo postavimo diagnozo. Mulkens et al. (2004) so pri bolnikih, starejših od 65 let, pri slikanju glave z zmanjšanjem doze za 50% ugotovili, da je kakovost slik z uporabo nizke doze še diagnostično sprejemljiva. Podoben rezultat je pokazala raziskava, kjer so uporabili CT slike, dobljene z običajnim protokolom slikanja in z računalniško simulacijo dodali šum na slike. Ugotovili so, da zmanjšanje doze za 50% ne vpliva bistveno na diagnostično sprejemljivost slik (Britten et al., 2004). Omejitev teh študij je majhno število bolnikov. Pri raziskavi na vzorcu 60 bolnikov so pri CT slikah glave ocenjevali tri referenčna področja. Pri 50% znižanju doze so bile slike diagnostično sprejemljive, pri 60% znižanju so bili rezultati slabši (Gündogdu et al., 2005).

Skupna ugotovitev avtorjev je, da nizko dozno CT slikanje glave lahko uporabimo pri bolnikih, pri katerih je potrebno večkrat opraviti preiskavo in želimo spremljati večje spremembe na možganih (krvavitve, hidrocefalus, masivne ishemične spremembe,...). Za prikaz majhnih sprememb uporaba protokola z nizko dozo ne bi bila upravičena zaradi slabše kvalitete slik.

NAMEN

Namen raziskave je bil ugotoviti, ali lahko pri bolnikih z vstavljeno zunanjo ventrikularno drenažo (ZVD), ki potrebujejo večkratno kontrolno CT slikanje glave, uporabimo protokol slikanja z nizko dozo in s tem pomembno zmanjšamo dozno obremenitev bolnika, toda brez bistvenega vpliva na kakovost in diagnostično uporabnost slik.

METODE DELA

V raziskavo je bilo vključenih 10 bolnikov, ki so bili po možganski operaciji napoteni na kontrolno CT slikanje glave. Indikacija za preiskavo je bila spremljanje položaja ZVD. Bolniki so bili izbrani glede na določene pogoje: vsi so imeli že prej opravljen CT glave s standardnim protokolom, napotnega zdravnika je zanimal le položaj drenaže, torej bolniki niso imeli znakov drugih obolenj možganov.

Protokol slikanja

Vsi bolniki so bili slikani na 40-rezinskem računalniškem tomografu Siemens Sensation Open. Pri prvem slikanju je bil uporabljen standardni protokol za slikanje glave in sicer spiralno slikanje z ekspozicijskimi pogoji 280 mAs in 120 kV ter rekonstrukcijo slik 3 mm. Pri kontrolnem slikanju pa je bil uporabljen nizko dozni protokol, ki ima vse pogoje enake kot standardni, le produkt toka v cevi in časa rotacije je bil zmanjšan in je tokrat znašal 180 mAs.

CTDI, DLP in efektivna doza

Za vsak protokol smo na aparatu odčitali CT dozni indeks (CTDI) in produkt doze in dolžine (DLP) ter z upoštevanjem utežnega faktorja za glavo (E_{DLP}=0,0023 mSv/mGycm) izračunali efektivno dozo sevanja po formuli: $E= E_{DLP} \cdot DLP$. Zaradi linearne povezave med dozo in produktom toka in časa je doza pri 180 mAs 36% nižja kot doza pri 280 mAs.

Kakovost CT slik

Uporabljena je bila dvojno slepa študija, pri kateri so bili podatki o dozi in podatki o bolniku izbrisani. Diagnostično uporabnost standardnih slik in slik, dobljenih z nizko doznim protokolom je naključno ocenjeval izkušen nevroradiolog s pomočjo izdelanega ocenjevalnega lista. Le ta je na slikah ocenjeval naslednje parametre:

- diagnostična sprejemljivost (1-nesprejemljivo, 2-suboptimalno, 3-povprečno, 4-dobro, 5-odlično; ocena diagnostične sprejemljivosti 2 pomeni še sprejemljivo sliko),
- diferenciacija sive in bele možganovine (1-nesprejemljivo, 2-suboptimalno, 3-sprejemljivo),
- ostrina subarahnoidalnega prostora (1-nesprejemljivo, 2-suboptimalno, 3-dobro definiran),
- prikaz struktur v zadnji kotanji (1-nesprejemljivo, 2-suboptimalno, 3-sprejemljivo),
- prisotnost črtastih artefaktov (1-prisotnost z vplivom na diagnozo, 2-prisotnost brez vpliva na diagnozo, 3-odsotnost),
- ponovitev slikanja (1-potrebno, 2-pogojno potrebno, 3-ni potrebno) (Mullins et al., 2003; Udayasankar et al., 2008).

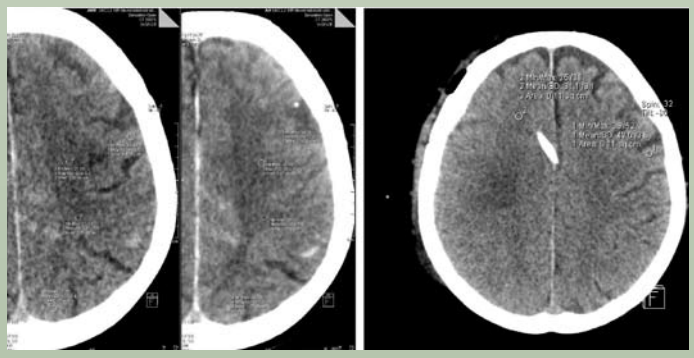
Rezultati, pridobljeni z ocenjevalnimi listi so bili statistično obdelani z računalniškim programom SPSS. Uporabljena je bila različica neparametričnega testa in sicer Willcoxon-ov test, s katerim smo preverjali vsak, zgoraj napisan parameter posebej. Stopnja zaupanja je bila 0,05 (P=0,05).

Poleg tega smo na slikah, pridobljenih s standardnim in nizkodoznim protokolom, z meritvijo atenuacijskih koeficientov v izbranih interesnih področjih kvantitativno določali kakovost slike. Na področju zadnje kotanje (mali možgani) in na področju centrum semiovale (veliki možgani) smo postavili dva interesna področja v sivo in dva interesna

področja v belo možganovino ter izmerili Houndsfieldove enote (HU) in standardni odklon (SD) (slika 1 in 2). Interesna področja so bila pri vseh pacientih, tako na slikah, narejenih z nizko doznim protokolom kot na slikah, pridobljenih s standardnim protokolom, enake velikosti in postavljena na enako mesto. Pri standardnih slikah in slikah, pridobljenih z nizko doznim protokolom smo izračunali povprečje HU za sivo in belo možganovino ter povprečje standardnih odklonov (SD). SD predstavlja šum na sliki. S pomočjo pridobljenih meritev smo izračunali razmerje kontrast šum (contrast to noise ratio - CNR) po formuli (Mullins et al., 2003):

$$CNR = \frac{\text{povprečje HU SM - povprečje HU BM}}{\sqrt{(\text{SD HU SM}^2 + \text{SD HU BM}^2)}}$$

*SM – siva možganovina
*BM – bela možganovina



Slika 1 in slika 2: Prikaz postavitev interesnih področij v sivi in beli možganovini

REZULTATI

V raziskavo je bilo vključenih 10 bolnikov (2 ženski in 8 moških), katerih povprečna starost je znašala 63,7 let (od 36 do 83 let). Vsi bolniki so bili po vstavitvi ZVD napoteni na kontrolno slikanje glave, ki smo ga izvedli z nizko doznim protokolom slikanja.

CTDI, DLP in efektivna doza

Pri standardnem protokolu (280 mAs, 120 kV) je vrednost CTDI znašala 52,42 mGy, povprečna vrednost DLP 942 mGycm in efektivna doza 2,1 mSv. Pri nizko doznem protokolu (180 mAs, 120 kV) je vrednost CTDI znašala 33,70 mGy, povprečna vrednost DLP 582 mGycm in efektivna doza 1,3 mSv. Uporaba nizko doznega protokola je v našem primeru v povprečju pripomogla k zmanjšanju doze za 38%.

Kakovost CT slik

Pri ocenjevanju diagnostične sprejemljivosti so bile tako slike, narejene s standardnim protokolom kot slike, narejene z nizko doznim protokolom ocenjene kot diagnostično sprejemljive pri vseh pacientih. Med slikami, narejenimi z različnima protokoloma, ni bilo statistično značilne razlike (P=0,564). Pri parametru razlikovanja med sivo in belo možganovino prav tako ni bilo statistično značilne razlike med uporabljenima protokoloma (P=0,655), kot je bilo pričakovano.

Pri ocenjevanju ostrine subarahnoidalnega prostora, prisotnosti črtastih artefaktov in potrebe po ponoviti slikanja med skupinama ni bilo nikakršnih razlik. Torej stopnja zaupanja je pri teh merjenih parametrih znašala P=1.

Pri prikazu struktur v zadnji kotanji prav tako ni bilo statistične razlike med slikami, narejenimi s standardnim protokolom in slikami, narejenimi z nizko doznim protokolom (P=0,564).

V tabeli 1 so prikazani rezultati meritev atenuacijskih koeficientov in standardnih odklonov v izbranih interesnih področjih, določenih v sivi (SM) in beli možganovini (BM) ter razmerje kontrast šum (CNR), za nizko dozni protokol slikanja glave. V tabeli 2 pa so prikazni rezultati meritev, pridobljenih na slikah, narejenih s standardnim protokolom. Iz tabel je razvidno, da so razlike v HU pri prikazu SM in BM glede na uporabljen protokol slikanja zelo majhne, saj je pri nizko doznem protokolu v povprečju vrednost SM znašala 46,55 HU, pri standardnem protokolu pa 47,44 HU. Vrednost BM pri prvem protokolu je bila v povprečju 32,64 HU, pri drugem protokolu pa 32,57 HU.

Tabela 1: Povprečje HU in standardnega odklona sive in bele možganovine pri nizkodoznem CT protokolu slikanja glave

	Nizkodozni protokol slikanja				
Pacient	povprečje HU SM	SD HU SM	povprečje HU SM	SD HU SM	HU CNR
1	46,00	3,25	32,10	3,35	2,98
2	48,07	3,63	32,47	3,67	3,02
3	44,40	3,53	29,97	3,90	2,74
4	52,97	3,20	35,33	3,30	3,84
5	47,43	3,43	34,20	4,93	2,20
6	46,13	3,83	31,67	4,13	2,57
7	45,17	4,10	31,07	3,50	2,62
8	43,80	2,77	36,23	2,87	1,90
9	47,23	4,03	32,13	3,80	2,72
10	44,30	3,25	31,23	3,07	2,92
Povprečje	46,55	3,50	32,64	3,65	2,75

Tabela 2: Povprečje HU in standardnega odklona sive in bele možganovine pri standardnem CT protokolu slikanja glave

	Standardni protokol slikanja				
Pacient	povprečje HU SM	SD HU SM	povprečje HU BM	SD HU BM	HU CNR
1	49,38	2,10	34,35	1,88	5,34
2	47,73	2,40	32,43	3,07	3,93
3	47,73	1,92	30,47	2,17	5,96
4	53,73	2,20	35,87	2,30	5,61
5	48,30	2,77	34,60	2,67	3,57
6	46,37	2,60	31,77	2,77	3,85
7	43,87	3,03	30,13	2,43	3,53
8	46,27	2,57	32,00	2,13	4,27
9	46,67	3,47	33,00	3,27	2,87
10	44,40	2,50	31,03	2,73	3,61
Povprečje	47,44	2,56	32,57	2,54	4,25

Na podlagi analize rezultatov (prikazanih v tabelah 1 in 2) s t testom, smo prišli do ugotovitev, da med uporabljenima protokoloma (280 mAs in 180 mAs) v prikazu SM in BM ni statistično značilne razlike (P=0,47 in P=0,932).

Statistično značilna razlika med protokoloma se je pojavila v količini šuma, prisotni na slikah pri prikazu SM in BM (P=0,0001 in P=0,001). Pri nizko doznem protokolu je standardni odklon (SD) na področju SM v povprečju znašal 3,5 HU, na področju BM pa 3,65 HU, kar je bistveno več kot pri standardnem protokolu, pri katerem je SD na področju SM v povprečju znašal 2,56 HU, na področju BM pa 2,54 (tabela 1 in 2).

Analiza rezultatov je prav tako pokazala, da obstaja med protokoloma statistično značilna razlika v razmerju kontrast-šum (CNR), saj je le to pri nizko doznem protokolu bistveno slabše kot pri standardnem protokolu. CNR je bilo pri nizko doznem protokolu (2,75 ± 0,51 HU) za približno 35% manjše kot pri standardnem protokolu, pri katerem je CNR znašalo 4,25 ± 1,03 HU.

RAZPRAVA

Računalniška tomografija je danes zelo razširjena in lahko dostopna slikovno diagnostična metoda, s katero lahko hitro diagnosticiramo morebitno prisotno patologijo slikanega področja. Na področju nevrologije med drugim predstavlja diagnostično metodo, ki omogoča spremljanje bolnikov po opravljenih možganskih operacijah ali endovaskularnem zdravljenju. Gre za bolnike, s katerimi se srečujemo vsakodnevno in pri katerih je potrebno večkratno kontrolno slikanje glave, ki nam omogoča spremljanje učinkov zdravljenja.

V raziskavi smo s spremembo produkta toka in časa iz 280 mAs na 180 mAs, zaradi linearne povezave le tega z dozo, vplivali na zmanjšanje doze in sicer v povprečju za 38%. Pri tem smo prišli do podobnih spoznanj kot v raziskavah, ki so jih naredili Udayasankar et al. (2008), Mulkens et al. (2004), Britten et al. (2004), Gündogdu et al. (2005) in drugi. Le te so pokazale, da znižanje tokovnega sunka za 50% in več bistveno vpliva na znižanje prejete dozo, toda brez pomembnega vpliva na diagnostično sprejemljivost CT slik. Do enakih zaključkov smo s pridobljenimi rezultati prišli tudi sami.

Prav tako kot navedeni avtorji smo ugotovili, da znižanje parametrov slikanja vpliva na kakovost slike. Slike, pridobljene z nizko doznim protokolom vsebujejo bistveno več šuma, kar privede do slabšega razmerja kontrast-šum in s tem slabše kakovosti slike. CNR se je v našem primeru zmanjšal za 35%. Udayasankar et al. (2008) pa navajajo, da se pri znižanju tokovnega sunka za 63% RKŠ zmanjša za 60%. Torej z zniževanjem parametrov slikanja se zmanjšuje tudi kakovost slike. Toda kljub temu, so na ta način pridobljene slike diagnostično uporabne.

Naštete raziskave imajo tako kot naša določeno pomanjkljivost in sicer v raziskavo je vključeno premajhno število bolnikov. Z večjim obsegom zajetih bolnikov bi bili statistično pridobljeni rezultati bolj relevantni. Toda kljub temu je naša raziskava pokazala pomembne ugotovitve in sicer pri bolnikih z vstavljeno ZVD bi lahko pri kontrolnem slikanju uporabili nizko dozni protokol slikanja glave in s tem bistveno zmanjšali prejeto dozo, brez pomembnega vpliva na diagnostično kakovost slik.

V raziskavo bi lahko poleg bolnikov z vstavljeno ZVD vključili tudi bolnike, pri katerih je potrebno kontrolno slikanje glave zaradi spremljanja velikosti hidrocefalusa, velikosti krvavitve ali hematomov ter položaja vstavljenih elektrod za merjenje možganskega pritiska. Pridobljeni rezultati so torej le preliminarni. Morda bi v nadaljevanju raziskave poskusili še nekoliko znižati dozo in ugotoviti najmanjšo dozo, pri kateri so pridobljene slike še diagnostično uporabne.

ZAKLJUČEK

Pomembno se je zavedati, da je pri bolniki po možganskih operacijah potrebno večkratno CT slikanje glave bodisi zaradi spremljanja učinkov zdravljenja bodisi zaradi poslabšanja bolnikovega stanja. V nekaterih primerih so bolniki slikani tudi več desetkrat. V naši raziskavi smo CT protokol spremenili tako, da smo za 36% znižali tokovni sunek in s tem posledično vplivali na zmanjšanje doze v povprečju za 38%. Z uporabo nizko doznega protokola slikanja glave lahko bistveno pripomoremo k zmanjšanju prejete doze bolnikov in s tem tveganja za nastanek stohastičnih učinkov zaradi izpostavljenosti ionizirajočemu sevanju. Torej je uvedba nizko doznega protokola slikanja zaradi teh bolnikov v vsakodnevno prakso potrebna in zelo pomembna.

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Strokovni članek

PRIMERJAVA ANALOGNE IN DIGITALNE PANORAMSKE TER CBCT SLIKE ZOB

Professional Article

COMPARISON BETWEEN ANALOGUE AND DIGITAL PANORAMIC AND CBCT DENTAL IMAGING

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POVZETEK

Uvod: Digitalna tehnologija v dentalni radiologiji ponuja veliko prednosti pred analogno in kot vse nastajajoče tehnologije predstavlja nov izziv. Tako je digitalni zajem slike, prenos slik v računalnik ter delo z njimi na delovni postaji, shranjevanje in prenos po medmrežju danes nekaj vsakdanjega na večini zobnih rentgenskih diagnostik in omogoča boljše rezultate ter večjo diagnostično vrednost slik (Zdešar, 2008). Velik napredek v razvoju digitalne dentalne tehnologije predstavlja CT s konusnim snopom (CBCT).

Namen: Namen članka je predstaviti analogno in digitalno dentalno radiologijo, in sicer področje panoramskega slikanja zob. Z opisom primera predstaviti značilnosti analognega in digitalnega oprtopantomograma ter CBCT-ja s poudarkom na značilnostih vsake tehnike in njenega vpliva na kvaliteto in diagnostično uporabnost slik.

Metode dela: Predstavljen je opis primera pacientke, pri kateri so v procesu protetičnega zdravljenja posneli analogni in digitalni ortopantomogram ter CBCT. Predstavljen je pregled in primerjava vseh treh tehnik.

Rezultati: Digitalna slika ima v primerjavi z analogno višjo kontrastno ločljivost ter širši dinamični razpon. Zaradi manjšega vpliva razmazanosti je slika struktur bolj ostra. CBCT ima sicer manjšo prostorsko ločljivosti, a zaradi presečnega in volumskega prikaza struktur daje visok diagnostični prispevek.

Razprava: Glavna prednost digitalnega panoramskega slikanja zob pred analognim je naknadna računalniška obdelava slik z možnostjo spreminjanja lastnosti slike (kontrastnosti, ločljivosti in svetlosti) ter z možnostjo opravljanja preglednih meritev in načrtov vstavljanja implantantov. Panoramski posnetki nam dajejo dovolj dobre informacije v mezo-distalni smeri zob, a se zaradi faktorja povečave na različnih območjih del podatkov izgubi. Omejitve ortopantomograma so tako večinoma posledica geometrijskih lastnosti panoramskega slikanja. CBCT-jev izotropični volumski element pa daje prostorsko informacijo in s tem omogoča natančne meritve v vseh treh ravninah.

Zaključek: Zobna rentgenska diagnostika je področje, na katerem so digitalni sistemi nedvomno dokazali svoje prednosti v primerjavi s filmi, posledično so digitalne rentgenske slike kvalitetnejše in imajo večjo diagnostično vrednost.

Ključne besede: digitalno slikanje zob, ortopantomograf, CT s konusnim snopom

ABSTRACT

Introduction: Digital technology in dental radiography offers advantages over film radiography, and like any emerging technology represents a new challenge. Capturing, transmission over the internet and storage of digital images is feasible with all workstations in contemporary departments of dental radiography, thus providing better performance and higher diagnostic value of images (Zdešar, 2008). The latest development in digital dental technology is cone-beam CT (CBCT).

Purpose: The aim of the article is to describe the characteristics of digital dental radiology, especially the panoramic digital teeth imaging. With the help of a sample case, we will present the features of analogue and digital ortopantomography, and CBCT with the emphasis on the characteristics of each technique and the impact on quality and diagnostic value of images.

Methods: a case report of a patient, who was undergoing a prosthetic treatment process and has taken an analogue and digital ortopantomography and CBCT was presented with an examination and comparison of all three techniques.

Results: In comparison with analogue image, a digital one has higher contrast resolution and higher diagnostic value. Even though CBCT has a lower contrast resolution, its ability to show longitudinal sections and volume of structures makes it an important diagnostic tool.

Discussion: The advantage of digital panoramic imaging is the computer image processing with possibility of changing the image parameters i.e. contrast, resolution and brightness. Panoramic shots provide us with adequate information on mezo-distal teeth relation; however, some data get lost on various spots due to magnifying. Therefore, the lacks of ortopantomography can be mainly contributed to the geometric characteristics of panoramic imaging. Meanwhile,

the CBCT's isotropic voksel provides spatial information thus enabling exact measurements in all three planes.

Conclusion: Digital dental radiology is a field where the digital systems undoubtedly proof their advantages to films; therefore the digital x-ray images are of better quality and have a greater diagnostic value.

Keywords: digital dental radiography, ortopantomography, cone-beam CT

UVOD

Radiološka diagnostika ima pomemben diagnostični prispevek v dentalni medicini. Po razvoju panoramskega slikanja v šestdesetih letih prejšnjega stoletja, ki je omogočil pregled čeljusti in maksilofacialnih struktur na eni sliki, je dentalna radiologija doživela ogromno tehnološkega napredka. Za prehod iz analognega na digitalno panoramsko slikanje je več vzrokov kot npr. nezaželene posledice neustreznega razvijanja filmov in posledično slabša kvaliteta posnetkov. S tem je ukinjena uporaba nevarnih kemikalij, ki predstavljajo tveganje in obremenitev okolja, zato je digitalna tehnologija pridobila tudi vzdevek »ekološko čiste« radiologije. Tako digitalna tehnologija v dentalni radiologiji kot vse nastajajoče tehnologije predstavlja nov izziv. Digitalni zajem slike, prenos slik v računalnik ter delo z njimi na delovni postaji, shranjevanje in prenos po medmrežju je danes nekaj vsakdanjega na večini zobnih rentgenskih diagnostikah in omogoča boljše rezultate ter večjo diagnostično vrednost slik (Zdešar, 2008).

Ortopantomogram

Ortopantomogram je pregledna slika obeh čeljusti, čeljustnih sklepov in maksilarnih sinusov in je relativno enostavna tehnika slikanja. Med panoramskim slikanjem se izvor sevanja in detektor sinhrono premikata okoli pacientove glave, s čimer dobimo jasno sliko samo izbrane plasti preiskovane strukture, ostale plasti pa so zabrisane. Indikacije za panoramski posnetek so motnje v izraščanju zob, protetično zdravljenje in za sodnomedicinske potrebe. Pri protetičnem zdravljenju se ortopantomogram indicira pred začetkom zdravljenja, med zdravljenjem in za kontrolo po koncu zdravljenja. Analiza panoramskega posnetka zob zajema opredelitev stanja zob, in sicer kariesa, polnitev koreninskih kanalov, apikalnih procesov, plomb in prevlek in analizo prostorskih razmer v zobnih lokih ter kosti (nivo alveolarne kosti, kostne lezije in frakture) (Farčnik in sod., 2005).

CT s konusnim snopom

Razvoj CBCT-ja (angl. Cone Beam Computed Tomography) v poznih devetdesetih letih prejšnjega stoletja predstavlja velik napredek v razvoju digitalne dentalne tehnologije, ki omogoča prikaz presečnih in tridimenzionalnih slik maksilo-facialnega skeleta. CBCT je računalniška tomografija s konusno oblikovanim rentgenskim žarkom, ki uporablja ekstraoralni skener za zajem slik in precej nižjo dozo v primerjavi s klasično računalniško tomografijo (CT) (Mozzo et al. 1998, Arai et al. 2001, cit po Patel, 2009). S CBCT-jem v eni rotaciji tridimenzionalno zajemamo podatke, z uporabo direktne povezave med detektorjem in virom, ki se sinhrono vrtita v območju od 180° do 360° okoli pacientove glave. Rentgenski žarek je konusno oblikovan, od koder izvira tudi samo ime tehnike, in tako pridobiva obseg volumskih podatkov valjaste ali sferične oblike. CBCT omogoča različne velikosti vidnega polja (FOV), od velikega, ki zajame celotno področje maksilo-facialnega skeleta, do manjšega za lokalno usmerjeno diagnostiko ter polja, ki zajame samo spodnjo ali samo zgornjo čeljust. Skenirni čas CBCT-ja je tipično dolg 10 – 40 sekund, vendar je zaradi pulznega rentgenskega žarka realni čas ekspozicije 2 – 5 sekund, s katerim pridobimo 580 individualnih ekspozicij oz. projekcijskih slik z matriko 512 x 512 piksli. Nabor podatkov obsega 580 posameznih matrik, ki so rekonstruirane v tridimenzionalne podatke, ki so sestavljeni iz sto milijonov volumskih elementov. Tomografske rezine velikosti 80 – 400 µm so prikazane v aksialni, sagitalni in koronarni ravnini, z možnostjo tridimenzionalne rekonstrukcije slikanega predela (Patel, 2009).

Čeprav panoramski posnetek zagotavlja primerno informacijo v številnih kliničnih primerih, priporočajo uporabo CBCT posnetkov pri načrtovanju števila, velikosti in položaja implantatov, pred in po kirurškem posegu v maksilo-facialnem predelu, za natančen prikaz lege maksilarnega sinusa ali mandibularnega kanala, za oceno velikosti in oblike kostnih žepov pri paradontalni bolezni, pri poškodbah in kot dodatno diagnostično metodo v nekaterih nejasnih endodontskih primerih (Panicker et al., 2011).

NAMEN

Namen članka je predstaviti analogno in digitalno dentalno radiologijo, in sicer področje panoramskega slikanja zob. Z opisom primera predstaviti značilnosti analognega in digitalnega oprtopantomograma ter CBCT-ja s poudarkom na značilnostih vsake tehnike in njenega vpliva na kvaliteto in diagnostično uporabnost slik.

METODA DELA

Opis primera pacientke pri kateri so v procesu protetičnega zdravljenja posneli analogni in digitalni ortopantomogram ter CBCT. Predstavljen je pregled in primerjava vseh treh tehnik.

Opis primera

Pacientka, stara 50 let z izbranim zobozdravnikom v Zdravstvenem domu Ljubljana (ZDL) je v procesu protetičnega zdravljenja v krajšem obdobju opravila analogni in digitalni ortopnatomogram ter CBCT. Pri pacientki je bila izvedena izdelava nadzidka – ˝štifta˝ desnega zgornjega sekalca. Analogni ortopantomogram je bil posnet leta 2010 v ZDL za kontrolo zaključenega protetičnega zdravljenja. Zaradi suma na zlom korenine zdravljenega zoba je bila pri pacientki potrebna nadaljnja radiološka obravnava. Ker so v začetku leta 2011 v ZDL obnovili in digitalizirali zobno rentgensko diagnostiko, so tega leta pri pacientki naredili digitalni ortopantmogram. Za potrebe diagnosticiranja in načrtovanja možnega ponovnega protetičnaga zdravljenja je pacientka dodatno opravila še CBCT pri zasebniku. Po opravljeni dodatni radiološki diagnostiki je bila napotena na ponovno zdravljenje na Stomatološko kliniko UKC Ljubljana.

Podatki o rentgenskih aparatih

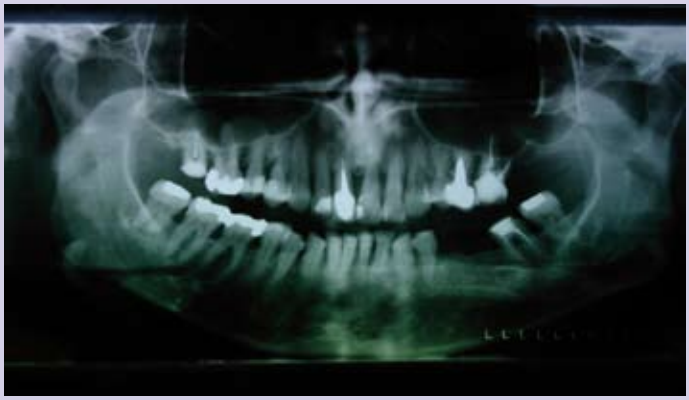
Analogni ortopantomogram je bil posnet na rentgenskem aparatu Instrumentarium Orthopantomograph OP 100, digitalni ortopantomogram na aparatu Instrumentarium Orhtopantomograph OP 200, CBCT pa na aparatu Instrumentarium Ortophantomograph OP 300.

Tabela 1: Tehnične specifikacije rentgenskih aparatov

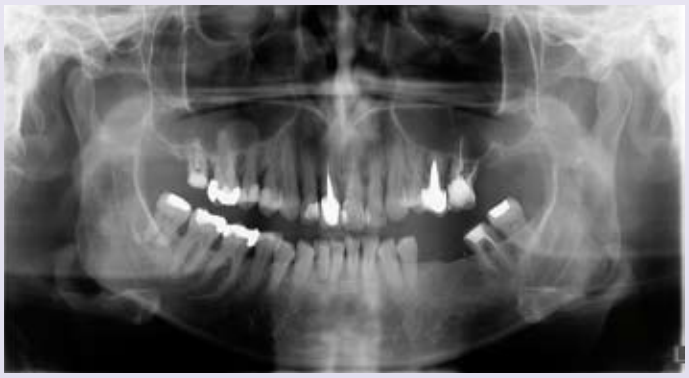
Proizvajalec	*Instrumentarium dental*		
Tip naprave	*Orthopantomograph OP 100*	*Orthopantomograph OP 200*	*Orthopantomograph OP 300*
napetost	*57 – 85 kV*	*57 – 85 kV*	*57 – 90 kV*
tok	*2 – 16 mA*	*2 – 16 mA*	*4 -16 mA*
gorišče	*0,5 mm*	*0,5 mm*	*0,5 mm*
filtracija	*2,5 mm Al*	*2,5 mm Al*	*3,2 mm Al*
vrsta slikovnega detektorja	*film/folija*	*CMOS*	*CMOS*
čas ekspozicije	*17,6 s*	*2,7 – 14,1 s*	*2D: 16,1s / 3D: 10-20s (Pulsed X-ray - 2,34s)*

REZULTATI

Na dvodimenzionalnem panoramskem posnetku sta prikazana oba zobna loka z zobmi, vidne so strukture zgornje in spodnje čeljustnice, maksilarni sinus in čeljustna sklepa. Pri obeh posnetkih, analognem (slika 1) in digitalnem (slika 2), je bil položaj glave pravilen, jezik potisnjen ob nebo, zato je področje korenin v zgornjem zobnem loku lepo prikazano. Na obeh ortopantomogramih je v intrakaninem predelu viden svetel zabris zaradi prekrivanja struktur vratnih vretenc, na digitalni sliki je to prekrivanje nekoliko manj izrazito. V prekritem predelu je tako omejena diagnostična vrednost pri kontroli zdravljenja zgornjega desnega sekalca. Digitalna slika ima v primerjavi z analogno višjo kontrastno ločljivost, zaradi manjšega vpliva razmazanosti pa je slika struktur bolj ostra. Širši dinamični razpon pri digitalni sliki ponuja večji nabor tonov svetlosti, zaradi česar na sliki vidimo v zelo temnih oz. zelo svetlih območjih slike več detajlov npr. detajli v maksilarnem sinusu.

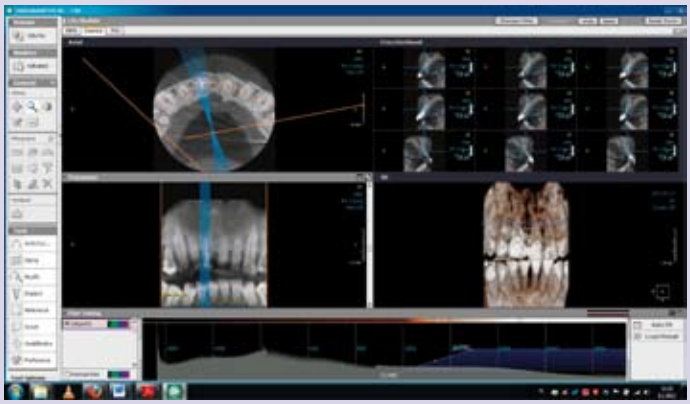


Slika 1: Analogni ortopantomogram, posnet na sistem folija/film velikosti 15x30cm

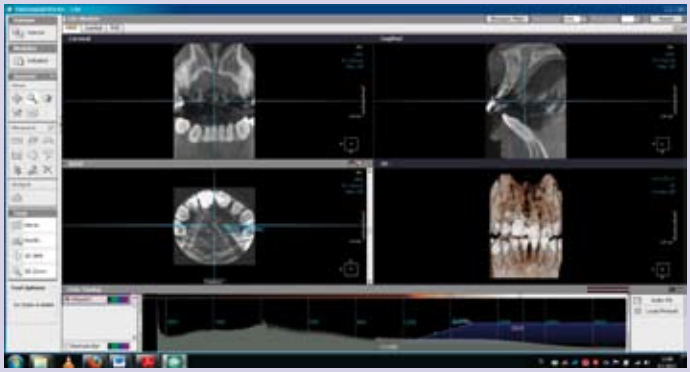


Slika 2: Digitalni ortopantomogram, slika je naknadno računalniško obdelana. Spremenjena je kontrastnost rentgenograma in uporabljen kernel za ostrenje robov in glajenje šuma

CBCT (slika 3) je bil zajet z manjšim FOV za lokalno usmerjeno diagnostiko v področju zgornjih in spodnjih sekalcev. Slike so rekonstruirane z MPR (multi planarno rekonstrukcijo) v koronarni, sagitalni in transverzalni ravnini ter 3D rekonstrukcijo slikanega predela (slika 4). CBCT ima kljub manjši prostorski ločljivosti zaradi presečnega in volumskega prikaza struktur visok diagnostični prispevek. Diagnostično vrednost zmanjšuje efekt tršanja kovine nadzidka v zgornjem desnem sekalcu.



Slika 3: CBCT



Slika 4: CBCT, MPR rekonstrukcija v koronarni, sagitalni in tranzverzalni in 3D rekonstrukcija

RAZPRAVA

Za uspešno in natančno protetično zdravljenje je izrednega pomena natančna rentgenska diagnostika. Za načrtovanje protetičnega zdravljenja se običajno uporablja analiza klasičnega dvodimenzionalnega panoramskega posnetka. Klasični panoramski posnetek prikaže dvodimenzionalno sliko organov in tkiv, ki so tridimenzionalne narave. Iz

takšnega posnetka dobimo dovolj dobre informacije v mezio-distalni, ne pa tudi v buko-lingvalni smeri zob. Ravno tako se faktor povečave zaradi distorzije in različne povečave na različnih delih posnetka razlikuje tudi v mezio-distalni smeri. Dvodimenzionalni posnetek omejuje oceno debeline kosti in določitev bukalne in palatinalne korenine večkoreninskih zob ter določitev apeksov zgornjih zob glede na maksilarni sinus in spodnjih zob glede na mandibularni kanal. Računalniški prikazi presečnih več reznih slik, ki zagotavljajo natančen dvodimenzionalen in tridimenzionalen prikaz, je pomemben za natančno oceno in načrtovanje protetičnega zdravljenja. Trend ogromnega in hitrega tehnološkega napredka v radiologiji je opazen tudi na področju razvoja protetičnega zdravljenja z različnimi oblikami in namestitvami vsadkov, ki zahtevajo visoko raven natančnosti in zaupanja v radiološko tehnologijo. CBCT ponuja nove razsežnosti načrtovanja protetičnega zdravljenja s podajo informacij v z-smeri in tako omogoča določitev buko-lingvalne širine in topologije ter naklona in širine razpoložljive alveolarne kosti. S posebnimi programskimi orodji proizvajalcev protetičnega materiala je tako na 2D in 3D digitalnih posnetkih možno enostavnejše in natančenješe načrtovanje protetičnega zdravljenja. Ortopantomogram je tomografska tehnika slikanja, pri kateri pot cevi in slikovnega detektorja ni krožna ampak eliptična. Eliptično premikanje omogoča prikaz zobovja v ortoradialni smeri in prikaz interdentalnih prostorov. Omejitve ortopantomograma so razmazanost, distorzija in povečava, ki so posledica geometrijskih lastnosti panoramskega slikanja. Razmazanost nastane zaradi lastnosti tehnike tomografskega slikanja, ki nadzorovano zabriše strukture, ki niso v področju, ki nas zanima, iz tega razloga v področju zgornjih in spodnjih sekalcev nastane prekrivanje slike s senco vratnih vretenc. Drugi vzrok razmazanosti slike pri analogni tehniki je uporaba ojačevalnih folij. Tomografski premiki in razdalja med žariščem in filmom povzročijo distorzijo in povečanje končne slike.

Digitalizacijo panoramskih zobnih rentgenskih aparatov poenostavlja dejstvo, da je površina detektorja mnogo manjša od površine filma, saj mora detektor pokrivati le tanko režo, snop rentgenskih žarkov pa je zaslonjen na velikost te reže, s čimer dosežemo manjšo razmazanost slike. Poleg tega so digitalni sistemi bistveno bolj občutljivi na rentgensko svetlobo kot kombinacija folija-film kar omogoča boljši izkoristek sistema, s čimer dosežemo zmanjšanje dozne obremenitve preiskovanca. Glavne prednosti digitalnega panoramskega posnetka pred analognim so visoko kakovostne slike z višjo kontrastno ločljivostjo in širšim dinamičnim razponom slike. Naknadna računalniška obdelava slik z možnostjo spreminjanja lastnosti slike (kontrastnosti, ločljivosti in svetlosti) ter z možnostjo opravljanja preglednih meritev in načrtov vstavljanja implantantov slikam doda diagnostično vrednost. Zaradi bistveno boljše preglednosti celotnega zobovja prav tako mnogokrat odpade potreba po dodatnih lokalnih posnetkih. CBCT sestavi sliko iz velike količine podatkov, pridobljenih iz atenuacijskih koeficientov tkiva v več miljonih volumskih elementov. Volumski elementi CBCT-ja so izotropni, kar pomeni da so enake dolžine, višine in globine in omogočajo geometrijsko natančne meritve v transverzalni, sagitalni in koronarni ravnini. To omogoča večjo natančnost kasnejših slik, kar je pomembno predvsem pri implantantni analizi posnetkov. Trenutne omejitve CBCT-ja so povezane z geometrijo konusnega snopa, občutljivostjo detektorjev in kontrastno ločljivostjo, ki zmanjšujejo razmerje signal – šum, kar omejuje diagnostično uporabnost posnetkov. Slike, pridobljene s tehnologijo CBCT imajo nižjo prostorsko ločljivost od klasičnih panoramskih slik. Pomemben problem, ki vpliva na kakovost in diagnostično uporabnost CBCT slik je efekt tršanja, ki ga povzročajo visoke gostote sosednjih struktur, kot so emajl in kovinski deli. Razvoj tehnike in programske opreme CBCT-ja je usmerjen k razvoju algoritmov za izboljšanje razmerje signal – šum in posledično za izboljšanje kontrastne ločljivosti sistema.

ZAKLJUČEK

Zobna rentgenska diagnostika je področje, na katerem so digitalni sistemi nedvomno dokazali svoje prednosti v primerjavi s filmi, zato so digitalne rentgenske slike kvalitetnejše in imajo večjo diagnostično vrednost. Pri panoramskem slikanju digitalni zajem slike omogoča napredne metode rekonstrukcije slike, česar rezultat je CBCT. CBCT vse bolj postaja zlati standard pri načrtovanju protetičnega zdravljenja in v prihodnosti lahko tridimenzionalni posnetki nadomestijo klasične dvodimenzionalne tehnike, ki pa imajo trenutno še vedno višjo ločljivost kot CBCT slike. Zato se CBCT uporablja kot dodatna diagnostična metoda h klasičnemu ortopantomogramu.

Zahvala

Za strokovno pomoč se iskreno zahvaljujeva Karmen Poženel Upelj, dipl. inž. rad.

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Sponzorski članek

DIGITAL BREAST TOMOSYNTHESIS

A clinical assessment based on literature

WHY BREAST TOMOSYNTHESIS?

Breast cancer is one of the most common cancers in women in the Northern Hemisphere. More than 10% of all women can expect to have some manifestation of the disease during their lifetime. Although earlier detection and better treatment may have reduced mortality in recent years, 30% of women with breast cancer will die from the disease. X-ray mammography is still the golden standard of investigational procedures. Digital mammography has improved diagnostics, especially in younger women and in denser breasts, and CAD can be of some help. However, every effort is necessary to raise the early cancer detection rate and thereby reduce the mortality rate. The sensitivity of mammography alone decreases with increasing parenchymal density. Numbers of missed cancers in very dense breasts have been reported to be as high as 52% – 76% (1, 2); in analog screening programs, up to 30% of detectable cancers were not detected. There are numerous reasons for this, the most important being the "structured" or anatomical noise produced by the overlapping tissue structures in the 2D imaging of a 3D object. Misinterpretation of architectural distortion and asymmetrical density, fibroglandular tissue overlapping the cancer and obscuring the margins of the cancer lead to false negative results. False positive findings which may mimic cancer can also be a result of these summation artefacts. The diffuse growth pattern of some tumors with ill-defined borders presents a special problem. Early detection of breast cancer is mandatory. Treatment will be less invasive and prognosis much better for the small noninvasive tumors or clusters of microcalcifications associated with DCIS. Any procedure which can reduce the anatomical noise has the potential of improving early breast cancer detection.

Background

Tomography is a well known procedure in radiography. Analog tomography of the female breast is not feasible (moving table, dose). With digital breast tomography (DBT) came new possibilities. The procedure was first described approximately 25 years ago. In later years an increasing number of reports and studies have discussed the difficulties and possible benefits of DBT. Still, a search in April 2010 in the public literature databases of PubMed and Embase revealed only a hundred papers and communications on the topic for the last 2 years. DBT is a three-dimensional imaging technique which provides an arbitrary set of reconstruction planes in the breast from a limited angle series of projection images acquired while the X-ray tube moves through an arc above the stationary detector (3, 4). The result is a 3D data set of the entire breast volume. The individual "planes of interest" of a chosen slice separation/slice distance, usually 1 mm, can be viewed separately from the rest of the image, thereby reducing the impact of anatomical noise. The individual slice shows enhancement of a lesion, while there is a blurring of the out-of-focus information of the breast tissue. The angular span of the tube is up to 50 degrees (20-60) and the number of projections is usually 25 or less. Expanding the angle and number of slices does not seem to give any further diagnostic information and may prolong the examination time and patient motion noise as well as raise the dose (5, 6). As an adjunct, 1 cm thick slices may provide additional information because of a better delineation of lesions, especially tumors (7). It may also facilitate a quicker look through the whole breast before turning to the 1 mm slices. This is under evaluation. Reconstruction of slices is still done parallel to the detector plane. Future developments which allow you to choose different reconstruction planes in the 3D volume set may expand the diagnostic value of the procedure. Due to the limited acquisition angle the possibilities cannot be compared to computed tomography.

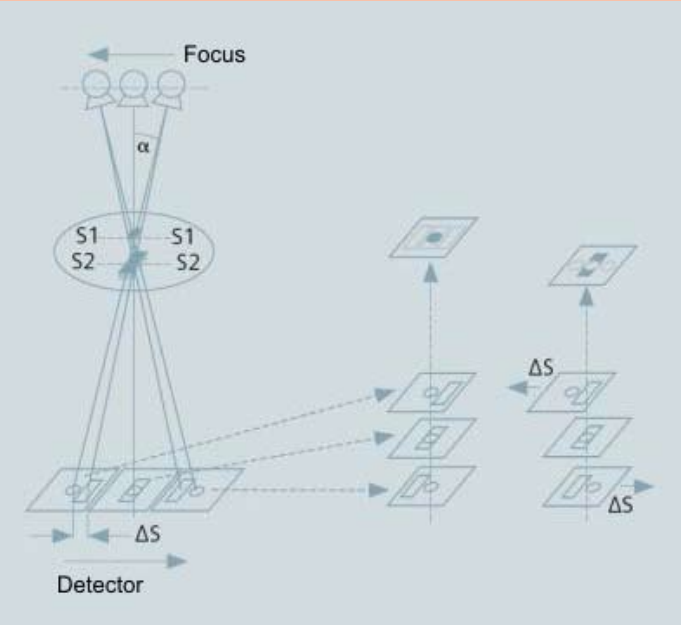

Figure 1: The Principle of Tomosynthesis

CLINICAL CONSIDERATIONS

Dose

The radiation dose for one DBT procedure in the CC or MLO projection is generally comparable to the dose of a two-view screening mammogram: 1–2 mGy in average glandular dose (AGD). The beam quality is similar to that of mammography (4). European Guidelines suggest that the AGD for one mammography exposure to a standard breast of 4.5 cm thickness should be kept below 2.5 mGy (8). Andersson et al. found the mean absorbed dose (exposure angle range 50 degrees, 25 projections, scan time 20 seconds) to be double the dose of a one-view digital mammogram: approx.1.6 mGy (9). Teertstra et al. (22) found an AGD of 1.74 mGy. One DBT procedure is well below the guideline dose. Further investigations will show whether a dose reduction is possible

without losing important diagnostic information. If DBT is used in a screening setting, at least one of the screening mammograms could be replaced by the DBT procedure. For the individual woman this indicates a larger dose. If DBT can replace all screening projections, dose will be the same as today provided one-view tomosynthesis is sufficient from a diagnostic point of view. In a clinical follow-up DBT will replace at least one and may be all additional projections. For the total population DBT, if used in screening, should lead to a lower acquired dose if many recalls and further mammographic examinations can be avoided.

Acquisition Time/Clinical Throughput

Currently the through-put of one tomosynthesis system can be up to 8–10 patients per hour if performing FFDM with DBT. Correct positioning is essential. The scan time can be up to 25 seconds depending on the angular range and the number of projections. As mentioned above, scan time and dose have to be considered under the aspect of obtaining better image quality and more clinical information. Therefore a longer examination (scan) time is feasible in the clinical follow-up situation where usually only a few patients are scheduled per hour. It would, however, never fulfill the requirements in the screening room if all women were scheduled to have one or two DBT per breast. The discussion of whether to use DBT in one projection (MLO) or both will be solved by coming screening trials. Performing DBT on all women may not be justified since 25% of screening participants have fatty breasts. Offering DBT in general for most screening participants would mean a huge investment in equipment, rooms and personnel. At the moment, a better way of performing the DBT examination seems to be to reserve DBT for clinical examinations of both first-timer and follow-up patients, and for women who still want to participate in the screening program but are at high risk and/or have very dense breast tissue as found during an earlier screening procedure, or for those who present with new clinical symptoms. These topics will be addressed in further studies.

Compression

Mammography can be unpleasant, because the compression of the breast is painful. Some women may even refrain from further mammographic procedures. DBT requires a scan time of 20 seconds (see above) which may cause further discomfort and thus create motion artefacts. In a phantom study, Saunders et al. (10) found that for a constant glandular dose, mass and microcalcification conspicuity remained almost constant with decreasing compression, up to 12%. Förnvik et al. (11) found that compression could be performed using only half of the force automatically proposed by the equipment before exposure without losing any important diagnostic information. There was a tendency to more noise in the thickest part of the breast (oblique projection, pectoral area) but this presented no difficulties for the readers. Reduced compression is also of value in contrast-enhanced tomosynthesis (CE-DBT) for ensuring appropriate blood flow in the breast (12, 27).

Reading Time

Of course, adding any tool to the diagnostic process of reading screening mammograms will prolong the reading time. A very recent study (13) concludes that when adding DBT to FFDM the time to review and evaluate an examination increases by 33% compared to reading the FFDM images alone in a previous setting. Good et al. (14) found, in a small study, that reading of DBT studies took almost double the time of reading FFDM studies alone. There were significant differences between the reading radiologists, but in general malignant cases took a little longer to finish than benign cases. Gur et al. (15) report a 50% longer reading time for FFDM + DBT studies compared to FFDM alone. In a personal communication (16), Ingvar Andersson, Malmö, Sweden, who experienced a 50% increase in reading DBT v. FFDM, declares that the goal is to achieve a speed of 50 read DBT cases per hour in a coming large-scale screening trial. But much depends on the training of the radiologists and on the performance and facilities of the reporting workstation

CLINICAL BENEFITS OF TOMOSYNTHESIS?

Recall Rate

There seems to be a general agreement that DBT has an effect on the recall rate. The overlap of structures can be reduced with DBT. Equivocal lesions on 2D images, i.e.: tumor or not, can be disproved. Rafferty (17) reports from an early pilot study that radiologists could reduce the false positive recall rate by 83% (!) with DBT compared to conventional mammography without any significant difference in the cancer detection rate. Poplack et al. (18) found a 40% reduction in recalls in a study comparing DBT with FFDM screening mammography. The type of the finding, masses and architectural distortions in the images influenced the recall rate. Poplack used DBT in suspicious cases referred from screening (recalls), a highly select population. The result of DBT will vary according to the percentage of recalled women (19, comment on Poplack). In the United States more than 10% are recalled, in some of the screening programs in Denmark less than 3%. The greatest effect of DBT on the recall rate can be seen in the United States. It seems difficult to lower the recall rate much with DBT in a Danish screening program. But, of course, some patients with benign findings from DBT will not undergo an otherwise planned biopsy or further investigations. Gur et al (15) comparing FFDM + DBT with DBT alone in a retrospective study of mixed malignant and benign cases found a 30% reduction in the recall rate for cancer-free examinations.Using DBT alone would have reduced the recall rate by 10%.

Sensitivity and Specificity

Gur (15) and Gennaro (20) found no significant improvement in sensitivity or specificity. The latter found that even if DBT improves the image quality and lesion conspicuity (specificity) this has no influence on the clinical performance (sensitivity). The number of detected lesions did not change when DBT was introduced, but the radiologist could be more confident in making decisions. Most authors, though,

find that DBT increases the number of cancers detected and improves the characterization of the lesions compared to one-view or two-view FFDM. In 2007, Rafferty reported (17) from an earlier study, DBT v. two-view screening mammography, that in 89% of cases radiologists found DBT to be equal or better in defining masses and architectural distortions. In 88% of cases microcalcifications were visualized better with DBT. In a small study of subtle cancers, Andersson et al. (9) found that 3/4 of detected cancers were rated more visible with DBT and half of them were upgraded in the BI-RADS classification. In FFDM, of course, the two-view examinations performed better than one-view examinations, but still not as good as one-view DBT. The distribution of clusters of microcalcifications was seen easily enough although the morphologic details of individual calcifications were blurred. 10% of cancers (4 patients) were not found with either examination and one was missed with DBT because of its closeness to the thoracic wall, i.e. mispositioning. Svahn (21) from the same group found that one-view DBT + one-view FFDM, usually the CC projection, had superior specificity to two-view FFDM. Teertstra et al. (22) found the sensitivity in cancer detection to be 93% and the specificity to be 84/86% (BI-RADS 4+5 cases) for both DBT and FFDM.3% of cancers, all invasive lobular carcinomas, were not visible with either modality. 7% of cancers were false negatives with DBT, and these would, of course, have been missed in a screening setting with DBT alone, as well as with FFDM. Pathology revealed an overrepresentation of ILCs, the rest being IDCs and DCISs. The majority of biopsy-proven benign cases, where DBT had initially classified the lesion as BI-RADS 4 or 5 (false positives), were benign microcalcifications, a few cysts and some benign architectural distortions. One third in this false-positive group were suspected masses or densities, but all with negative biopsies and follow-ups.

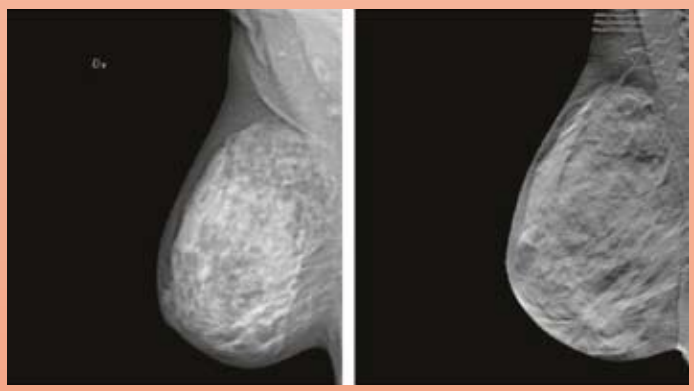

Figure 2: Tomosynthesis slice 25 (right), 2.8 cm ductal carcinoma, grade 3; Patient with a 2.8 cm, grade 3, invasive ductal carcinoma in the right breast imaged with digital mammography and breast tomosynthesis. The MLO digital mammography view shows dense breast tissue with subtle distortion in the lower breast. The MLO tomosynthesis slice shows a spiculated mass in the lower breast, much more evident than the corresponding mammogram.

OUTLOOK

DBT and CAD

CAD (computer aided detection or diagnosis), which has been found to be useful for radiologists in the detection of breast cancer in screening mammography (23), can be implemented with DBT. Some American groups have found a sensitivity of 85% in the detection of masses as well as a reduced false-positive marking rate compared to FFDM + CAD (24-26). DBT + CAD would certainly be helpful when having to scroll through the many reconstructed slices from one DBT exposure.

Contrast-Enhanced DBT

CE-DBT seems an easy way to obtain better information about a mass in the breast. Abnormal blood flow in the breast, tumor uptake and tumor border delineation can be visualized. The X-ray dose can still be held at an acceptable level and only a slight compression of the breast is necessary to avoid patient motion artefacts (27).

Breast Cancer Risk Estimation

DBT may play a role in this field in the near future. Risk assessment is a tool in planning further investigations, treatment and preventive strategies for high-risk women. Hereditary factors, number of childbirths, environmental factors and hormone treatment are known today as potential risk factors. The density and texture structure of the breast parenchyma especially in the retroareolar area can also be indicative of a woman's risk of developing breast cancer. DBT reduces the anatomical noise of skin and subcutaneous fat and offers superior texture visualization. One central DBT projection taken with 20% of the dose of an FFDM exposure correlates better to breast percent density than FFDM (28, 29). DBT can therefore help decide which of the women participating in the screening program should be offered a DBT scan in forthcoming screening rounds, either as an additional procedure or as the only procedure. It is still an open question whether some of the high-risk women who today are offered periodical MRI scans would benefit equally from DBT. Compared to MRI, the sensitivity in detecting small lesions (not necessarily demanding immediate treatment) may decrease slightly, but economic savings would be substantial.

CONCLUSION

Digital Breast Tomosynthesis (DBT) has so far proved to be a helpful tool in the portfolio of diagnostic radiologic procedures in the field of early breast cancer detection. DBT addresses one of the major problems of conventional 2D imaging of the breast: the structural or anatomical noise of overlapping tissue components. An improvement in both sensitivity and specificity in lesion detection and characterization is found in many of the newer publications and reports. Dose is acceptable. Breast compression can be reduced. Because acquisition time and diagnostic work-up for DBT take substantially longer than the fast screening procedure, it seems not feasible today to implement DBT in the screening room as a routine. Although the screening recall rate can be expected to decrease considerably, i.e. 30% or more, if DBT were used as an adjunct to screening, today's DBT must be reserved for the clinical follow-up of screening recalls, for symptomatic women and for women who have a high-risk history of breast cancer. After DBT the biopsy rate is expected to decrease. Some MRIs may not need to be performed. DBT may be combined with CAD (computer aided detection), which should

speed up the decision-making process when reading DBT images. Coming large-scale screening trials will clarify if it is possible to integrate DBT as one of the screening procedures, alone or with FFDM.

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Sponzorski članek

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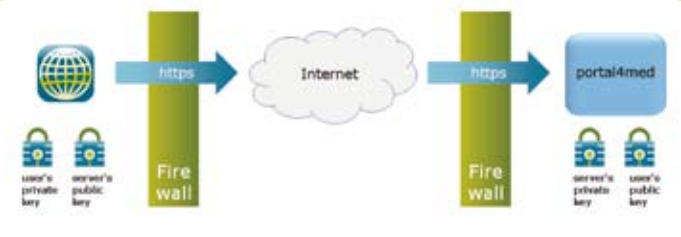

Figure 1

Streamlining tasks

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portal4med is permanently connected to the participating systems, patient information is always up-to-date and complete. When new reports or images are produced, they are automatically synchronized with the patient record.

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Portal4med brings efficiency to telemedicine. You define the conditions external service providers have to fulfill for reports and second opinions. Data access can be managed with equal flexibility, e.g. by setting time limits. Image data is exchanged between locations in the background. All those involved have permanent and complete access to reports and images – in clinics, medical centers or anywhere with an Internet connection.

Patient portal

Portal4med is a platform for patients, where they can view their electronic patient record at any time. In addition, the portal complies with the high data protection standards required. If a second or third opinion is necessary, patients can give their consent directly in the system by issuing an authorization ticket. Only then can the respective physician access the relevant information.

Continuous communication

Gateway4med is the communication server for our portal4med platform. It keeps going where conventional technology ends:

FASTER, BETTER, MORE SECURE.

Comprehensible communication

The environment in which portal4med operates is characterized by a number of different transport protocols and interfaces that speak completely different languages. gateway4med consolidates these differences and creates a streamlined foundation, which is essential for unlimited data flow.

Traceable communication

Complex data traffic is susceptible to transmission errors. gateway4med creates complete message histories for all communication processes, enabling the user to track the error source back to the respective system.

Secure communication

Transmitters and receivers maintain a secure HTTPS connection to the Internet. They communicate in gateway4med using the ReLaBIT (Reliable Large Binary Transfer Protocol), a transport layer developed by medavis for large amounts of data, which prevents the information from being manipulated or accessed externally during transmission.

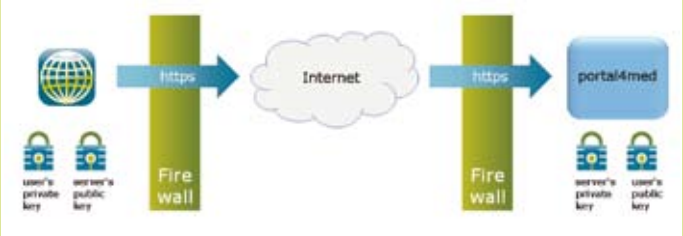

Figure 3

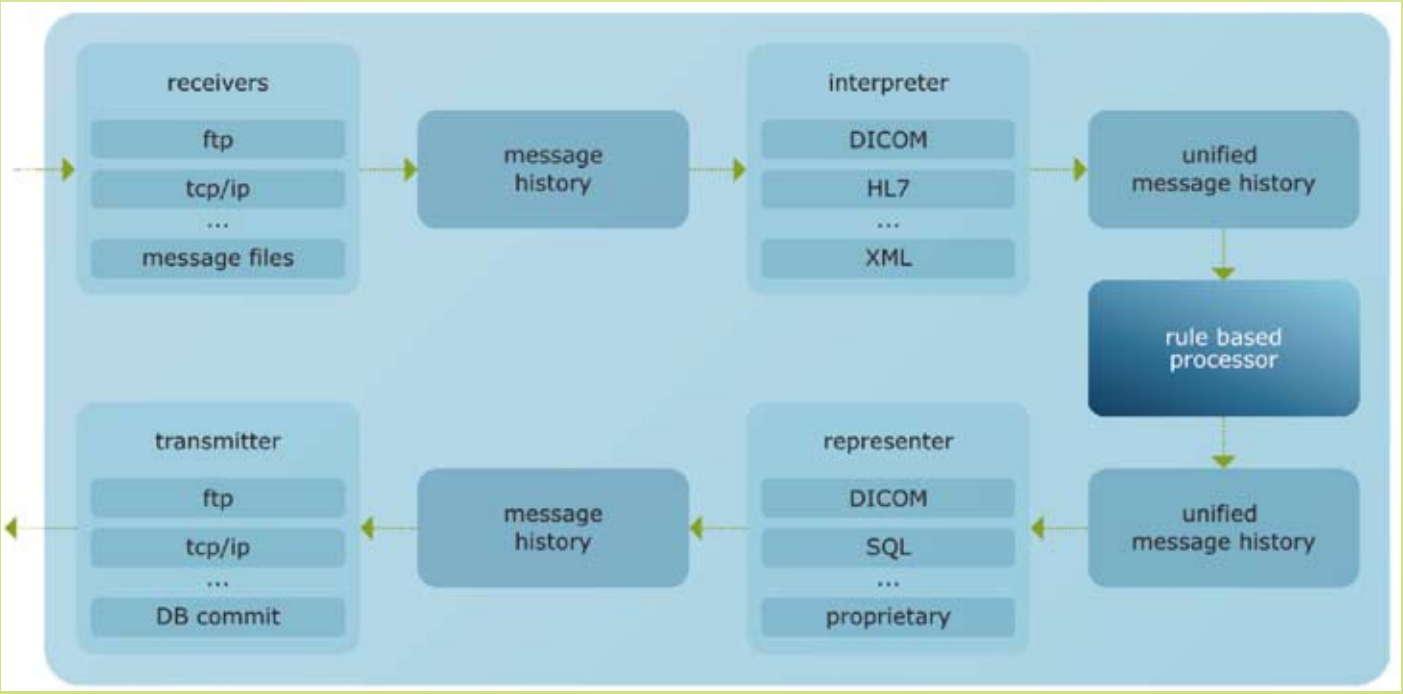

Figure 2

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Does Higher Gadolinium Concentration Play a Role in the Morphologic Assessment of Brain Tumors? Results of a Multicenter Intraindividual Crossover Comparison of Gadobutrol versus Gadobenate Dimeglumine (the MERIT Study)

ORIGINAL RESEARCH

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BACKGROUND AND PURPOSE: Gadobenate dimeglumine has proved advantageous compared with other gadolinium-based contrast agents for contrast-enhanced brain MR imaging. Gadobutrol is a more highly concentrated agent (1.0 mol/L). This study intraindividually compared 0.1-mmol/kg doses of these agents for qualitative and quantitative evaluation of brain tumors.

MATERIALS AND METHODS: Adult patients with suspected or known brain tumors underwent 2 identical MR imaging examinations at 1.5T, 1 with gadobenate dimeglumine and the other with gadobutrol, both at a dose of 0.1-mmol/kg body weight. The agents were injected in randomized order separated by 3–14 days. Imaging sequences and acquisition timing were identical for the 2 examinations. Three blinded readers evaluated images qualitatively for diagnostic information (lesion extent, delineation, morphology, enhancement, global preference) and quantitatively for CNR and LBR.

RESULTS: One hundred fourteen of 123 enrolled patients successfully underwent both examinations. Final diagnoses were intra-axial tumors, metastases, extra-axial tumors, "other" tumors, and "nontumor" (49, 46, 8, 7, and 4 subjects, respectively). Readers 1, 2, and 3 demonstrated preference for gadobenate dimeglumine in 46 (40.7%), 54 (47.4%), and 49 (43.0%) patients, respectively, compared with 6, 7, and 7 patients for gadobutrol ($P < .0001$, all readers). Highly significant ($P < .0001$, all readers) preference for gadobenate dimeglumine was demonstrated for all other qualitative end points. Inter-reader agreement was good for all evaluations ($\kappa = 0.414–0.629$). Significantly superior CNR and LBR were determined for gadobenate dimeglumine ($P < .019$, all readers).

CONCLUSIONS: Significantly greater morphologic information and lesion enhancement are achieved on brain MR imaging with 0.1-mmol/kg gadobenate dimeglumine compared with gadobutrol at an equivalent dose.

ABBREVIATIONS: CNR = contrast-to-noise ratio; GBCA = gadolinium-based contrast agent; GRE = gradient-recalled echo; LBR = lesion-to-background ratio; NSF = nephrogenic systemic fibrosis; SE = spin-echo; SI = signal intensity

BRAIN

ORIGINAL RESEARCH

Optimal detection and characterization of brain tumors on contrast-enhanced T1-weighted MR imaging depends as much on the contrast agent used as on the sequence parameters applied for image acquisition. Among the GBCAs currently approved by the FDA, gadobenate dimeglumine (MultiHance; Bracco, Milan, Italy) has proved superior to other GBCAs at equivalent dose for MR imaging of tumors of the CNS.[1-8] The superior diagnostic performance achievable with gadobenate dimeglumine, which is reflected in a recently updated "Summary of Product Characteristics,"[9] is due to high in vivo R1 relaxivity (6.3–7.9 L × mmol^{-1} × sec^{-1} at 1.5T,[10,11]) which derives from weak and transient interactions of the gadobenate contrast-effective molecule with serum albumin.[12,13] The increased R1 relaxivity leads to increased SI enhancement and thus significantly improved lesion visualization and better depiction of morphologic features relative to those achieved with GBCAs, which do not interact with serum protein, when these agents are administered at an equivalent dose of 0.1 mmol/kg of body weight.[1-8]

Recently, gadobutrol (Gadavist [Gadovist]; Bayer Healthcare, Berlin, Germany) has been approved by the FDA for imaging of the CNS.[14] This GBCA has a reported R1 relaxivity of 4.7–5.2 L × mmol^{-1} × sec^{-1} in human blood plasma at 1.5T[10,11] and differs from gadobenate dimeglumine and other approved GBCAs in that it is formulated at twice the concentration (1 mol/L rather than 0.5 mol/L), meaning that twice the concentration of gadolinium is present per unit volume.

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Accordingly, gadobutrol should be administered at half the volume (0.1 mL/kg) to attain the approved dose of 0.1 mmol/kg of body weight.[14] Studies in human subjects have suggested that gadobutrol may have advantages over other conventional GBCAs (ie, GBCAs that do not interact with serum albumin) for imaging of brain metastases.[15-17] However, to our knowledge, no studies have been performed to compare the more highly concentrated gadobutrol with the higher relaxivity agent gadobenate dimeglumine for MR imaging of brain tumors.

The aim of this study was to compare these 2 agents by using a rigorously controlled multicenter double-blind randomized intraindividual crossover study design in which each patient received 0.1-mmol/kg doses of both of these agents in 2 identical MR imaging examinations.

Materials and Methods

The study was Health Insurance Portability and Accountability Act–compliant, was conducted according to Good Clinical Practice standards, and was registered at www.clintrials.gov (ref. NCT00907530). All patients signed an approved informed consent form before enrollment.

Patients

One hundred twenty-three patients referred for contrast-enhanced MR imaging for known or suspected brain tumors were enrolled in a consecutive manner at 12 participating centers between September 2009 and November 2010. The highest number of patients enrolled at any center was 28. Six further centers enrolled between 8 and 16 patients. The remaining 5 centers enrolled between 2 and 5 patients. Patients were ineligible if they had received any investigational drug within 30 days before administration of either study agent. Subjects were also excluded if they were to receive any treatment that could affect lesion visualization before or between the 2 examinations (eg, whole-brain fractionated radiation therapy, steroids, or chemotherapy). Patients were also ineligible if they were pregnant or nursing or had impaired renal function, congestive heart failure, claustrophobia, gadolinium allergy, a cardiac pacemaker, or other contraindications to MR imaging.

One patient withdrew from the study after signing the informed consent form but before administration of either contrast agent. The remaining 122 eligible patients (67 men, 55 women; mean age, 56.1 ± 12.6 years; range, 20–84 years) were prospectively randomized to 2 study groups (A and B) to receive contrast agent according to 1 of 2 administration orders. Group A ($n = 59$) received gadobenate dimeglumine for the first examination and gadobutrol for the second; group B ($n = 63$) received the agents in opposite order.

MR Imaging

MR imaging was performed on 1.5T systems from several vendors (Avanto [$n = 16$], Sonata [$n = 18$], Symphony [$n = 9$], Siemens, Erlangen, Germany; Achieva [$n = 34$], Intera [$n = 12$], Gyroscan NT [$n = 3$], Philips Healthcare, Best, the Netherlands; Signa Excite [$n = 14$], HDx [$n = 16$], GE Healthcare, Chalfont St. Giles, United Kingdom) by using a standard head coil.

A rigorously controlled imaging protocol comprising T1 SE and T2 fast SE acquisitions before contrast injection and T1 SE and 3D high-resolution T1 GRE acquisitions after injection ensured protocol uniformity across sites and within individual patients. Sequence parameters varied between centers within predefined ranges because of the different imaging systems in use at these centers. However, the same MR imaging scanner, imaging planes, section prescriptions, and sequence parameters were used for both examinations in each patient. The range of parameters for the T1 SE sequence was as follows: TR = 350–680 ms, TE = 7.7–17 ms, excitations = 1–2, section thickness = 3–5 mm, FOV = 16 × 22–26 × 26 cm. The parameters for the T1 GRE sequence ranged as follows: TR = 7–2050 ms, TE = 2.99–6.28 ms, flip angle = 8°–60°, excitations = 1, section thickness = 1–3 mm, FOV = 23 × 17–30 × 23 cm. Parallel imaging was not used for any patient at any of the investigating centers.

Contrast agent administration was performed intravenously in an identical manner in both examinations by using either manual bolus injection ($n = 118$) or a power injector ($n = 4$). Both agents were administered at 0.1 mmol/kg of body weight, corresponding to 0.2 mL/kg for gadobenate dimeglumine and 0.1 mL/kg for gadobutrol. To maintain the study blind, an independent drug dispensing person administered each agent in the order determined by a randomization list. Care was taken to ensure that the injection duration was comparable for the 2 injections in each patient. All injections were followed by a saline flush of up to 30 mL.

Acquisition of postcontrast images began at a fixed time point, which was mandated to occur between 3 and 10 minutes after injection but could vary within this range depending on the site-specific protocol. However, the timing and sequence order of postcontrast acquisitions were identical for both examinations in each patient. The interval between the 2 MR imaging examinations was >48 hours in all patients to avoid carryover effects but <14 days to minimize the chance of measurable disease progression or lesion evolution.

Image Evaluation

All images were evaluated by 3 independent experienced radiologists (G.S., S.B., J.R.) who were unaffiliated with the study centers and blinded to the contrast agent used, to all patient clinical and radiologic information, and to all interpretations by on-site investigators. Each reader evaluated the patient images separately and independently.

All images from each patient were evaluated in a global matched-pairs fashion on a multimonitor imaging workstation. For each randomized patient number, all images from the first examination (examination 1) were displayed simultaneously with the corresponding images from the second examination (examination 2). Each reader was able to perform all routine interactive image-manipulation functions (eg, window/level, zoom, pan) on both image sets. If the postinjection images from either examination were considered technically inadequate by any of the 3 readers (eg, if artifacts compromised interpretability), no further assessment was performed for that patient by that reader. Once the readers' assessments were recorded and signed on an electronic case report form, the data base for that reading was automatically locked.

Qualitative Assessment of Diagnostic Information

Technically adequate images were evaluated qualitatively for diagnostic information and scored in terms of the following: 1) lesion border delineation, 2) disease extent, 3) visualization of lesion internal morphology, and 4) lesion contrast enhancement compared with surrounding normal tissue. All assessments were performed by using 3-point scales from −1 (examination 1 superior) through 0 (examinations equal) to +1 (examination 2 superior). For the various end points, superiority for 1 examination was recorded if it allowed better separation of ≥1 lesion from surrounding tissue, structures, or edema; better definition of lesion extent; clearer depiction of intralesion

features; better difference in SI between lesions and surrounding normal tissue; or depiction of ≥1 lesion only after that examination.

The readers also indicated whether they had an overall diagnostic preference for 1 examination over the other. When diagnostic preference was expressed, the reader then selected ≥1 of the following reasons for this preference: superior contrast enhancement, better delineation of normal structures, better delineation of at least 1 lesion, better visualization of lesion internal structure, more lesions identified, or greater diagnostic confidence.

Quantitative Assessment

Quantitative evaluation was performed by each reader independently by using a simultaneous matched-pairs approach. SI measurements were made at ROIs positioned on areas of normal brain parenchyma and on up to 3 enhancing lesions per patient identified on postcontrast images from both examinations. Additional SI measurements were made at ROIs placed in selected areas external to the brain to determine the background noise. Each ROI placed on the selected postinjection image from 1 examination appeared simultaneously at identical coordinates on the corresponding image from the other examination. Care was taken to avoid inclusion of vessels, and to ensure that ROIs of equal size were positioned on all corresponding image sets. If multiple lesions were present in a given patient, ROIs were placed on up to 3 of the largest most conspicuous lesions. A multimonitor imaging workstation (AquariusNET server, Version 4.4.1.4; TeraRecon, San Mateo, California) was used to determine SI values on a pixel-by-pixel basis and to calculate the percentage of enhancement of lesions for T1 SE acquisitions and the CNR and LBR for both T1 SE and T1 GRE acquisitions. CNR and LBR were determined by using the equations below, in which *SI* represents signal intensity, "brain" represents surrounding normal brain parenchyma measured on the same image section, and *SD* is the standard deviation of the background *SI* measured in an area of the same image section out of the body and devoid of artifacts.

$$\text{CNR} = \frac{SI \text{ of lesion} - SI \text{ of brain}}{SD\ (SI \text{ of noise})}$$

$$\text{LBR} = \frac{SI \text{ of lesion}}{SI \text{ of brain}}$$

Safety Assessments

Monitoring for adverse events was performed from the moment the patient signed the informed consent form until 24 hours after administration of the first study agent and then from the moment the second study agent was administered until 24 hours after administration of the second agent. Events were classified by the principal investigator at each center as either serious (ie, death, life-threatening, requiring or prolonging hospitalization) or not serious. Any perceived relationship to the agent was recorded.

Statistical Analysis

Power determination was based on the primary efficacy assumption that a 0.1-mmol/kg dose of gadobenate dimeglumine is superior to an equivalent dose of gadobutrol according to reader preference. Based on the results of a recent study[5] and assuming an "equal" response in 50% of cases, a ratio of superiority for either agent of 2.8:1, and an effect size of 0.111, enrollment of approximately 118 subjects was needed to demonstrate superiority with 85% of power considering a dropout rate of 15% (nQuery Advisor, Version 6.01; Statistical Solutions, Cork, Ireland).

Analysis of blinded reader evaluations was performed by using the statistical software package SAS, Version 8.2 (SAS Institute, Cary, North Carolina). The distribution of reader preferences for the diagnostic information end points was tested by using the Wilcoxon signed rank test. Inter-reader agreement for diagnostic preference was presented as a percentage agreement and was assessed by using generalized κ statistics. Agreement was classified as excellent (κ values $>$ 0.8), good ($\kappa = 0.61–0.8$), moderate ($\kappa = 0.41–0.6$), fair ($\kappa = 0.21–0.4$), or poor ($\kappa \leq 0.2$).[18]

Differences between gadobenate dimeglumine and gadobutrol in terms of quantitative enhancement were analyzed by using a mixed-effects model. The change from predose was the response variable, and factors included in the model were patient, period, sequence, study agent, and predose score, where patient nested within sequence was the random effect.

For the comparison of qualitative parameters, a Bonferroni adjusted significance level of $P < .01$ was used to take into account the multiple qualitative end points. All other statistical tests were conducted at a significance level of $P < .05$.

Results

Patients

Of the 122 patients randomized and evaluated for safety, 8 (6.5%; 4 after gadobenate dimeglumine; 4 after gadobutrol) were withdrawn prematurely after the first examination. The reasons for discontinuation were initiation of treatment (surgery or steroid therapy, $n = 2$), deterioration of patient condition ($n = 2$), or nonenhancing or no lesions seen on the first examination ($n = 4$). A total of 114 patients (55 in group A, mean age, 57.6 ± 11.9 years; 59 in group B, mean age, 55.0 ± 12.5 years) were, therefore, evaluated for diagnostic efficacy. There were no significant between-group differences in sex ($P = .174$), age ($P = .257$), age group (18–64 years, ≥65 years; $P = .057$), weight ($P = .595$), height ($P = .352$), or race ($P = .367$) distribution.

The diagnoses of these 114 patients were primary glial tumor in 49 (43%) cases (glioma [$n = 9$], glioblastoma multiforme [$n = 17$], astrocytoma [$n = 11$], oligodendroglioma [$n = 6$], mixed oligoastrocytoma [$n = 3$], ependymoma [$n = 1$], ganglioglioma [$n = 1$], gliomatosis cerebri [$n = 1$]); secondary metastases in 46 (40%) cases (primary lung cancer [$n = 20$], breast cancer [$n = 8$], renal carcinoma [$n = 3$], melanoma [$n = 3$], prostate cancer [$n = 3$], colon cancer [$n = 1$], esophageal cancer [$n = 1$], ovarian cancer [$n = 1$], testicular cancer [$n = 1$], carcinoma of the maxillary sinus [$n = 1$], unknown cancer [$n = 4$]); extra-axial tumors in 8 (7%) cases (meningioma [$n = 7$], acoustic neuroma/schwannoma [$n = 1$]); other tumor diagnosis in 7 (6%) cases (brain infiltration by lymphoma [$n = 4$], leukemia [$n = 1$], craniopharyngioma [$n = 1$], glomus tumor [$n = 1$]); or "other diagnosis" in 4 (4%) cases (postoperative scar/fibrosis [$n = 1$], leukoaraiosis [$n = 1$], radiation necrosis [$n = 1$]; and white matter microangiopathic ischemic disease [$n = 1$]).

Qualitative Image Assessment

Readers 2 and 3 considered all image sets from each of the 114 evaluable patients to be technically adequate, while reader 1

Table 1: Qualitative assessment of patients with brain tumors[a]

Diagnostic Information End Point	Reader	Gadobenate Dimeglumine Preferred	Gadobutrol Preferred	Significance (*P* Value)	3-Reader Agreement (κ value)
Global diagnostic preference	1	46 (40.7%)	6 (5.3%)	<.0001	0.524 (61.9%)
	2	54 (47.4%)	7 (6.1%)	<.0001	
	3	49 (53.2%)	7 (6.1%)	<.0001	
Lesion border delineation	1	43 (38.1%)	5 (4.4%)	<.0001	0.544 (66.4%)
	2	39 (34.2%)	3 (2.6%)	<.0001	
	3	37 (34.0%)	3 (2.6%)	<.0001	
Definition of disease extent	1	18 (15.9%)	1 (0.9%)	<.0001	0.414 (73.5%)
	2	21 (18.4%)	3 (2.6%)	<.0001	
	3	20 (17.5%)	0	<.0001	
Visualization of lesion internal morphology	1	39 (34.5%)	5 (4.4%)	<.0001	0.629 (73.5%)
	2	35 (30.7%)	4 (3.5%)	<.0001	
	3	36 (31.6%)	1 (0.9%)	<.0001	
Lesion contrast enhancement	1	53 (46.9%)	7 (6.2%)	<.0001	0.547 (62.8%)
	2	62 (54.4%)	10 (8.8%)	<.0001	
	3	50 (43.9%)	7 (6.1%)	<.0001	

[a] Comparisons based on 113 patients for reader 1 and 114 patients for readers 2 and 3. All other comparisons were considered equal. Numbers in parentheses represent proportions of patients.

Table 2: Reasons for global diagnostic preference as expressed by blinded readers

	Preference Expressed					
	Reader 1 (n = 52)		Reader 2 (n = 61)		Reader 3 (n = 56)	
Specifications of Global Diagnostic Preference	Gadobenate Dimeglumine (n = 46)	Gadobutrol (n = 6)	Gadobenate Dimeglumine (n = 54)	Gadobutrol (n = 7)	Gadobenate Dimeglumine (n = 49)	Gadobutrol (n = 7)
Superior contrast enhancement	34 (73.9%)	4 (66.7%)	53 (98.1%)	7 (100%)	47 (95.9%)	7 (100%)
Better delineation of normal structures	0	0	1 (1.9%)	0	1 (2.0%)	0
Better delineation of at least 1 lesion	28 (60.9%)	4 (66.7%)	21 (38.9%)	0	17 (34.7%)	1 (14.3%)
Better visualization of lesion internal structure	14 (30.4%)	4 (66.7%)	16 (29.6%)	3 (42.9%)	9 (18.4%)	0
Detection of more lesions	2 (4.3%)	0	1 (1.9%)	1 (14.3%)	3 (6.1%)	0
Greater diagnostic confidence	2 (4.3%)	0	2 (3.7%)	0	3 (6.1%)	0

considered the postdose T1 SE images of 1 patient to be technically inadequate. Qualitative assessments were, therefore, performed for 114 patients by readers 2 and 3 but for 113 patients by reader 1.

The findings of the 3 readers for global diagnostic preference and each of the individual end points are shown in Table 1. Readers 1, 2, and 3 reported global preference for gadobenate dimeglumine in 46 (40.7%), 54 (47.4%), and 49 (43.0%) patients, respectively, compared with 6 (5.3%), 7 (6.1%), and 7 (6.1%) patients for gadobutrol ($P < .0001$, all readers). Similar highly significant preference ($P < .0001$; all evaluations, all readers) was demonstrated for each individual diagnostic information end point. κ values for 3-reader agreement ranged from $\kappa = 0.414$ for definition of disease extent to $\kappa = 0.629$ for visualization of lesion internal morphology (Table 1). All 3 readers agreed completely for 61.9%–73.5% of the patients, depending on the diagnostic information end point under consideration. Agreement between 2 of the 3 readers was obtained for ≥97.3% for all end points.

Further evaluation of patients for whom a preference was expressed revealed that in most cases, this was due to superior contrast enhancement and better delineation of lesions and/or lesion internal structures (Table 2). Examples of the improved imaging performance achieved with gadobenate dimeglumine are shown in Figs 1–3.

Quantitative Evaluation

Readers 1, 2, and 3 recorded lesion SI measurements relative to normal brain parenchyma and background noise for 116, 103, and 92 lesions, respectively, on T1 SE images, and for 116, 102, and 92 lesions, respectively, on T1 GRE images. The mean percentage of enhancement of lesions on T1 SE images was highly significantly greater with gadobenate dimeglumine compared with gadobutrol for all 3 readers (reader 1, 119.9 ± 68.7 versus 97.3 ± 58.2; reader 2, 121.6 ± 65.9 versus 99.8 ± 56.9; reader 3, 111.9 ± 62.3 versus 89.7 ± 55.9; $P < .0001$ for all 3 readers) with no obvious differences across different scanner manufacturers.

Determinations of CNR and LBR based on SI measurements on T1 SE images relative to precontrast images are shown in Fig 4. Highly significant increases in quantitative enhancement for gadobenate dimeglumine was noted by all 3 readers for both CNR ($P = .0186$, $P < .0001$, $P = .0007$; readers 1, 2, and 3, respectively) and LBR ($P < .0001$, all 3 readers).

On postdose T1 GRE images readers 1, 2, and 3 determined CNR values of 67.49, 73.58, and 79.59, respectively, for gadobenate dimeglumine and 31.23, 33.16, and 35.47, respectively, for gadobutrol. The greater CNR achieved with gadobenate dimeglumine (+116.11%, +121.89%, and +124.39%, respectively) was highly significant ($P < .0001$) for each reader. Similar highly significant ($P < .0001$) differences between

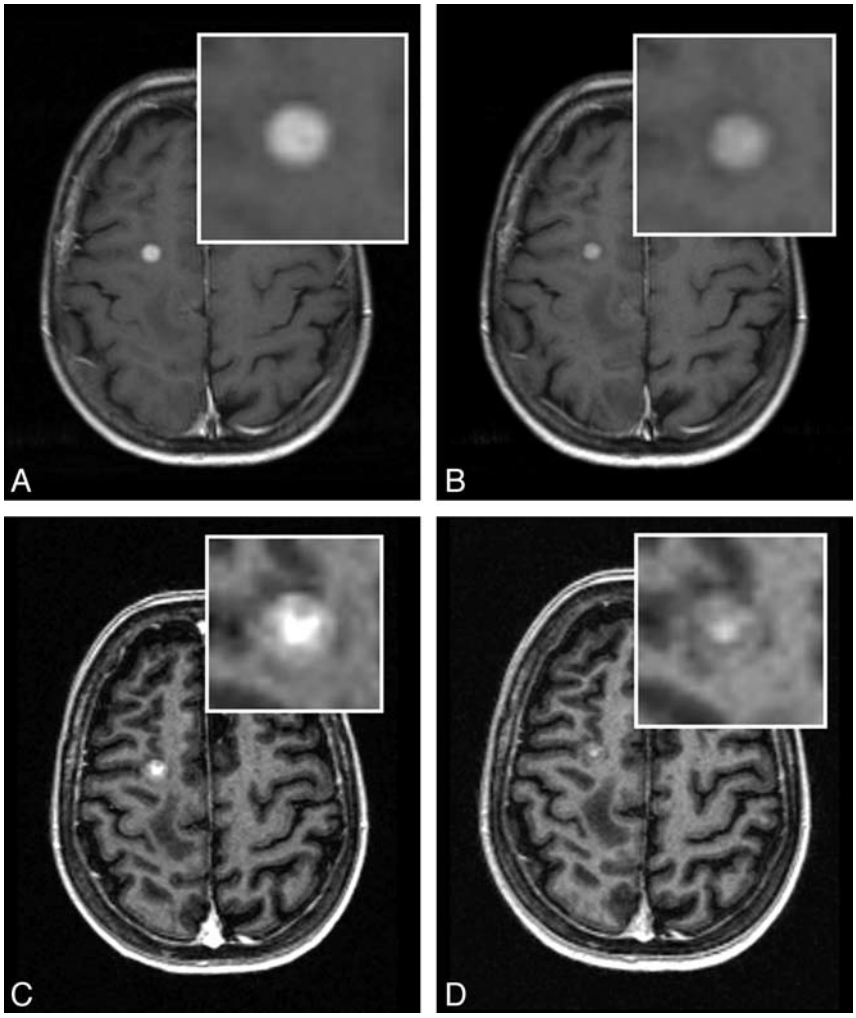

Fig 1. A 58-year-old woman with metastasis from melanoma undergoing MR imaging for definite staging of metastatic disease. T1 SE (*A* and *B*) and T1 GRE (*C* and *D*) images reveal a metastasis in the right superior frontal gyrus. However, the lesion appears larger and shows more conspicuous enhancement with gadobenate dimeglumine (*A* and *C*) than with gadobutrol (*B* and *D*).

gadobenate dimeglumine and gadobutrol were noted by each reader for postdose comparisons of LBR.

Safety

No clinically meaningful differences were noted in terms of the incidence of adverse events: Eight of 118 (6.8%) patients reported 12 nonserious events after gadobenate dimeglumine compared with 7/118 (5.9%) patients who reported 10 nonserious events after gadobutrol. Minor gastrointestinal symptoms and injection site conditions were the most frequent events reported with both agents. All contrast-related adverse events were mild and self-resolving, apart from 1 case of injection site inflammation after gadobutrol, which was considered moderate in intensity.

Discussion

Gadobutrol differs from other approved GBCAs in that it is formulated at a 2-fold higher concentration.[14] It has a macrocyclic structure similar to that of gadoteridol (ProHance, Bracco, Princeton, New Jersey)[19,20] and physicochemical properties that resemble those of other GBCAs that have conventional in vivo R1 relaxivity.[10,11,18.19] Consistent with the results of previous intraindividual comparisons,[1-8] the results of this study show that when administered at its approved dose of 0.1 mmol/kg, gadobutrol is preferred in significantly ($P <$ .0001) fewer patients than gadobenate dimeglumine at the same dose. Specifically, 3 blinded independent readers reported superiority for gadobenate dimeglumine in significantly ($P <$ .0001) more patients for all evaluated end points. Most important, the opinions of the 3 readers were identical for 61.9%–73.5% of the patients, resulting in κ values of $\kappa =$ 0.414–0.629 for inter-reader agreement. κ values of this magnitude are very good for qualitative evaluations of this type.

Concerning quantitative lesion enhancement, our results are again consistent with those in previous studies[1-8] in showing a significantly greater percentage of enhancement of lesions and significantly superior CNR and LBR with gadobenate dimeglumine. Although the magnitude of the difference in CNR was slightly lower for reader 1 (43.6% greater CNR with gadobenate dimeglumine compared with 72.3% and 73.0% greater CNR with gadobenate dimeglumine for readers 2 and 3, respectively), the differences were in all cases significant. As noted in comparisons with other GBCAs,[5-8] the increase in CNR with gadobenate dimeglumine

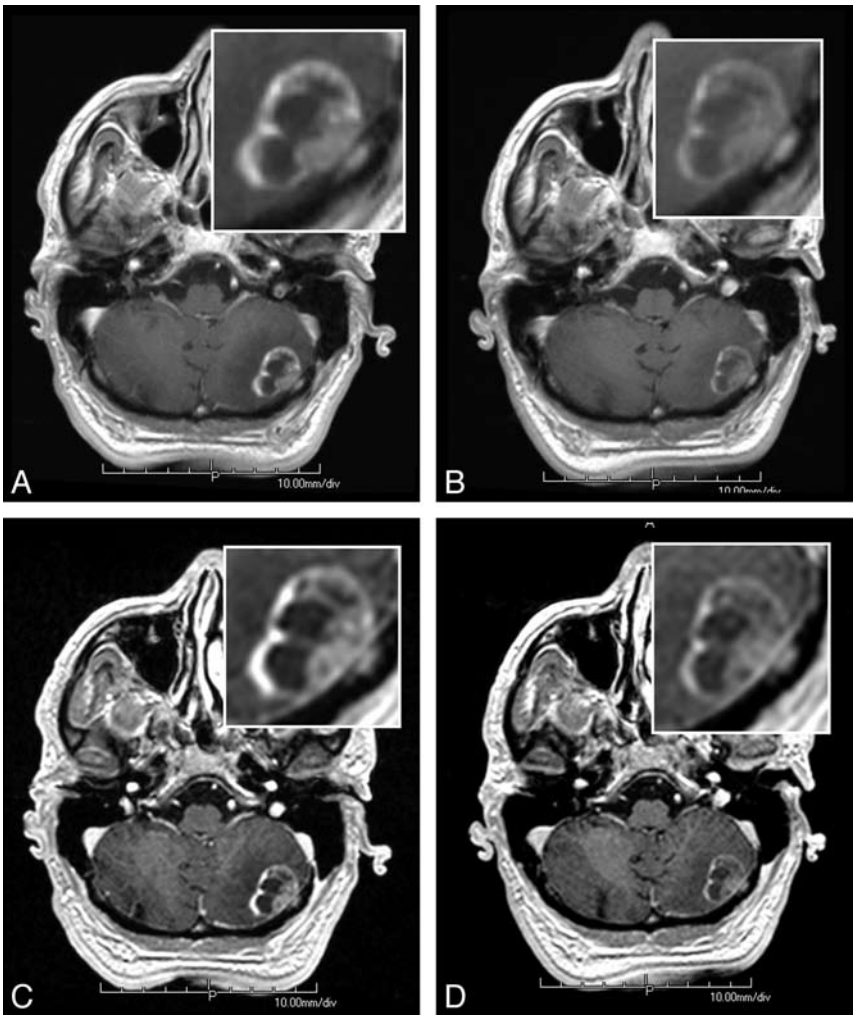

Fig 2. A 70-year-old man with metastasis from lung carcinoma undergoing MR imaging for identification and location of metastatic disease. T1 SE (*A* and *B*) and T1 GRE (*C* and *D*) images reveal a large metastasis in the posterior aspect of the left cerebellar hemisphere. The lesion appears larger, shows more conspicuous enhancement, and is better demarcated with gadobenate dimeglumine (*A* and *C*) than with gadobutrol (*B* and *D*).

compared with gadobutrol can be considered comparable with the magnitude typically observed with a double dose of GBCA compared with a single dose.[21,22] Although comparable enhancement to that achieved with gadobenate dimeglumine might have been obtained with a double dose of gadobutrol (ie, an identical volume), injections of high doses of GBCAs are not to be recommended, given the risk of NSF in certain patients with severe renal impairment. In this regard, although gadobutrol is a macrocyclic agent and thus widely considered one of the "safer" GBCAs, cases of NSF following its sole injection have been reported.[23,24]

Our study suggests that gadobutrol, though reported to have slightly higher relaxivity compared with established standard relaxivity agents,[11,25] provides little or no benefit over other GBCAs for brain tumor imaging when compared specifically with the imaging performance achieved with 0.1 mmol/kg of gadobenate dimeglumine. In support of this conclusion, the package insert for gadobutrol describes an as yet unpublished comparison of gadobutrol and gadoteridol and states that "performances of Gadavist and gadoteridol for visualization parameters were similar."[14] Although a recent study by Katakami et al[17] suggests that a single dose of gadobutrol is noninferior to a double dose of gadoteridol for detection of brain metastases, their study was inherently flawed in that no comparison was performed between a single dose of gadobutrol and a single dose of gadoteridol. Thus it is not possible to say whether a single dose of gadoteridol would have been equally noninferior to a single dose of gadobutrol by using their study design and statistical methodology.

Two conclusions can be drawn from our findings. First, it is clear that contrast agent concentration in the vial has no effect on imaging performance because injection of the more highly concentrated (1.0 mol/L) GBCA at 0.1 mmol/kg of body weight provides no appreciable clinical advantage relative to published findings for conventional GBCAs at a standard concentration (0.5 mol/L) when compared with gadobenate dimeglumine at an identical dose of 0.1 mmol/kg of body weight.[1-8] The lack of any appreciable benefit with gadobutrol can be ascribed to the fact that the SI during the interstitial phase (ie, at postinjection acquisition times of 3–10 minutes as typically performed for brain tumor imaging) depends solely on the total amount of gadolinium in the lesion (ie, the total number of gadolinium molecules) and its relaxivity rather than on the gadolinium solution concentration. Second, it is

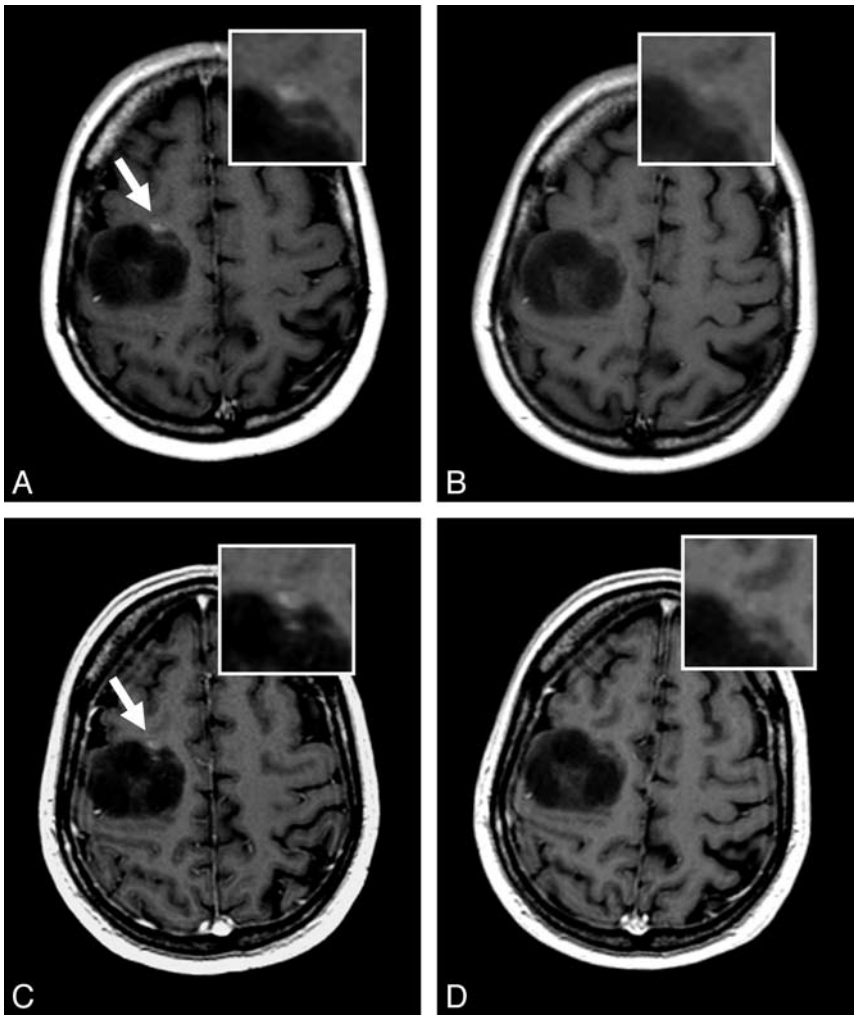

Fig 3. A 49-year-old woman with juxta-/prerolandic right frontal glioma undergoing MR imaging for assessment of tumor evolution. T1 SE (*A* and *B*) and T1 GRE (*C* and *D*) images reveal a large inhomogeneous tumor. The presence of a small enhancing focus (*arrow*) in the ventral portion of the tumor is seen clearly only on gadobenate dimeglumine–enhanced images (*A* and *C*). The enhancing area is nearly undetectable on gadobutrol-enhanced images (*B* and *D*).

clear that higher R1 relaxivity is instrumental in improving diagnostic performance relative to that achievable with conventional GBCAs at equivalent dose. In support of both conclusions are the findings of a recent study by Achenbach et al,[26] in which gadobutrol and gadobenate dimeglumine were compared at equivalent total volume (0.1 mL/kg of body weight, corresponding to a full dose of gadobutrol [0.1 mmol/kg of body weight] but only a half dose of gadobenate dimeglumine [0.05 mmol/kg of body weight]) for contrast-enhanced MRA of the peripheral arteries. In their study no differences were found in terms of quantitative enhancement, image quality, or diagnostic accuracy, indicating that the higher T1 shortening by gadobutrol per unit of time due to the double concentration was of no benefit compared with the greater relaxivity of gadobenate dimeglumine at only half the dose.[26]

To appreciate the role that relaxivity plays in improving diagnostic performance, one must understand the molecular properties of the various GBCAs and the influence each agent has on shortening the T1 relaxation time during image acquisition. Gadobenate dimeglumine differs from the widely used conventional GBCA gadopentetate dimeglumine (Magnevist; Bayer Healthcare, Berlin, Germany) through the presence of a hydrophobic benzyloxymethyl substituent on the gadobenate molecule.[20] This substituent confers 2 unique properties: First, it results in the gadobenate contrast-effective molecule undergoing elimination from the body in part through the hepatobiliary route, thereby rendering this agent appropriate for hepatobiliary applications.[27,28] Second and more pertinent for extrahepatic applications, this substituent causes the gadobenate molecule to interact weakly and transiently with serum albumin.[12,29] These interactions result in a slowing of the tumbling rate of the gadobenate molecule, leading to a longer rotational correlation time with inner shell water protons and hence an increase in the T1 relaxation rate.[29,30] Thus, while the R1 relaxivity values of gadobenate dimeglumine and gadopentetate dimeglumine are roughly similar in water,[11,29] the relaxivity of gadobenate dimeglumine is considerably higher when evaluated in vivo or in solutions containing plasma proteins.[10,11,29] Moreover, the R1 relaxivity of gadobenate dimeglumine is consistently higher across all magnetic field strengths,[10,11] resulting in improved imaging performance even at higher (3T) field strengths.[8,31] In contrast, the molecular structure of gadobutrol differs from that of gadoteridol only in that a hydroxypropyl group on the gadoteridol mole-

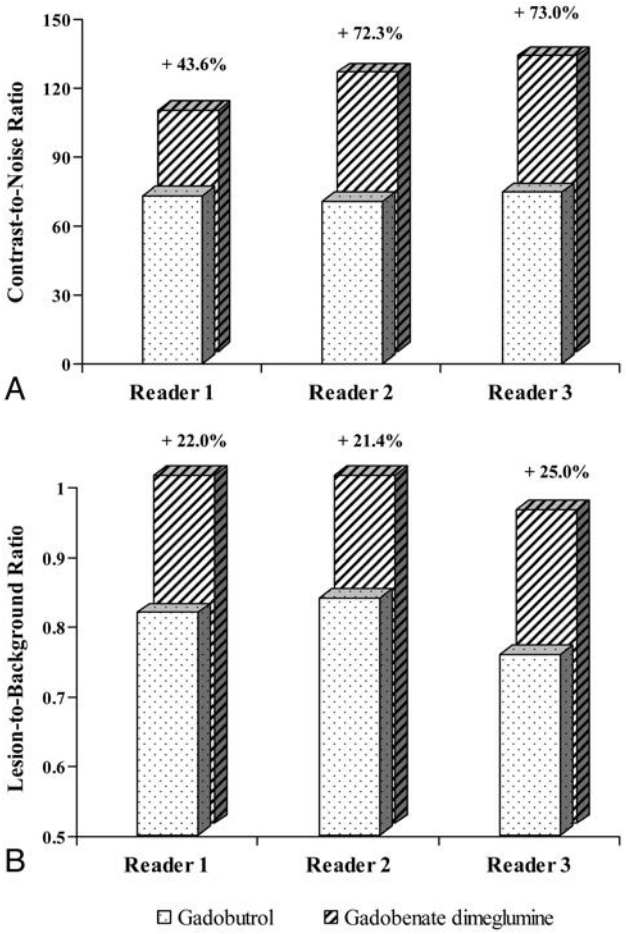

Fig 4. Blinded reader comparison of CNR (*A*) and LBR (*B*) after 0.1-mmol/kg doses of gadobenate dimeglumine and gadobutrol. Highly significant increases in quantitative enhancement for gadobenate dimeglumine are noted by all 3 readers for both CNR ($P < .02$) and LBR ($P < .0001$).

cule is replaced by a trihydroxybutyl group on the gadobutrol molecule.[20] Unlike gadobenate dimeglumine, gadobutrol does not interact to any appreciable extent with serum proteins and is excreted almost exclusively through the kidneys.[14,32,33] As a consequence, its R1 relaxivity in vivo is due entirely to the size and innate T1 shortening capacity of the gadobutrol molecule itself rather than to any augmentation of relaxivity and T1 shortening through interaction with serum albumin. Although reported relaxivity values vary slightly across publications depending on experimental conditions,[10,11,13] the results of well-conducted intraindividual comparative studies confirm that differences in relaxivity in vivo lead clinically to significantly better outcomes.[1,5-8,34-36]

A final consideration concerns the fact that this study was performed at 1.5T only. Although significant superiority for gadobenate dimeglumine compared with gadopentetate dimeglumine for brain tumor imaging has previously been demonstrated at 3T,[8] to our knowledge no studies have yet compared gadobenate dimeglumine and gadobutrol at higher field strengths. Nevertheless, given that the reported R1 relaxivity of gadobenate dimeglumine at 3T (5.5–5.9 $L \times mmol^{-1} \times sec^{-1}$) is again higher than that of gadobutrol (4.5–5.0 $L \times mmol^{-1} \times sec^{-1}$)[10,11] and given that the same issues apply with regard to SI dependence on total gadolinium dose (number of gadolinium molecules) rather than gadolinium concentration, it is to be expected that superior imaging performance would again be achieved with gadobenate dimeglumine relative to gadobutrol at this higher field strength.

Conclusions

Our results confirm expectations based on theoretic considerations of GBCA molecular structures and properties.[20,37] Thus, 3 blinded readers found no relevant benefit for the more highly concentrated gadobutrol in terms of lesion conspicuity, visualization, or sensitivity for detection. Rather, our intraindividual comparison of gadobenate dimeglumine and gadobutrol at an identical dose of 0.1 mmol/kg of body weight confirms that significantly improved qualitative and quantitative enhancement of brain tumors is achieved with gadobenate dimeglumine without any difference in safety.

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Sponzorski članek

STELLAR DETECTOR PERFORMANCE IN COMPUTED TOMOGRAPHY

The first fully-integrated detector in the CT industry sets a new reference in image quality with HiDynamics, TrueSignal and Ultra Fast Ceramics

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Siemens has continually evolved its technology for the most critical components in the CT scanner, including the X-ray tube, detector array and efficient image reconstruction algorithms. Back in 2002, Siemens introduced a revolutionary concept for a new X-ray tube. The STRATON® tube's compact design led to the development of fast rotation speeds and Dual Source Technology. STRATON X-ray tubes have a high power output, small focal spot sizes and virtually no cooling delays, thanks to unique technology that cools the anode directly. Siemens has also improved its image reconstruction methods continuously. While other vendors still use single-slice techniques which require compromises between image quality and speed, Siemens has developed SureViewTM for the first generation of multi-slice detectors, offering optimal dose utilization and excellent image quality at arbitrary pitch values. Such extensive research and development has fueled the latest generation of iterative reconstruction approaches, which include IRIS, and SAFIRE – Siemens´ raw-data-based iterative reconstruction application available commercially.

HIGH ABSORPTION, FAST DECAY AND LOW AFTERGLOW

CT scanner detectors convert the attenuated X-ray beam into a digital signal that can be processed by computers. To achieve very high dose efficiency, the detector's capacity for X-ray absorption must be as high as possible. After decades of using Xenon gas detectors in CT, Siemens introduced the first solid-state detector in 1999 (Fig. 1). Based on the proprietary scintillator material, Ultra Fast Ceramics (UFC™), the detector offered high X-ray absorption, short decay times, and extremely low after-glow. The UFC layer used in Siemens CT scanners converts almost 100% of the X-rays into visible light, whereas Xenon detectors can only convert between 60% and 90% of the X-ray into a usable signal. A direct comparison of Xenon detectors and UFC-based detectors indicated an increase of 23% in dose efficiency (Fuchs et al., 2000). Decay time and afterglow are two other important properties of scintillator materials that characterize the light out-put of the scintillator after the X-rays are switched off. Decay refers to the short-term behavior of the signal directly after the X-ray is switched off and afterglow is the longer-term composition of the signal output due to luminescence. UFC has set an industry standard with a consistent decay time of 2.5 microseconds, and an afterglow below 10-4 after 1 millisecond and 10-5 after 10 milliseconds. Until recently, other vendors still had to use afterglow correction mechanisms (Hsieh et al., 2000) since long decay time and high after-glow can completely ruin spatial resolution. Siemens has continued this trend of innovation by developing the first fully-integrated detector, which is designed to dramatically reduce electronic noise, extend the dynamic range and increase spatial resolution in combination with new reconstruction methods.

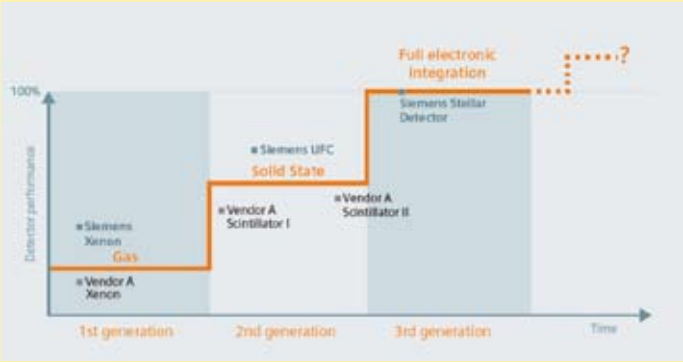

Figure 1: First generation detectors still used Xenon gas under high pressure to convert the incoming X-rays into electric current. Second-generation detectors use solid-state ceramic scintillators to convert X-rays into light, photodiodes to convert the light into current, and analog-to-digital converters (ADC) to digitize the signal. The Stellar Detector is the first third-generation detector that combines the photodiode and the ADC in one Application-Specific Integrated Circuit (ASIC), dramatically reducing electronic noise, power consumption, and heat dissipation.

REVOLUTIONARY NEW DETECTOR DESIGN

Detector performance is not only measured by fast and high X-ray absorption, short decay times, and low afterglow; low electronic noise levels and a high dynamic range are also key to designing effective detectors. With the new Stellar Detector, Siemens is pioneering the first fully-integrated CT detector. Conventional solid-state detectors consist of a scintillator layer that converts the incoming X-rays into visible light, a photodiode array that converts the visible light into an electric current and an analog-to-digital converter (ADC) which digitizes the signal on a separate electronic board (Fig. 2).

Figure 2: Prototype configuration of a second-generation detector module includes anti-scatter collimator, scintillator layer, photodiode array and a separate electronic board with ADCs

The number of electronic components and relatively long conducting paths increase power consumption, and add to the electronic noise produced by the detector. In the Stellar Detector, Siemens has combined the photodiode and the ADC in one application-specific integrated circuit (ASIC) for the first time in the history of CT, reducing the path of the signal. Fig. 3A shows a schematic of the new Stellar Detector configuration. The light from the UFC scintillator reaches the back-illuminated photodiode on top of the CMOS wafer, which houses the ADC. A digital signal is then produced on the other side of the wafer. This geometry consists of a 3D package of electronic circuits in a through-silicon via (TSV); a high performance technique for creating vertical connections that pass completely through the silicon wafer. Fig. 3B shows the complete configuration of the compact Stellar Detector array with the ADC positioned entirely underneath the photodiode array. This small module replaces all the boards and electronic components shown in Fig. 2. Stellar Detectors transfer the digitized signal without any losses and the electronic noise produced by the detector is reduced by a factor of two (TrueSignal Technology).

Figure 3: Schematic drawing shows the configuration of the new Stellar Detector. The light from the UFC scintillator reaches the back-illuminated photodiode on top of the CMOS wafer that contains the ADC. The digital signal is then produced on the other side of the wafer (Fig. 3A). A picture of the compact Stellar Detector array with the ADC positioned entirely underneath the photodiode array (Fig. 3B).

The new ASIC consumes 85% less power and dissipates less heat, further reducing electronic noise. Fig. 4 shows the reduced noise produced by the new Stellar Detector compared to a conventional second-generation detector.

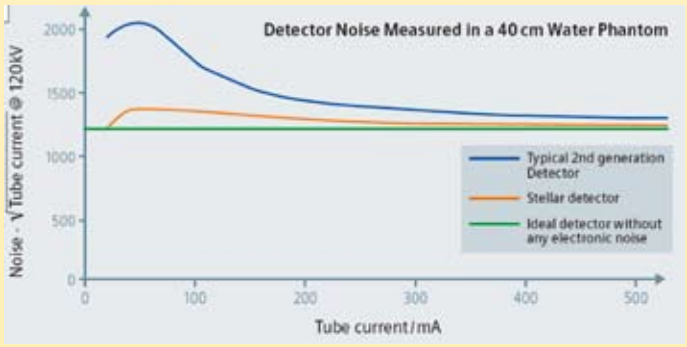

Figure 4: Reduced noise of the new Stellar Detector measured with a 40 cm water phantom and compared to a conventional second-generation detector. Stellar produces almost no electronic noise (green line), benefiting low dose applications and large patient scans where signals are very low.

LOW ELECTRONIC NOISE AND HIGH DYNAMICS

In clinical CT, the attenuation of the measured object varies dramatically and so do the signal levels at the detector. The dynamic range describes the range of the input signal levels that can be reliably measured simultaneously without saturation. HiDynamics has an exceptionally high dynamic range of 120 dB, 15% more than conventional detector systems, eliminating the need to modify amplification and avoiding detector saturation. Combined with the noise reduction provided by TrueSignal, Stellar Detectors can measure smaller signals over a wider dynamic range which directly enhances CT image quality (Fig. 5). Applications with extremely low signal levels at the detector benefit especially from HiDynamics and TrueSignal, such as scanning large patients and low-dose scans, as well as the low-kV datasets of Dual Energy examinations.

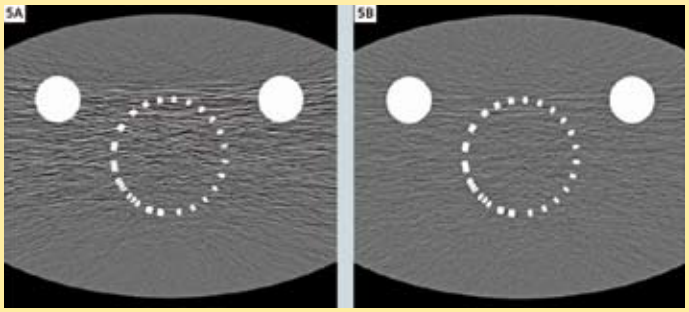

Figure 5: Simulation of a hip phantom with resolution insert, conventional detector technology and the new Stellar Detector. Using conventional technology, low signal levels in projections with high attenuation cause streak noise patterns in clinical images (left). With the Stellar Detector and TrueSignal Technology these unwanted noise patterns are eliminated (right).

MODEL-BASED AND DETECTOR-OPTIMIZED RECONSTRUCTION

With SAFIRE (Sinogram Affirmed Iterative Reconstruction), Siemens introduced the first model-based and raw data-based iterative reconstruction application capable of reducing noise and artifacts, suited for a broad range of applications in clinical routine. SAFIRE can thus model the Stellar Detector precisely, including the cross talk between detector elements, detector aperture, detector grid, and the

focal spot of the STRATON X-ray tube, reconstructing true 0.5 mm slices and unmatched spatial resolution in routine clinical protocols with excellent dose efficiency (Fig. 6).

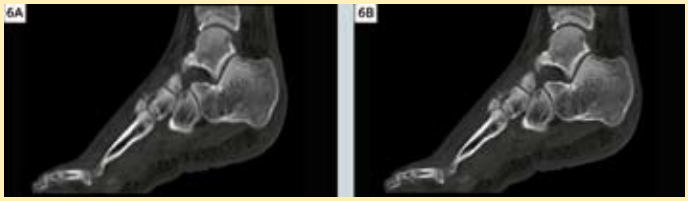

Figure 6: A foot has been scanned and reconstructed with conventional technology (Fig. 6A) and Stellar technology with optimized SAFIRE model-based reconstruction (Fig. 6B).

SOMATOM DEFINITION EDGE AND SOMATOM DEFINITION FLASH NOW EQUIPPED WITH NEXT-GENERATION DETECTOR TECHNOLOGY

Siemens high-end scanners are now equipped with the latest Stellar Detector1 in Single Source and Dual Source configurations.

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4 LETA PO TEM … - INFORMACIJSKA TEHNOLOGIJA NA ODDELKU ZA RADIOLOGIJO NA ONKOLOŠKEM INŠTITUTU V LJUBLJANI

4 YEARS LATER - INFORMATION TECHNOLOGY AT THE DEPARTMENT OF RADIOLOGY AT THE INSTITUTE OF ONCOLOGY IN LJUBLJANA

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Uvod in namen: S selitvijo oddelka za radiologijo Onkološkega inštituta Ljubljana v nove prostore v drugi polovici leta 2007 se je za oddelek pričelo obdobje digitalne radiologije. Ob novih in boljših delovnih pogojih smo se soočili tudi s sodobnimi, računalniško podprtimi delovnimi procesi. Danes minevajo štiri leta od tedaj in digitalna radiologija je postala del našega vsakdana. V prispevku bova predstavila informacijsko tehnologijo oddelka in njeno uvajanje v uporabo. Skušala bova tudi ugotoviti, kako je uvajanje digitalne radiologije potekalo in še poteka drugje.

Metode dela: Metoda dela, ki sva jo uporabljala, je pregled strokovne literature in slikovnega materiala.

Rezultati: Ugotovila sva, da se v primerjavi z drugimi evropskimi državami v zdravstvenih ustanovah vsej Sloveniji, ne le na Onkološkem inštitutu, digitalna radiologija in informacijska tehnologija uvaja razmeroma pozno. Huang in sodelavci (1989) omenjajo, da je bilo leta 1989 na Japonskem že 50 PACS sistemov, medtem ko jih je bilo istočasno v ZDA in Evropi le 30. Veliko težav, ki se pojavljajo pri tem, je največkrat povezanih z denarjem, kar potrjuje tudi Planykh (2008). Na Onkološkem inštitutu je bila velika prednost uvajanja digitalne tehnologije v tem, da se je oddelek postavljal na novo in ni bilo potrebno izvajati integracije starih aparatur z novimi sistemi.

Razprava: Kljub temu, da je oddelek star že štiri leta, se še vedno srečujemo s težavami, ki jih povzroča predvsem računalniško-programska oprema, sistemi pa se morajo stalno nadgrajevati. V veliki meri smo za pravilno delovanje odgovorni tudi radiološki inženirji, ki stalo delamo s temi sistemi in prvi opažamo težave. Ažurnost pri obveščanju skrbnikov sistema je pomembna za hitro odpravljanje napak (Huang et al., 1989). Pri uvajanju tehnologije na našem oddelku smo se tako srečevali predvsem s težavami pri uporabi programske opreme (počasno delovanje sistema, prilagajanje sistema potrebam oddelka, izpadi delovanja zaradi okvar strojne opreme) kot tudi z delovanjem mrežne opreme (izpadi v delovanju povezav med aparaturami in programsko opremo). Te težave so bile ob sočasnem nadgrajevanju sistema odpravljene.

Zaključek: V štirih letih delovanja novega oddelka je bilo ugotovljeno, da kljub vsem težavam s katerimi se je osebje srečevalo, informacijska tehnologija deluje. Tudi drugod so se na začetku srečevali s podobnimi težavami kot pri nas. Obstajajo pa še možnosti za nadaljnji razvoj sistema (Hurby, 2001), kar pa bo še bolj olajšalo delo vsakodnevnim uporabnikom kot tudi vsem tistim, ki so v sistem vključeni.

Ključne besede: digitalna radiologija, onkologija, informacijska tehnologija

Introduction and purpose: With the relocation of the Department of Radiology at the Institute of Oncology in Ljubljana to new premises in the second half of 2007, the era of digital radiology has begun. Under new and better working conditions, we were also included in the modern, computerised work processes. Today, four years later, digital radiology has become a part of our daily routine. In this article, we are going to present the information technology of the Department and its implementation into service. We will try to find out how the introduction of digital radiology was (and still is) performed elsewhere.

Method of work: The working method that we used is a review of the professional literature and picture material.

Results: We have found out that, in comparison with other European countries the health institutions throughout the country, not only the Institute of Oncology have introduced digital radiology and information technology quite late. Hooshang (1989) mentions that it was in 1989 when Japan already had 50 PACS systems, while in the US and Europe only 30 were installed. Many problems that followed are mostly associated with financing, which is also confirmed by Pianykh S. O. (2008). One of the great advantages of digital technology implementation at the Institute of Oncology in Ljubljana was the fact that the Department was newly build and there was no necessity for the integration of the old apparatus.

Discussion: Despite the fact that the Department is already four years old, we are still facing difficulties, caused primarily by computer-software equipment and systems, which must be continuously upgraded. To a large extent, the radiological engineers are responsible for the proper functioning of the system, since we are the ones who work with the system and the ones who first come across problems. The prompt informing of the system administrators is important for fast troubleshooting (Hooshang et al, 1989). When the new technology at our department was introduced, we faced particular difficulties in the application usage (slow functioning of the system, adapting the system to the needs of the Department, operation outages due to hardware

defects) as well as operation of network equipment (connection outages in the links between the apparatus and software). These problems have been discarded with the system upgrade.

Conclusion: In the last four years of Department operation, we have realised, that despite of all the problems the information technology works. At the beginning institutes in other countries have faced similar problems as we did. Luckily, there are still opportunities for further development of the system (Hurby W, 2001), which will make the work easier for beginners, as well as for all those who are involved in the system.

Keywords: digital radiology, Oncology, information technology

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CIRSE 2011

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Uvod in namen: Vrednotenje znanja diplomiranih radioloških inženirjev je bilo predstavljeno v okviru Evropske federacije radioloških inženirjev (EFRS), na srečanju Društva kardiovaskularnih in interventnih radiologov Evrope (CIRSE), v Münchnu 2011. Nazivi poklica so v enaintridesetih evropskih državah, ki so včlanjene v EFRS, različni. Na srečanju so aktivno sodelovali predstavniki Irske, Avstrije, Nizozemske in Slovenije, iz vsake države po dva povabljena člana, ki sta na eni izmed štirih delavnic uvodoma predstavila nekaj problemov dela radiološkega inženirja v interventni radiologiji:

- Irci so predstavili probleme izobraževanja, posebej pridobivanje znanja o varovanju pacienta ter pomen nadaljevanja izobraževanja o zaščiti pred sevanjem v interventni radiologiji.
- Avstrijski kolegici sta govorili o E-izobraževanju: teoretične prednosti E-izobraževanja, uporabi teoretičnih metod v reševanju vprašanj tega načina izobraževanja ter o sterilnosti, materialih in metodah v interventni radiologiji.
- Nizozemca sta se osredotočila na pacientovo varnost v interventni radiologiji, in sicer na: pomen priprave pacienta na poseg, kontrolo njegovega stanja pred posegom, pravilno ravnanje radiološkega inženirja po posegu, njegovo znanje o hemostazi, nefropatiji in alergiji ter prednostih naročanja na posege po elektronski poti.
- Avtorici sva predstavili naše izkušnje s timskim delom v interventni radiologiji, uporabo kontrastnih sredstev in uporabo pravilnih protokolov za posamezne posege.

Po zaključku delavnic so bili udeleženci anketirani, predstavljeni so rezultati ankete.

Metode: Enournih delavnic se je udeležilo 119 poslušalcev, med katerimi niso bili le radiološki inženirji, ampak tudi drugi udeleženci iz različnih držav, tudi iz Amerike in Azije. Število udeležencev na posameznih delavnicah je bilo različno (od 10 do 63), največje je bilo na tisti, ki so jo vodili Irci, najmanjše pa na avstrijski.
Po zaključku vsake delavnice so bili udeleženci anketirani. Anketa je bila v pisni obliki in anonimna. Vsebovala je pet vprašanj:

1. ali je bil namen delavnice reklamirati izdelke proizvajalcev radiološke opreme?
2. ali so udeleženci imeli možnost postavljati vprašanja?
3. ali so se udeleženci na delavnici kaj naučili?
4. ali so za osvojitev predstavljene vsebine potrebne tudi vaje?
5. ali sta bila, po pričakovanjih udeležencev, naslov in vsebina delavnice skladna?

Potek delavnic je nadzorovala komisija EFRS. Napake so ocenili s komentarji, ocene so nam vrnili v elektronski obliki.

Rezultati in razprava: Rezultati ankete udeležencev so prikazani v tabeli 1. Večina anketiranih je bila mnenja, da delavnice niso bile namenjene reklami izdelkov proizvajalcev opreme, da so vsi udeleženci imeli enake možnosti postavljanja vprašanj. Delavnice so predstavile nove vsebine, za osvojitev katerih so potrebne vaje,vnaslovi uvodnih predavanj so bili skladni s podano vsebino.

Tabela 1: Rezultati ankete

država/ številka vprašanja/ odgovori	*1*		*2*		*3*		*4*		*5*	
	da	**ne**	**da**	**ne**	**da**	**ne**	**da**	**ne**	**da**	**ne**
Irska	3	48	42	4	52	2	50	4	50	1
Avstrija	1	7	9	0	9	0	8	1	9	0
Nizozemska	2	21	17	4	22	1	19	4	17	3
Slovenija	0	15	12	1	13	2	10	5	11	3
Skupaj	***6***	***91***	***80***	***9***	***96***	***5***	***87***	***14***	***87***	***7***
%	***6***	***94***	***90***	***10***	***95***	***5***	***86***	***14***	***93***	***7***

Potek delavnic je ocenjevala komisija EFRS, katere komentarji so predstavljeni v tabeli 2.

Tabela 2: Ocene in komentarji komisije EFRS

država	*komentar*
Irska	*Zelo dobro! Izvrsten govor!*
Avstrija	*Dobro!*
Nizozemska	*V predstavitvi bi bilo potrebnih več različnih primerov iz različnih bolnišnic; izvodi bi morali biti predstavljeni v angleškem jeziku. Celotna predstavitev, z izjemo elektronskega naročanja, je preveč preprosta.*
Slovenija	*Pacienti morajo biti anonimni – brez slik obrazov!*

Irci in Avstrijci so svoje delo opravili izvrstno.
Nizozemca sta v svoji predstavitvi uporabila laboratorijske izvide izključno iz ene bolnišnice, ki niso bili prevedeni v angleški jezik. Ta del predstavitve je bil preveč enostaven, primerno je bil predstavljen sistem elektronskega naročanja pacientov (RIS).
Člani komisije so bili s predstavitvijo Slovenije zadovoljni, niso pa se strinjali z načinom prikazovanja postopkov na fotografijah, na katerih so bili prikazani tudi obrazi pacientov, ker bi morali ostati pacienti anonimni. Avtorici sva mnenja, da sva ravnali v skladu z etičnimi pravili, saj sva pridobili pisne privolitve pacientov, po tem, ko so bili seznanjeni z namenom fotografiranja.

Zaključek: Na delavnicah smo imeli priložnost primerjati znanje in izkušnje radioloških inženirjev iz štirih različnih evropskih držav, pridobili pa smo tudi nekaj novega znanja. Rezultati ankete in komentarji komisije so nam dali informacije o visokem nivoju našega teoretičnega in praktičnega znanja.

Ključne besede: interventna radiološka tehnologija, izobraževanje

Introduction and purpose: The evaluation of knowledge of graduated radiological engineers was presented within the European Federation of radiological engineers (EFRS) on the meeting of the Society of Cardiovascular and Interventional Radiology in Europe (CIRSE) which took place 2011 in Munich. Occupation titles in thirty-one European countries - EFRS members - are different. On the meeting, two representatives from four countries i.e. Ireland, Austria, Netherlands and Slovenia, were actively participating at four workshops and presented some problems that radiological engineers have encountered during their work in interventional radiology:

- The Irish presented the problems of education, particularly the acquisition of knowledge on protection of the patient and the importance of constant education on radiation protection in interventional radiology.
- The Austrian colleagues spoke about E-learning: theoretical benefits of e-learning, application of theoretical methods in solving the issues of this mode of education and sterility, materials and techniques in interventional radiology.
- The Dutch focused on safety of the patient in interventional radiology, especially: the importance of preparing the patient for the procedure, checking the patient's condition before the surgery, proper treatment by radiological engineers after the surgery, his knowledge of haemostasis, nephropathy and allergies and benefits of making an appointment for the examination via e-mail.
- The authors of the present article presented the experience with team work in interventional radiology, the use of contrast agents and the application of correct protocols for specific interventions.

After the workshops, participants were interviewed; the results of the survey were presented.

Methods: The one-hour workshop was attended by 119 attendees, which were not only radiological engineers, but also other participants from different countries, for example from America and Asia. The number of participants in each workshop was different (from 10 to 63), the largest was the one led by the Irish and the smallest one by the Austrians. After each workshop, the participants were interviewed. The survey was anonymous and handed out in written form. It contained five questions:

1. Was the intent of the workshop advertising the products of the manufacturers of radiological equipment?
2. Were the participants given the opportunity to ask questions?
3. Did the participants learn something from these workshops?
4. Do you need practice to acquire necessary knowledge of the presented themes?
5. According to the expectations of participants - were the workshop title and its content consistent with one another?

The workshops were supervised by the EFRS Commission. They have evaluated our work and have sent us an e-mail with their notes about our presentation.

Results and discussion: Results of the survey are shown in Table 1. Most respondents felt, that these workshops were not intended to advertise the company that sells the equipment and that all participants had equal opportunities to ask questions. These workshops have presented new ways to gain necessary experience. The title of introductory lectures describes well the lecture itself.

Table 1: Survey results

country/ number of issues / answers	1		2		3		4		5	
	yes	no	yes	no	yes	no	yes	no	yes	no
Ireland	3	48	42	4	52	2	50	4	50	1
Austria	1	7	9	0	9	0	8	1	9	0
Netherland	2	21	17	4	22	1	19	4	17	3
Slovenia	0	15	12	1	13	2	10	5	11	3
overall	6	91	80	9	96	5	87	14	87	7
In %	6	94	90	10	95	5	86	14	93	7

Document Commission workshops were evaluated by EFRS whose comments are presented in Table 2.

Table 2: Ratings and comments from the EFRS commission

country	comment
Ireland	Very good! Excellent speech!
Austria	Good!
The Netherlands	You should have examined more cases from different hospitals and the data you have presented, should have been in English. The entire presentation was not complex enough, except of the electronic order sets, which were interesting!
Slovenia	Patients should be anonymous – no pictures of patients' faces!

The Irish and the Austrians have done a great job.
In their presentation the Dutch have used laboratory results just from one hospital, and they were not even translated in English. This part of the presentation was too simple, while the presentation of the electronic patient appointment system was on the adequate level.

Commission members were pleased with the presentation of Slovenia, except one issue: they did not approve, that the faces of the patients on the photos were not blurred, as the patients should have remained anonymous. The authors of the presentation believe to have been in accordance with ethnical rules, as we had obtained a written consent from each patient, after we have informed them about the purpose of these photos.

Conclusion: The workshop offered us a chance to compare the radiological expertise of engineers from four different European countries, but we have also gained some new knowledge. Survey results and comments from the Commission gave us information about the level of our theoretical and practical knowledge.

Keywords: intervention radiological technology, education

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DILATIRANJE STENOZ POŽIRALNIKA

DILATION OF ESOPHAGEAL STENOSIS

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Uvod in namen: Stenoza požiralnika je zožitev požiralnika, ki nastane kot posledica intrinzičnih bolezni požiralnika ali različnih ekstrinzičnih bolezni in lahko vodi do motenj požiranja, neprijetnega občutka pri požiranju, občutka zastajanja hrane v požiralniku ter do izgube teže. Namen prispevka je predstaviti metode dilatacije požiralnika in prikazati podatke za posamezne metode.

Metode dela: Načini dilatiranja stenoz požiralnika so: balonska dilatacija, bužiranje in vstavitev stenta. Statistični podatki o posegih na Kliničnem institutu za radiologijo v Univerzitetnem kliničnem centru Ljubljana so prikazani za obdobje treh let in sicer od leta 2007 do leta 2009. Prvi način dilatiranja stenoz požiralnika je z dilatacijskim balonom. S pomočjo endoskopa preko stenoze uvedemo fleksibilno žico, nato endoskop odmaknemo in preko žice uvedemo balonski dilatator. Napihnemo ga na mestu zožitve in vbrizgamo vodotopno jodovo kontrastno sredstvo. Balonski dilatatorji so različnih dimenzij. Drugi način je s pomočjo bužijev. To so enostavni, radiopačni, fleksibilni dilatatorji različnih debelin. Uvedemo jih v požiralnik, najprej najtanjšega, nato postopoma do najdebelejšega, ki ga je še možno uvesti. To je najenostavnejša in najhitrejša metoda razširitve požiralnika. Včasih pa moramo v požiralnik namestiti stent. Indikacije za stentiranje so ezofagitične in kavstične zožitve požiralnika, neoperabilni karcinom požiralnika, ezofagotrahealne fistule, perforacije požiralnika in fistule na ezofago-gastrični anastomozi. Stentiranje požiralnika je lahko paliativno in terapevtsko. Uporabljamo plastične, žične in silikonske stente.

Rezultati in razprava: V obdobju od leta 2007 do 2009 je število preiskav na Institutu za radiologijo UKC Ljubljana naraščalo. Leta 2007 smo opravili 70 preiskav z dilatacijskim balonom, 60 z bužiji in 5 z vstavitvijo stentov. Leta 2008 je bilo 75 preiskav z dilatacijskim balonom, 70 z bužiji in 15 s stenti, leta 2009 pa 80 z dilatacijskim balonom, 90 z bužiji in 25 z vstavitvijo stentov. Poseg običajno ne traja več kot pol ure, po njem je malo bolečin, lahko ga naredimo v enodnevni bolnišnici, zapletov praktično ni in poseg lahko ponovimo.

***Zaključek*:** Po končanem dilatiranju stenoze požiralnika je potrebno bolnika spremljati, saj lahko le tako ugotovimo uspešnost zdravljenja in morebitno ponovitev zožitve. Število ponovitev je različno, glede na učinkovitost.

Ključne besede: požiralnik, stenoza, dilatiranje

Introduction and purpose: Esophageal stenosis is a narrowing of the esophagus which is caused by intrinsic diseases of the esophagus or different extrinsic diseases and can cause swallowing difficulties, discomfort during swallowing, feeling that food gets stuck in the esophagus and can lead to weight loss. The purpose of this article is to present methods of esophageal dilation and to share the information about each method.

Methods: Types of dilation esophageal stenosis: balloon dilatation, bougling and stent insertion. Statistical data are shown for a period of three years; from 2007 to 2009. The first method of dilation esophagus stenosis uses the balloon expansion. Firstly we put a flexible wire through the esophagus stenosis and then we remove the endoscope. The balloon dilator is put through the wire. We blow up the balloon dilator at the narrow point and inject water soluble iodinated contrast agent. There are different sizes of balloon dilators. The appropriate size is selected according to the size of esophageal stenosis. The other method uses the bougles. These are simple, radiopaque, flexible dilators with various thickness. They are inserted into the esophagus - in the beginning the thinnest and gradually the thickest that can still be inserted. This is the easiest and the quickest way to widen the esophagus. Sometimes, however, we have to use a stent. Indications for stent placement are inflammatory and corrosive esophageal structures, inoperable esophageal cancer, tracheoesophageal fistulas, esophageal perforation and fistulas on esophagogastric anastomosis. Stent placement can be used for palliation or for therapeutic purposes. Plastic, wire and silicon stents are used.

Results and discussion: From 2007 to 2009 the number of examinations increased. In the year 2007 we performed 70 investigations with the balloon dilation, 60 with bouglings and 5 with stents. In 2008 there were 75 investigations with the balloon dilation, 70 with bouglings and 15 with stents, in 2009 there were 80 investigations with the balloon dilatation, 90 with bouglings and 25 with stents. The procedure usually takes no more than 30 minutes and only minor pain can be experienced afterwards. It can be done in an outpatient clinic, there are practically no complications and the procedure can be repeated.

Conclusion: After carrying out the dilation of esophageal stenosis, it is necessary to monitor patient in order to determine whether the treatment was successful or not, and to detect if the strictures occur again. The number of repetitions changes with effectiveness.

Key words: esophagus, stenosis, dilation

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KLASIČNA ARTROGRAFIJA RAMENSKEGA SKLEPA

CONVENTIONAL SHOULDER ARTHROGRAPHY

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Uvod: Klasična artrografija ima tako diagnostični kot terapevtski pomen. Začele so jo dopolnjevati CT, MR in CT/MR artrografije (pri poškodbah mišic rotatorne manšete, nestabilnosti ramenskega sklepa, utesnitvenem sindromu) in UZ preiskava (za oceno lezij v labrumu glenoidale in sklepni kapsuli ter poškodbe sklepnega hrustanca).

Namen: Namen klasične artrografije je prikaz notranje površine sklepne ovojnice (za oceno poškodbe tetiv, vezi in ovojnic) in adhezivnega kapsulitisa z jodovim neionskim vodotopnim kontrastnim sredstvom (KS). Poseg omogoča odločanje o morebitni nadaljnji diagnostični obdelavi bolnika.

Metoda: Pacienta vprašamo o anamnezi in mu razložimo potek preiskave. Kontraindikacije so alergije na jod, zdravila in lokalni anestetik. Pacient leži na mizi na hrbtu, zaščiten je z gonadnim predpasnikom. Roko ima obteženo v zunanji rotaciji. Med preiskavo asistiramo zdravniku (priprava sterilnega seta, kontrasta, igle, obliža). Zdravnik sterilno očisti in pokrije ramo ter jo omrtviči z 2,5 ml Lidokaina. Z markerjem označi mesto vboda ter vbrizga 8 do 10 ml Iopamira 370. Po odstranitvi igle pacient razgiba ramo. Naredimo AP rentgenograme rame v supinaciji, pronaciji, abdukciji in addukciji. Na rentgenogramih morajo biti vidni: humeroskapularni sklep, lateralni tretjini ključnice, lateralni del lopatice, mišice rotatorne manšete. Pri normalnem artrogramu se s KS napolni celotna sklepna kapsula, lahko je vidno tudi področje bicepsa in subskapularne mišice.

Rezultati: Terapevtski pomen klasične artrografije je zdravljenje adhezivnega kapsulitisa. Pri sumu na poškodbo labruma ter prisotnosti prostih teles v sklepu opravimo CT artrografijo. Pri poškodbah hrustanca in mehkih tkiv naredimo MR artrografijo.

Zaključek: Klasična artrografija s KS je invazivna preiskava za prikaz notranje površine sklepne ovojnice, poškodbe ovojnic, tetiv in vezi.

Ključne besede: rotatorna manšeta, artrografija ramenskega sklepa, poškodbe rame.

Introduction: Conventional shoulder arthrography has both, diagnostical and therapeutical value. Computed tomography (CT), magnetic resonance imaging (MRI) - with and without arthrography techniques (rotator cuff injury, shoulder instability, compartment shoulder syndrome) are now being complemented with conventional arthrography and with ultrasound (US) (for the assessment of the shoulder joint, for evaluation of labral and articular capsule lesions and labral injuries).

Aim: The aim of conventional arthrography is to show the inner surface of the articular capsule (for the evaluation of tendon injuries of, ties and the articular capsule) and diagnosis of adhesive capsulitis with non-ionic iodine contrast media. This examination helps to determine the further diagnostic treatment of the patient.

Methods: For a successfully implemented procedure, it is very important that the patient is informed about the procedure. Contraindications are allergies on iodine contrast medium, medicines and local anaesthetic. The patient is positioned supine on the x-ray table and protected with gonads apron. The arm is in external rotation and fixed with a sandbag. During the procedure our job is to help the doctor (preparation of sterile kit, iodine contrast medium, needle, patch). The skin is disinfected, sterile covered and 2,5 ml Lidokain is applied. The position of puncture is marked with a metal marker, followed by the injection of 8 to 10 ml Iopamiro 370. After the needle removal, the shoulder is passively moved. Then we make arthrograms in AP position with the shoulder in supination, pronation, abduction and adduction. The humero-scapular joint, lateral thirds of clavicula, lateral part of scapula and muscles of rotator cuff must be seen on the arthrograms. In normal arthrograms contrast medium is seen in the whole articular capsule, as well as in the subscapular muscle and biceps area.

Results: The thrapeutic significance of conventional arthrography is treatment of adhesive capsulitis. In case of suspicion on the labrum injuries or for evaluation of loose bodies in the joint, a CT arthrography is performed. MRI arthrography is performed when we believe cartilage and soft tissue injuries are possible.

Conclusion: Conventional arthrography with contrast media is an invasive procedure, which shows us the inner surface and injuries of articular capsule, tendons and ties.

Key words: rotator cuff, shoulder arthrography, shoulder injury.

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LOKALIZACIJA NETIPLJIVIH LEZIJ V DOJKI – IZOTOP ALI ŽIČKA?

LOCALIZATION OF NON-PALPABLE BREAST LESIONS - ISOTOPE OR WIRE?

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Uvod in namen: Lokalizacija netipljive lezije v dojki na Onkološkem inštitutu v Ljubljani poteka na dva načina, pod rentgensko ali ultrazvočno kontrolo. Opisala bova prvi pristop. Pri rentgenski lokalizaciji uporabljamo izotop 99m Tc (ROLL - radioguided occult lesion localization) in metodo z žičko. Predstavila bova obe metodi in skušala ugotoviti ali je lokalizacija z žičko sama po sebi dovolj za učinkovito lokalizacijo lezije ter zakaj se v prvi vrsti odločamo za lokalizacijo z izotopom.

Metode dela: Kot metodi dela sta bili uporabljeni pregled slikovnega materiala in literature.

Rezultati: Lokalizacija z izotopom je učinkovita metoda za ekscizijo netipljivih lezij v dojki. S to metodo se lahko lezijo natančno razpoznamo v treh dimenzijah, kar omogoča natančnejši operativni poseg z minimalnim izrezom tkiva z varnostnim robom, to pa vodi v boljše estetske rezultate in manjše pooperativne zaplete. Pri lokalizaciji z žičko je vzorec odstranjenega tkiva večji, saj meje lezije niso dovolj jasne. Pri gostem, maščobnem tkivu ali pa zaradi premikov dojke lahko pri tej metodi pride tudi do premika žičke. Ne glede na to, kako dobro se lahko izvede ROLL, pa ne more v celoti nadomestiti žičke. V primeru večjih lezij, ob lokalizaciji dveh lezij v eni dojki ali pa zatekanju izotopa v mlečne vode, je tehnika z žičko še vedno potrebna.

Razprava: Obe metodi sta lahko uporabljeni samostojno ali po potrebi v kombinaciji ena z drugo. Odločitev o izboru metode sprejme zdravnik, ki poseg izvaja. Metodi sta trenutno najboljši način za natančno lokalizacijo netipljivih lezij v dojki.

Zaključek: Na podlagi praktičnih izkušenj pri lokalizaciji in končni informaciji, ki nam jo je dal kirurga po posegu, je bilo ugotovljeno, da lokalizacija z žičko sama po sebi ni zadostna metoda za učinkovito lokalizacijo in odstranitev netipljive lezije, predstavlja pa dopolnilno metodo pri lokalizacijah z izotopom, ko se lezija nahaja v ali ob mlečnih vodih ali pa ko lokaliziramo dve leziji, ki sta v isti dojki.

Ključne besede: netipljiva lezija, lokalizacija z žičko, izotop

Introduction and purpose: At the Oncology Institute of Ljubljana, the localization of non-palpable breast lesions is performed in two different ways, i.e. using x-ray or ultrasonic examination. We will describe the first approach. For x-ray localization we use the method with the isotope 99m Tc (ROLL – radio guided occult lesion localization) and the wire guided method. In this article we will explain both methods and try to determine whether the localization with the wire method is sufficient for the effective localization of lesions and why do we, in the first place, decided to use the method of localisation with the isotope.

Results: The localization with the isotope is an effective method for excision of non-palpable breast lesions. With this method a lesion can be precisely recognized in three dimensions, allowing us more precise surgical procedures with minimal tissue cutting and with a safety margin which leads us to a better aesthetic result and fewer post-operative complications. When using the wire method, the sample of removed tissue is bigger, since the boundaries of lesions in the sample are not sufficiently clear. If dense fat tissue is present or the breast is moved while using this method, the wire might move. Regardless of how well a ROLL can be performed, it cannot fully replace the wire. In case of major lesions, the localization of two lesions in one breast or the resorting of the isotope into milk ducts the wire technique is still necessary.

Discussion: Both methods can be used alone or combined. Physician who is in charge of examination decides about the method. Methods are currently the best way for exact localization of non-palpable breast lesions.

Conclusion: Based on practical experience during localization and the final pieces of information given by the surgeon after a surgery, it was established that the localization with the wire method alone is not sufficient for effective localization and removal of non-palpable lesions, however, it represents a supplementary method to localization with the isotope in cases where a lesion is located in or beside milk ducts, or if there are two lesions in the same breast.

Keywords: non-palpable lesion, localization with wire, isotope

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Slikovni arhiv Oddelka za radiologijo Onkološkega inštituta v Ljubljani

MAMOGRAFIJA IN MR DOJK

MAMMOGRAPHY AND BREAST MR

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Uvod: Rak dojk je najpogostejši rak žensk v razvitem svetu in pri nas. V Sloveniji zboli okoli 1100 žensk letno, kar kaže na rezultat, da se približujemo pojavnosti v razvitem svetu (100 na 100 000 žensk). Najpogostejša dejavnika tveganja sta dedna obremenjenost (v družini rak dojk, jajčnika, debelega črevesja ali prostate) in reproduktivni dejavniki (dolgotrajno jemanje kontracepcijskih tablet, ženske, ki niso rodile in/ali niso dojile). Mamografija je osnovna preiskava. Če pa mamografija in ultrazvok ne pojasnita sprememb, se zdravnik odloči še za MR dojk.

Metode dela: Mamografija - screening je zanesljiva in natančna metoda za ugotavljanje začetnih rakavih sprememb v dojki. Mamografija je rentgensko slikanje dojk, ki se uporablja za presejanje ali diagnostično pojasnitev tipičnih sprememb v dojki. Pri slikanju dojko stisnemo med dve plošči, vedno slikamo v dveh osnovnih projekcijah, od zgoraj navzdol (CC) ali od znotraj navzven (MLO). Pravilno pozicioniranje dojk v obeh standardnih projekcijah omogoča največji možen pregled tkiva dojk. Mamografija je najboljša metoda za odkrivanje raka dojk. Mamografska oprema mora zagotoviti majhne doze sevanja in kakovostne preglede. Dopolnilna metoda je magnetnoresonančno slikanje MR. Pri preiskavi z MR okrog dojke ustvarimo močno magnetno polje, ki vzbudi protone v vodikovih atomih vode, ki se v telesu nahajajo praktično v vseh strukturah. Med preiskavo intravensko vbrizgamo kontrastno sredstvo. Bolnica leži na trebuhu, dojki sta nameščeni v odprtino posebne tuljave, namenjene le preiskavi dojk. Slika se z različnimi sekvencami, pred in po intravenski aplikaciji kontrastnega sredstva.

Rezultati in razprava: MR je najbolj zanesljiva pri odkrivanju invazivnih duktalnih karcinomov in se je izkazala za najbolj občutljivo (98 – 100%), vendar slabše specifično, kar je tudi vzrok, da je njena uporabnost omejena le na določene indikacije. MR uporabljamo za:

- pojasnitev mamografsko vidnih sprememb,
- odkrivanje izvora bolezni pri metastazah v pazduhi,
- izključitev dodatnih tumorskih jeder pri potrjenem karcinomu in mamografsko nepreglednih dojkah.

Mamografija je zelo občutljiva in edina metoda za prikaz mikrokalcinacij. Je cenovno ugodna preiskava. Slabost mamografije je izpostavljenost rentgenskim žarkom in slabša občutljivost pri dojkah z veliko žleznega tkiva.
Prednosti MR preiskave so:

- je povsem neinvazivna in neškodljiva preiskava, ki ne vključuje izpostavljenosti ionizirajočemu sevanju,
- je precej dražja od mamografije, zato se uporablja le v primerih, ko obstaja verjetnost za razvoj rakastega obolenja.

V naši bolnišnici smo v letu 2011 opravili 3000 mamografij. Od tega se je zdravnik odločil, v povprečju pri vsaki 60 mamografiji (1,6%) še za MR dojk.
Primerjava obsežne mednarodne raziskave v ZDA in EU glede učinkovitosti mamografije in MR pri 968 bolnicah je pokazala, da je pri 30 ženskah tumor v drugi dojki odkrila MR, medtem ko ga mamografija ni zaznala. To pomeni, da so z mamografijo spregledali raka kar v 3% v raziskavo vključenih bolnic.

Zaključek: Delo radiološkega inženirja zahteva izkušene in izobražene radiološke inženirje, ki so opravili vsa potrebna izobraževanja in imajo za to delo tudi licenco. Radiološki inženir ima osrednjo vlogo pri izdelavi visokokakovostnih mamografskih slik. Poznavanje različnih preiskovalnih metod, zlasti presejevanje in MR, s katerimi poskušamo odkriti raka dojk ali pridobiti zanesljivo oceno katerekoli lezije v dojki, omogoča ugotavljanje te nevarne bolezni v zgodnejšem stadiju. To pripomore k boljšim rezultatom zdravljenja in je zato neprecenljivega pomena. V prihodnosti se bo MR preiskava dojk uporabljala tudi kot ena od presejevalnih metod za odkrivanje raka dojk pri ženskah s povečanim tveganjem in pri ženskah z močno družinsko obremenitvijo in brez dokazanih specifičnih genov.

Ključne besede: MR – magnetna resonanca, mamografija, rak dojk.

Introduction: Breast cancer is the most common cancer which affects women in the developed world and in Slovenia as well. Around 1100 women are diagnosed with breast cancer in Slovenia each year, meaning that we are approaching the developed world (100 per 100 000 women) in this field. The most common risk factors are hereditary (family anamnesis of breast, ovarian, colon or prostate cancer), and reproductive factors (long-term administration of contraceptive pills, non-birth, non-lactation). Mammography is a basic examination; however, if mammography and ultrasound do not explain the changes, the doctor may decide to continue with breast MR.

Methods: Mammography - screening is a reliable and accurate method for detecting early changes in the breast cancer. Mammography is an X-ray breast imaging used for screening or diagnostic clarification of the typical breast changes. During the imaging breast is squeezed between two plates. The imaging is always performed in two basic projections, from top to bottom (CC) or inside out (MLO). Proper positioning of the breast in two standard projections gives the best possible review of the breast tissue.

Mammography is the best method for detecting breast cancer. Mammographic equipment should provide a small radiation doses and quality checks.

Results and discussion: MR is a complementary method. During breast MRI examination a strong magnetic field is created, inducing protons in water's hydrogen atoms which are contained in virtually all tissues. During the examination, we inject contrast intravenously. The patient lies on the abdomen, breasts are placed in openings of special coils intended only for breast examination. The pictures are taken in different sequences before and after contrast application. The results: MR is the most reliable in detecting invasive carcinomas ductal, and proved to be the most sensitive (98 - 100%) but less specific, which is also the reason why its applicability is limited to specific indications. MR is used for:

- Clarification of mammographic changes
- Identifying the source of the armpit metastases
- Exclusion of additional tumor nuclei in cases where cancer is confirmed and no mammography has been performed yet.

Mammography is a very sensitive method and the only one which shows micro locations. It is inexpensive. The disadvantages of mammography are exposure to X-rays and low sensitivity of breast cancer detection in breast with a lot of glandular tissue.
MRI Has the following advantages:

- It is completely non-invasive and harmless investigation that does not involve exposure to ionizing radiation
- Very effective, but the examination is very expensive and for this only applies in cases where there is high certainty of cancer development.

In 2011 our hospital performed 3000 mammographies. The physicians decided for further MR examination in approx. every 60th mammography (1.6%).

Comparison of large international research on the effectiveness of mammography and MRI which was made in the U.S. and EU shows that from 968 patients there were 30 cases where tumors were detected by the MRI and were missed by the mammography. This means that the missed detection ratio of mammography amounts to 3% of the patients enrolled in the study.

Conclusion: The work and role of a radiological engineer requires experienced and qualified radiographers who have completed all necessary training and are licensed for this work. Radiological engineer plays a central role in producing high-quality mammography images. Of outmost importance is to acquire knowledge on different methods of examination, particularly screening and MRI, which both aim to detect breast cancer or to obtain a reliable estimate of any lesions in the breast, thus allowing detection of this dangerous disease in the early stages. This improves the results of treatment.
In the future the breast MR examination will be used as a screening method for detection of breast cancer in women with increased risk and unfavorable family anamnesis and no evidence of specific genes.

Key words: MRI - magnetic resonance imaging, mammography, breast cancer.

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MR ARTROGRAFIJA KOLKA PREDSTAVITEV PRIMERA

MR ARTHROGRAPHY OF THE HIP CASE REPORT

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Uvod: Artrografija je slikovna rentgenska metoda, pri kateri se uporablja kontrastno sredstvo za prikazovanje sklepov (ramenski, kolenski, kolčni, ...). MR artrografija je nadgradnja te preiskave, kjer poleg jodovega uporabimo še gadolinijevo kontrastno sredstvo. V UKC Mariboru tedensko poleg MR artrografij ramena opravimo dve MR artrografiji kolka.

Namen: Namen MR artografije kolka je prikazati morebitne poškodbe acetabularnega labruma. Te poškodbe so lahko idiopatske (ni znanega razloga) ali pa so posledice raznih športnih poškodb (subluksacij, dislokacij itd.).

Metode dela: 28 letna pacientka je že nekaj let tožila zaradi ponavljajoče se bolečine v desnem kolčnem sklepu. Bolečina se je pojavljala po daljši in napornejši hoji. Po naročilu ortopeda je pacientka opravila klasično slikanje kolka, kjer ni bilo videti bistvenih sprememb, nato pa MR slikanje kolka, ki tudi ni pokazalo bolezenskih sprememb. Zato je bila napotena na MR artrografijo; po lokalni anesteziji smo ji pod rentgensko kontrolo s punktirno iglo (G21 0,8 x 80) v kolčni sklep najprej vbrizgali 10 ml razredčenega jodovega kontrastnega sredstva, s katerim smo dokazali, da je igla v sklepu, nato pa 20 ml gadolinijevega kontrasta (Artirem). Po injiciranju kontrastnega sredstva smo jo slikali na MR aparatu GE Signa Excite HD 1.5T v T1 obteženi sekvenci z dušenjem maščobe v treh ravninah (T1 FAT SAT, AX., COR., SAG.).

Rezultati: MR artrografija kolka je v labrumu pokazala razpoko, zaradi katere je pacientka imela težave. Zato je bila napotena na Ortopedsko kliniko, kjer so ji z artroskopskim posegom zašili okvaro labruma.

Razprava: V primeru pacientke, smo s pomočjo MR artrografije dokazali poškodbo, ki je bila uspešno odpravljena.

Zaključek: Metoda slikovnega prikazovanja poškodb sklepnih struktur z MR pripomore, k njihovi natančnejši diagnostiki in hitrejšemu odpravljanju težav pacientov.

Ključne besede: atrografija, kolčni sklep, labrum acetabulare

Introduction: Arthrography is a type of x-ray examination that uses a contrast agent to image an anatomical joint (such as the shoulder, knee, hip, etc.). MR arthrography is an „upgrade“ of the classical arthrography, that uses a gadolinium type contrast. However classical arthrography is still inevitable. UKC Maribor performs two MR arthrographies of the hip joint per week.

Aim: The aim of this study is to show acetabular labral tears. These tears can be idiopathic or occure secondary to trauma, athletic activities, etc.

Methods: A 28 year old female patient complained about intra-articular hip pain in her right hip. She was sent from the orthopaedic specialist; First a classical x-ray of the hip, then an MRI scan of the hip was performed. These two methods did not show any pathological processes. Then a MR artrography was performed. Following a treatment with local anaesthetic the 21G needle was introduced into the hip joint via the anterior approach utilizing fluoroscopic guidance. Intra-articular positioning of the needle is confirmed with a solution of iodinated contrast material. After the arthrography, a MRI scan of the area was performed on a GE Signa Excite HD 1.5T in T1 weighted pulse sequences in the axial, sagittal and coronal plane utilizing frequency-selective fat suppression.

Results: The MR arthrography showed a ruptured labrum, therefore the female pacient was sent to the orthopedic clinic where a laparoscopic surgery was performed.

Discussion: In the case of this pacient, MR arthrography was used for the diagnostic of the injury whic was successfully mended.

Conclusion: We can conclude that MR arthrography has its benefits by contributing to the pacients well being.

Keywords: arthrography, hip joint, labrum acetabulare

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OBSEVANJE DOJKE IN SUPRAKLAVIKULARNE LOŽE S SKUPNIM IZOCENTROM – MONOIZOCENTER

BREAST RADIATION THERAPY AND SUPRACLAVICULAR FOSSA WITH ONE ISOCENTER – MONO-ISOCENTER

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Uvod: Z obsevalno tehniko monoizocenter se pri obsevanju dojke in supraklavikularne lože (SLC) zmanjša področje dozimetrijske negotovosti na stikih polj med mamarno regijo in SLC. Takšno tehnikouporabljamo, kadar je poleg mamarne regije potrebno obsevati tudi bezgavke v vratu in če obsevalno polje za dojko ne presega dolžine 20 cm.

Namen: Na praktičnem primeru je predstavljen nov način obsevanja dojk in SCL lože ter prednosti te tehnike.

Metode dela: Tehnika temelji na stikih polj in natančno vrisanih tarčnih volumnih. Za čim natančnejše obsevanje se je priprava na obsevanje na simulatorju dopolnila s posebnim načinom fiksacije, z obrazno masko, ki je na področju obsevanja dojke novost.

Rezultati: Pri tej obsevalni tehniki dojke in SCL se polja stikajo v izocentru, in sicer se dojka obseva od izocentra navzdol, SCL paod izocentra navzgor. Ustreznost obsevalnega polja določamo s pravilnim zapiranjem čeljusti in s pravilno obrnjenim kolimatorjem v linearnem pospeševalniku. Dozni predpis za obe obsevalni področji mora biti enak, in sicer 25 x 2Gy = 50Gy in mora zagotavljati restrikcije na področjih srca in pljučnega krilana obsevani straniter hrbtenjače.

Razprava: Tehnika obsevanja dojke in supraklavikularne lože z monoizocentrom je sprejemljiva, varna, hitra, enostavna in smo jo sposobni izvajati s svojo opremo in osebjem. V primerjavi s konvencionalnim načinom obsevanja nam omogoča natančnejši nadzor porazdelitev doz na stikih polj med mamarno regijo in SCL-jem.

Zaključek: Obsevalna tehnika monoizocenter omogoča pri obsevanju dojke in SCL z enim obsevalnim planom natančno porazdelitev obsevalne doze in boljšo fiksacijo pacienta ter je časovno krajša od konvencionalnega načina obsevanja.

Ključne besede: obsevanje, dojka, supraklavikularna loža, monoizocenter, obrazna mask

Introduction: With mono-isocentric radiation technique for breast radiation therapy and supraclavicular fossa we decrease dosimetric uncertainty in areas where treatment fields of breast and supraclavicular fossa (SCL) are joined from edge to edge. We choose this technique, when we have to treat both breast and supraclavicular lymph nodes at the same time and when the treatment field of the breast doesn't exceed the length of 20 cm.

Purpose: This practical presentation introduces the new technique in breast radiotherapy and SCL fossa and its advantages.

Methods: This technique is based on strict planning tumour target volumes. To get most accurate results, the preparation on a radiation therapy simulation was supplemented with a special fixation i.e. face mask, which is a novelty in breast radiotherapy.

Results: With such technique in breast radiotherapy and SCL fossa the treatment fields are joining at the isocenter, where the breast is treated below the isocenter - caudally and the SCL above the isocenter - cranially. The correct treatment field is defined by moving jaws and collimator of a linear accelerator and depends on which breast we treat. Dose prescription for breast and SCL fossa must be equal for both, 25 x 2 Gy = 50 Gy and must not exceed the restrictions for heart, individual lungs and medulla.

Discussion: Breast and SCL radiotherapy technique with mono-isocenter is adequate, safe, fast and easy. We are able to utilize it with our own equipment and staff. Compared to conventional radiation technique it allows better control in dose distribution between breast and SCL field edges.

Conclusion: Monoisocentric radiation technique in breast radiotherapy and SCL enables strict radiation treatment dose, better fixation of the patient and is faster than classical breast radiotherapy and SCL with SSD (source-skin distance) technique.

Key Words: radiation therapy, breast, supraclavicular fossa, monoisocenter, face mask

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POVEČANA RAZDALJA GORIŠČE-SLIKOVNI SPREJEMNIK ZMANJŠA VSTOPNO KOŽNO DOZO

INCREASING SOURCE-TO-IMAGE-RECEPTOR DISTANCE REDUCES ENTRANCE SURFACE DOSE

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Uvod: Pri optimizaciji radioloških posegov uporabljamo veliko različnih tehnik in materialov. Ker doza ionizirajočega sevanja pada s kvadratom razdalje, bi lahko zmanjšali prejeto dozo na pacienta, če bi povečali razdaljo gorišče-slikovni sprejemnik.

Namen: Ugotoviti ali se pri slikanju urotrakta ob povečani razdalji gorišče-slikovni sprejemnik zmanjša vstopna kožna doza sevanja in ali povečanje razdalje vpliva na kakovost rentgenograma.

Materiali in metode: Meritve so potekale na dveh rentgenskih aparatih; SIEMENS Siregraph D2 (meritve na 115, 130 in 150 cm od gorišča) z AGFA CR ploščami in na digitalnem aparatu Luminos dRF (meritve na 115in 150 cm od gorišča). Fantom celega telesa PBU 60 (165 cm, 50 kg), vstopna kožna doza je bila merjena s Patient Skin dozimetrom (Unfors). Velikost polja je bila 43 × 30 cm. Kakovost slik so na podlagi evropskih smernic (EUR 16260) ocenili trije radiološki inženirji.

Rezultati in razprava: Vstopna kožna doza sevanja se je pri povečanju razdalje iz 115 cm na 130 cm zmanjšala za 16% in pri povečanju na 150 cm pa za 22%. Digitalni aparat ne dopušča zaustavitve cevi na višini 130 cm, zato sva opravila meritvi na razdaljah 115 cm in 150 cm od gorišča do detektorja; doza je bila na razdalji 150 cm manjša za 15%. Kvaliteta slik je vedno ostala skladna z evropskimi smernicami. Zaradi potrebnih višjih vrednosti kV in mAs produkta pri povečani razdalji bi sprva pričakovali, da bo vstopna kožna doza višja; zaradi zakona o spremembi intenzitete sevanja v odvisnosti od kvadrata razdalje, pa je vstopna kožna doza kljub višjim ekspozicijskim vrednostim manjša.

Zaključek: Zmanjšanje prejete doze pri CR plošči in digitalnem detektorju na razdalji 150 cm od sprejemnika ni bila enaka; pri CR plošči je bil 22%, pri detektorju pa 15%. Oba rezultata pa znatno znižata prejeto dozo, zato priporočava nadaljevanje raziskave na pacientih.

Ključne besede: optimizacija protokolov slikanja, slikanje urotrakta, zniževanje dozne obremenitve

Introduction: Many techniques or materials can be used for the optimization of radiological procedures. Based on the principle that x-ray beam intensity decreases with the square of the distance from the source, the enlargement of the source-to-image-receptor distance (SID) decreases the patient dose.

Purpose: The purpose of the study was to determine if the increase of the SID reduces entrance surface dose (ESD) for the plain urogenital image and how this affects the image quality.

Methods: The measurements were made in two different departments using two different x-ray devices; the first one was SIEMENS Siregraph D2 (measurements were made at 115, 130 and 150 cm SID) with an AGFA CR image receptor; the second one was Luminos dRF with DR image receptor (115 and 150 cm SID). A whole body phantom PBU 60 (Kyotokagaku Co., Ltd, Japan), simulating a man of 165 cm and 50 kg was used. ESD was measured with Patient Skin Dosimeter (PSD) (Unfors, Sweden). The image quality assessment was made by three radiographers according to the European guidelines (EUR 16260).

Results and discussion: ESD with SID of 130 cm instead of 115 cm has decreased for 16%, and SID of 150 cm results in the decrease of 22%. Because the Luminos dRF with DR image receptor does not allow 130 cm SID the measurement was made with the SID of 115 and 150 cm only. The ESD has decreased for 15% when using the 150 cm SID instead of 115 cm SID. There was no significant difference in image quality. Because of the increase of the exposure parameters due to the increased SID, one could expect the increase of ESD. Because the x-ray beam intensity decreases with the square of the distance from the source, the ESD has decreased even though the exposure parameters were higher.

Conclusion: The decrease of the ESD which occurred when CR image plates were used with the SID of 150 cm was not the same as with DR image receptor; There was still a significant decrease of 22% in CR and 15% in DR. Regarding the results and reduction of the dose we recommend further investigation of this study on patients.

Key words: protocol optimization, plain urogenital image, radiation dose

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RADIOLOŠKI DIAGNOSTIČNI POSTOPKI PRI ASEPTIČNI NEKROZI GLAVE STEGNENICE

RADIOLOGICAL DIAGNOSTIC PROCEDURES IN ASEPTICAL NECROSIS OF FEMORAL HEAD

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Uvod: Pri aseptični nekrozi glave stegnenice gre za propad kostnega tkiva zaradi motnje v prekrvavitvi kosti, kar vodi do sesedanja hrustanca v sklepu, ki tako postane nefunkcionalen.
Bolezen se praviloma prične z razvojem bolečin v prizadetem sklepu, ki so hujše v nočnem času in v mirovanju. Pogosto prizadene bolnike, ki uporabljajo glukokortikoide in dializne bolnike, pa tudi pa tudi alkoholike in druge paciente z jetrno cirozo, itd.

Metode dela: Dopolnjujoče radiološke preiskave za odkrivanje in diagnostiko nekroze stegnenične glave so:
Prva in najpomembnejša preiskava je magnetna resonanca (MR) kolka. Navado se opravi s T1, T2, STIR in PROTONSKO obteženimi slikami. Tako lahko bolezen dovolj zgodaj odkrijemo in tudi potrdimo. Če magnetna resonanca ni na voljo si lahko pomagamo tudi s scintigrafijo skeleta.
Rentgenogram medenice: Čeprav ga zaradi dostopnosti in cene pogosto uporabljamo, je v zgodnji fazi bolezni neuporaben, saj bolezen še ni prizadela kostne strukture. V napredovalih fazah rentgenogram medenice za postavitev diagnoze zadostuje.
Scintigrafija kolkov je preiskava, ki lahko dokaj zgodaj da jasno sliko motnje v prekrvavitvi kostnega tkiva glave stegnenice, ki kasneje lahko privede do aseptične nekroze. Vendar je dostikrat nezanesljiva.
Računalniška tomografija je preiskava, ki se s pojavom magnetne resonance pri sumu na to diagnozo vedno redkeje uporablja.

Rezultati in razprava: Obstaja vrsta diagnostičnih postopkov za čim zgodnejše in čim natančnejše odkrivanje aseptične nekroze glave stegnenice. Med pomembnejšimi so radiološki diagnostični posegi, pri katerih ima inženir radiologije ključno vlogo. Kot najprimernejša preiskava za odkrivanje aseptične nekroze glave stegnenice se je izkazala MR, vendar pa mora biti izvedena dovolj zgodaj. V tem primeru že sama po sebi da dovolj informacij za uspešno zdravljenje. Kadar pa je diagnostičnih podatkov premalo, jo kombiniramo z scintigrafijo in rentgenogramom kolka.

Zaključek: Ne glede na to, za kakšno bolezen ali poškodbo gre, radiološki diagnostični postopki so in bodo eni izmed pomembnejših, če ne celo najpomembnejši, pri odkrivanju in dokazovanju in v nekaterih primerih tudi zdravljenju poškodb in bolezni. V procesu diagnostike in terapije zato postaja tudi vloga inženirja radiologije vedno bolj pomembna.

Ključne besede: slikovna diagnostika, NMR - nuklearno magnetna resonanca, scintigrafija

Introduction: In the case of aseptic necrosis or osteonecrosis of femoral head, the bone tissue collapses because of blood circulation disorders in bone, leading to subsidence of cartilage in the joint thus making it non-functional. The disease usually begins with pain in the affected part of the joint, which is worse at night time and during rest. In most cases patients using corticosteroids and dialysis are affected.

Methods: Complementary radiological diagnostics are:

- First and foremost investigation of hip is Magnetic Resonance. It can detect the disease early enough and confirm the diagnosis. If MRI is unavailable in short time or the data is insufficient, we can use the skeletal scintigraphy.
- Native pelvic X-ray. Although it is often used for convenience, the X-ray examination is not efficient in the early stages of the disease because images show no irregularities. At this stage disease has not affected the bone structure yet. In the advanced stages the native X-ray is usually sufficient for diagnosis.
- Hip Scintigraphy give us early picture of the blood supply disruption in the head bone of femur, which may subsequently lead to aseptic necrosis; However, because of different processes which take place in the body, the examination is sometimes unreliable.
- Computed Tomography is the investigation, which is becoming increasingly obsolete with the appearance of MRI.

Results and discussion: There are a number of diagnostic procedures which detect the aseptic necrosis of femoral head as early as possible and most accurately. The key tools are certainly radiological diagnostic procedures, which may, if performed properly and accurately, give enough data for the detection and treatment of disease. In these procedures the radiological engineer plays a key role. The most appropriate investigation in the process of detection and treatment of aseptic necrosis femoral head has proven to be NMR, but it must be carried out early and with required quality. In this case we have sufficient information for successful treatment; However in case of insufficient diagnostic data we must combine it with additional radiological examinations.

Conclusion: Irrespective of the type of illness or injury, radiological diagnostic procedures will be one of the most important, if not the most important in detecting and proving injury and illness. In the process of diagnostic and therapy the radiological engineer has an increasingly important role.

Key words: NMR – nuclear magnetic resonance or shorter MR magnetic resonance, scintigraphy

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RAZLIKA OBSEVANOSTI PACINETOV PRI ANALOGNI IN DIGITALNI INTRAORALNI RADIOGRAFIJI

DIFFERENCE IN RADIATION DOSE BETWEEN ANALOG AND DIGITAL INTRAORAL DENTAL RADIOGRAPHY

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Uvod: Uporaba digitalnih detektorjev pri intraoralnem slikanju v stomatološki diagnostiki lahko zmanjša ekspozicijski čas, kar zmanjša tudi obsevanost pacientov.

Namen: Namen raziskave je ugotoviti, kakšne so razlike med vstopno kožno dozo (VKD) pri analogni in digitalni intraoralni radiografiji.

Materiali in metode: Meritve so bile izvedene na štirih stomatoloških diagnostikah, od tega dve diagnostiki uporabljata digitalne detektorje, drugi dve pa analogni sistem. Uporabljen je bil fantomu glave RS-108T (Radiology support devices inc., CA, USA), ki simulira pacienta, visokega 175 cm z maso 74 kg. VKD sem meril s pomočjo Patient Skin Dosimetra (PSD) (Unfors, Sweden). Meritve so bile izvedene v obeh čeljustih za vsako skupino zob (sekalci, podočniki, ličniki in kočniki) posebej. Uporabljeni so bili isti ekspozicijski pogoji, kot jih uporablja diagnostika, kjer sem izvajal meritve.

Rezultati: VKD se je v zgornji čeljusti pri uporabi digitalnih intraoralnih detektorjev v povprečju zmanjšala za ~56%, v spodnji čeljusti pa za ~51%. Največje zmanjšanje pri uporabi digitalnih detektorjev je bilo v področju kočnika v zgornji čeljusti, saj se je VKD zmanjšala iz 3,01 mGy na 0,94 mGy oz. za ~69%. Najmanjše zmanjšanje pa je bilo v področju podočnika v spodnji čeljusti, kjer se je VKD zmanjšala iz 1,71 mGy na 0,80 mGy oz. za ~50%.

Razprava: Rezultati sovpadajo z rezultati iz drugih raziskav, saj rezultati podobnih raziskav kažejo, da se VKD pri uporabi digitalnih detektorjev zmanjša od 31% do 60 %.

Zaključek: Pri intaraoralnem slikanju je priporočljiva uporablja digitalnih detektorjev, saj se VKD v primerjavi z analognim sistemom v povprečju zmanjša za približno polovico.

Ključne besede: intraoralna radiografija, digitalna radiografija, stomatološka diagnostika,

Introduction: The use of digital detectors in intraoral dental radiography can reduce exposure time which reduces the radiation dose for the patient.

Aim: The aim of the study was to determine the difference in entrance surface dose (ESD) between analogue and digital intraoral dental radiography.

Methods: The ESD was measured in four different stomatology departments. Two of them use analogue detectors and the other two digital detectors. The measurements were made on the head phantom (RS-108T) that simulates patient with 175 cm and 74 kg (Radiology support devices inc., CA, USA). ESD was measured with Patient Skin Dosimeter (PSD) (Unfors, Sweden). The measurements were made in both jaws for each group of teeth (incisors, canines, premolars and molars). The exposure parameters were the same parameters that are used in standard protocol of each department.

Results: On average the ESD in the upper jaw was reduced for approximately 56% and in the lower jaw the ESD was reduced for approximately 51%, in the departments where digital detectors are used. The highest dose reduction from 3.01 mGy to 0.94 mGy (~69%) in favour of digital detectors was recorded by the upper jaw molars. The lowest reduction from 1.71 mGy to 0.80 mGy (~50%) in favor of digital detectors was for recorded in the lower jaw canines

Discussion: Results correspond with the results from other researches, which show the ESD reduction of approximately 31% to 60% with the use of digital intraoral detectors.

Conclusion: According to the results we can conclude that the use of digital intraoral detectors can reduce the ESD for approximately 50% in comparison with analogue detectors.

Key words: intraoral dental radiography, digital radiography, dental imaging

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RENTGENSKA PREISKAVA POŽIRALNIKA ZA PRIKAZ ZENKERJEVEGA DIVERTIKLA

ZENKER'S DIVERTICULUM – X-RAY EXAMINATION OF THE ESOPHAGUS

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Uvod: Zenkerjev divertikel je vrečasta lokalna izboklina, ki nastane v zadnji požiralnikovi steni med spodnjim žrelom in požiralnikom. V njem zastaja in gnije hrana. Ločimo pulzijske in trakcijske divertikle. Kadar zaradi povečanega tlaka v steni požiralnika nastane izboklina v sluznici, govorimo o zenkerjevem divertiklu (pulzijski).

Namen: Predstaviti rentgensko preiskavo požiralnika pri pacientu z zenkerjevim divertiklom, vlogo radiološkega inženirja pri njej ter načine zdravljenja te bolezni.

Metode dela: Pacient pride na preiskavo po predhodnem pregledu pri specialistu. Indikacije za preiskavo so občutek zastajanja hrane, težko požiranje, vračanje hrane, bruhanje in redko tudi bolečina. Na Inštitutu za radiologijo prikažemo s pomočjo rentgenskega aparata, Axiom Iconos R200 Siemens, pretok kontrastnega sredstva (barijev sulfat) skozi požiralnik in zastoj v divertiklu. Radiološki inženir pripravi aparat, pacienta in kontrastno sredstvo. Med preiskavo prilagaja ekspozicijske pogoje ter poskrbi za obdelavo in pravilno arhiviranje slik po njej. Preiskavo opravi zdravnik radiolog, ki pod diaskopijo opazuje potek kontrasta. Najprej se naredita posnetka žrela in zgornjega dela požiralnika stoje, v anteroposteriorni in stranski projekciji, nato pa še na sliki v ležečem polstranskem položaju prikažemo prehod požiralnika v želodec.

Rezultati in razprava: Po zaključeni diagnostiki, ki vključuje rentgensko preiskavo, ezofagogastroskopijo z biopsijo in manometrijo požiralnika, pacienta z zenkerjevim divertiklom zdravijo s krikofaringotomijo, divertikulektomijo ali divertikulopeksijo. Na Kliničnem oddelku za torakalno kirurgijo so v treh letih (2006 do 2008) endoskopsko operirali 27 bolnikov. Pet bolnikov (19%) je imelo po operaciji še vedno disfagijo, pri štirih (15%) pa se je ponovno pojavil divertikel, večji kot 2 cm. Vse so še enkrat operirali v času od 2 do 84 mesecev (srednja vrednost 19,4 mesece) po prvi operaciji.

Zaključek: Z rentgensko kontrastno preiskavo požiralnika določimo velikost in lego zenkerjevega divertikla, kar je pomemben dejavnik za nadaljnjo obravnavo pacienta. Endoskopske operacije zenkerjevega divertikla so skoraj izpodrinile transcervikalne. Reoperacije so možne in tudi uspešne.

Ključne besede: Zenkerjev divertikel, rentgensko slikanje požiralnika, disfagija, endoskopska operacija

Introduction: Zenker's diverticulum is a bulge of mucosa in the pharynx, just above the cricopharyngeal muscle. When the pressure within the lower pharynx is too large, the weakest portion of the pharyngeal wall balloons out, forming a diverticulum, which may reach a diameter of several centimetres.

Aim: The purpose of this paper is to present the X-ray examination of the esophagus on a patient with Zenker's diverticulum, the role of the radiological engineer and methods of treatment.

Methods: The patient comes to an x-ray examination following a previous examination by a specialist. Zenker's diverticulum often causes clinical manifestations such as dysphagia (difficulty swallowing), retention of food, reflux, vomiting and occasional pain. At the Institute of Radiology, we observe the flow of contrast medium (barium sulphate) through the esophagus with the help of an x-ray machine i.e. Siemens Axiom Iconos R200. The radiological engineer prepares the x-ray machine, the patient and the contrast medium. The examination is performed by the radiologist. He observes the movement of the contrast medium through the esophagus with the help of x-rays and takes x-ray images. The patient is standing and lying on his back or stomach. As the patient swallows the barium suspension, it coats the esophagus with a thin layer of the barium and reveals the diverticulum.

Results and discussion: Following the examinations such as gastroscopy and esophageal manometry, the patient is sent to the endoscopic surgery. Within three years (2006 – 2008) the Clinic for thoracic surgery have treated 27 patients with endoscopic surgery. Five of these patients (19%) still suffered from dysphagia after the surgery, four of them (15%) still had diverticulum. All of them have to undergo another surgery in the time period between 2 and 84 months.

Conclusion: The purpose of the x- ray investigation is to determine the size and the location of diverticulum, which is an important factor for further consideration. Trans-cervical surgery procedures have been replaced by endoscopic surgery. Re-operations are possible and successful.

Key words: Zenker's diverticulum, X-ray of the esophagus, dysphagia, endoscopic surgery

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ULTRASONOGRAPHERS' UNDERSTANDING OF CHILD PROTECTION GUIDELINES: A COMPARATIVE STUDY BETWEEN MIDWIVES AND RADIOGRAPHERS PERFORMING FOETAL ULTRASOUND

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Introduction: Midwives and radiographers have a sensitive role in child protection. In the clinical setting, they are in a strong position to detect any foetal maltreatment and observe behaviours of family members. Understanding child protection guidelines aids in relevant procedures in child protection and safety.

Hypotheses: 1. Midwives have a more detailed knowledge of child protection than radiographers. 2. Radiographers view themselves as having a limited role in child protection compared to midwives. 3. Radiographers are more confident than midwives to report suspected child abuse.

Method: A questionnaire was developed, validated and pilot tested. Subjects were selected using purposive sampling. Eight interviews were conducted over a 3 week period. The sample was taken from a maternity hospital in Dublin, Ireland. The research underwent ethical exemption from UCD Human Research Ethics Committee.

Results: Both midwives (2 in 5) and radiographers (1 in 3) demonstrated poor knowledge of child protection guidelines yet they felt confident to report child abuse. Only 2 in 5 midwives and 1 in 3 radiographers received previous training in child protection.

Discussion: It is apparent that midwives and radiographers are viewed as having a role in child protection. According to the Children First, National Guidelines for the Protection and Welfare of Children (1999), radiographers are appointed as designated officers of health boards to report suspected child abuse. However, midwives were not mentioned as being included in the list of designated officers. According to the results, few midwives and radiographers voiced that they felt the need to have clear and well defined guidelines for ultrasound with regards to how they should report child protection concerns or how to deal with the family perceived to be at risk.

Conclusion: Although this was a small study it highlighted the importance of child protection training among these healthcare professionals. Neither midwives nor radiographers had detailed knowledge of child protection guidelines. Both healthcare professionals saw as their role in protecting the unborn if abuse was suspected. Midwives appeared to be more confident in reporting child abuse.

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UPORABA NAPRAVE TELOS STRESS DEVICE ZA DIGITALNO FUNKCIONALNO SLIKANJE Z OBREMENITVIJO SKLEPOV

USING THE TELOS STRESS DEVICE FOR DIGITAL FUNCTIONAL IMAGING OF JOINTS UNDER LOAD

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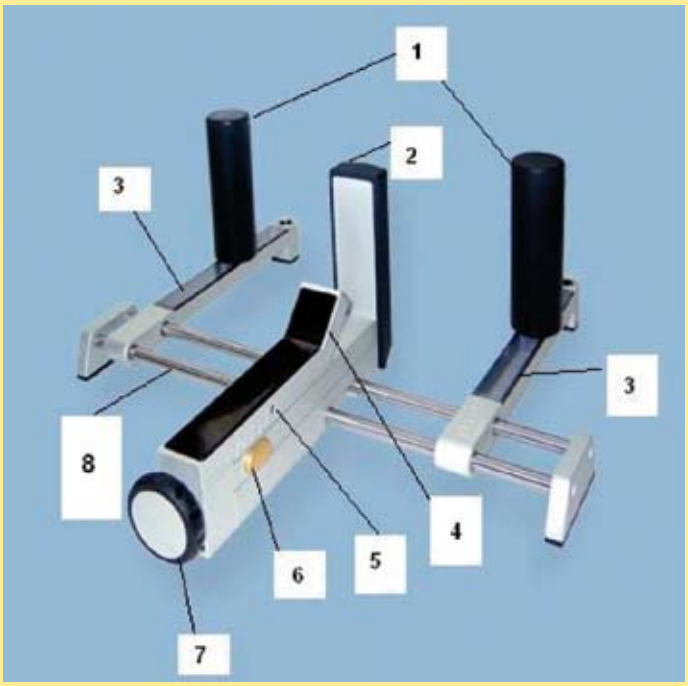
Uvod: Z napravo Telos lahko slikamo kolenske vezi, vezi v zgornjem in spodnjem skočnem sklepu, naprava pa pokaže tudi funkcije vezi oziroma funkcije kite. Napravo poznamo pod imenom »Telos Stress Device«. Nekateri uporabljajo za slikanje na tej napravi »stress« posnetke ali funkcionalno slikanje.

Namen: Ocene poškodbe vezi (kolenske vezi, vezi zgornjega in spodnjega skočnega sklepa) in vezi stopala v funkciji, ki jih ne dobimo s klasičnimi rentgenskimi posnetki.

Metode dela: Da napravimo optimalni rentgenogram, moramo med slikanjem z nadzorovano obremenitvijo z določeno silo pritiskati na določeno mesto na sklepu, da prikažemo stabilnost ali nestabilnost vezi. S tem preverimo morebitne premike v sklepih. Sklep pred slikanjem pustimo pod obremenitvijo 1 minuto. Za vsak prikaz vsake vezi sta projekcija in metoda dela določeni. Na sklep navadno pritiskamo s silo 15 kp.

Rezultati: S pravilnim slikanjem na napravi in z nadzorovano obremenitvijo lahko prikažemo spremembe na vezeh (nestabilnost sklepa). Z digitalnimi metodami zajema in obdelave slike lahko rentgenogram popravljamo. Prikazujemo lahko samo sklep in nakažemo, kje smo pritiskali ter na sliki označimo, s kakšno silo smo obremenitev izvedli.

Razprava: Pred uporabo naprave Telos so obremenitev med slikanjem izvajali zdravniki (specialisti), vendar sila obremenitve ni bila natančna. Pri preiskavah smo tako poleg pacienta obsevali tudi zdravnika, ki je sklep držal. Doza je pri digitalnem slikanju manjša, prav tako lahko zmanjšamo ekspozicijske pogoje in še vedno dobimo optimalen rentgenogram.



Slika 1: Telos naprava - 1 Okrogli blazinici za utrditev noge, 2 Sprednja blazinica , 3 Stranski osi, 4 Digitalni čitalec, 5 Priključek za polnitev baterije, 6 Gumb za sprostitev pritiska, 7 Gumb za navijanje, 8 Okvir (vir: http://www.google.si/imgres?q=telos+naprava&um)

Zaključek: Gre za funkcionalni prikaz vezi, ki nam ga omogoča naprava, s katero obremenjujemo ciljani sklep. Ugotavljamo, da je prednost digitalnega slikanja v tem, da se izognemo nepotrebnemu dodatnemu slikanju, s čimer se zmanjša sevalna obremenitev pacienta. Radiološki inženir in zdravnik sliko vidita takoj. Zdravnik se tako lahko hitreje odloči za morebitne dodatne projekcije, ki dajo več informacij za nadaljnjo diagnozo.

Ključne besede: slikanje, rentgenski posnetek, naprava Telos, rentgenogram, sklep, vezi, funkcionalno slikanje.
Introduction: With Telos device we can produce X- ray scanning of a knee brace, ties in upper and lower ankle joint as well as the function of ligaments and ties. Device is known as » Telos Stress Device«. Some use the imaging device for »stress« recordings or functional imaging.

Purpose: Estimation of tie injury (knee brace, ties in upper and lower ankle joint) and foot tie in function which is not possible with the classic X- ray scan.

Methods: If we want to make an optical roentgenogram we have to use controlled load and apply exact force on pre-defined spot on the joint, so we can show the stability or instability of ties. This way we check possible joints movements. One minute load on joint before X- ray scanning is permitted. For each tie review there are defined projection and work methods. The force of 15 kp is applied to the joint.

Results: With correct X- ray scanning and with controlled load we can show tie changes (instability of joint). Digital imaging methods and scan handling allow us to repair roentgenogram. It is possible to show just the joint and then to indicate where we have applied the force and afterwards mark on the scan the amount of force which was used to apply the desired load.

Discussion: Before using the Telos device physicians (specialists) applied load during scanning, but the applied force was never correct. During examination the doctor who held the joint was exposed to X-ray radiation together with patient. Dose is smaller in digital scanning and we can also reduce exposure and still get optical roentgenogram in the end.

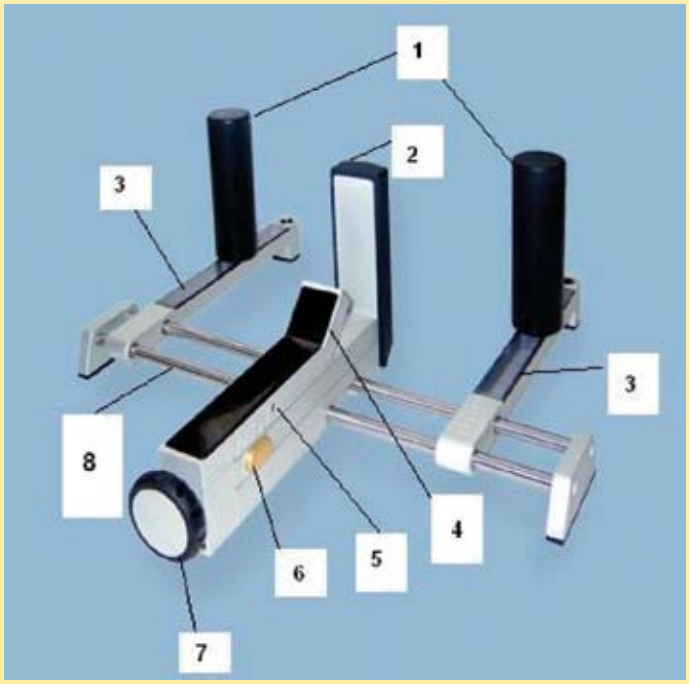


Fig. 1: Telos device - 1 Round cushions for leg imobilization, 2 Front cushion pad, 3 Lateral (side) axles, 4. Digital display, 5 Battery charge socket, 6 Load release button, 7 Rotating bottom, 8 Frame (source: http://www.google.si/imgres?q=telos+naprava&um)

Conclusion: By applying the load to the examined joint through the above device, the functional examination of ties is feasible.
The advantage of digital scanning is that we avoid unnecessary additional scanning thus reducing the radiation level for the patient. Radiologist (physician) and radiological engineer immediately see the scan. Physician can quickly decide for additional projection which may give more information required for further diagnosis.

Key words: X- ray scanning, X- ray scan, Telos device, roentgenogram, joint, ties, functional imaging.

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VLOGA RADIOLOŠKEGA INŽENIRJA PRI SLIKANJU KOLKA V OPERACIJSKEM BLOKU

ROLE OF RADIOGRAPHER IN THE HIP X-RAY IMAGING WITHIN THE OPERATING ROOM

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Uvod: Ena izmed nalog, ki jih opravlja radiološki inženir v operacijskem bloku je slikanje pri operaciji kolka. V operacijskem bloku splošne bolnišnice Murska Sobota uporabljamo rentgenski aparat s C-lokom znamke Siemens, s katerim je mogoče slikati in diaskopirati, slike pa lahko tudi obdelujemo in tiskamo. Na leto sodelujemo pri okoli 500 operacijah kolka, vendar se operacije ne izvajajo vsak dan. Delo je timsko. Radiološki inženir je pomemben del ekipe, saj brez rentgenskega slikanja ali diaskopije operater težko izvede operacijo.

Namen: Prikazati želimo, kako zahtevno in pomembno je delo radiološkega inženirja pri slikanju kolka v operacijskem bloku.

Metode dela: Radiološki inženir mora pred vstopom v operacijski blok upoštevati načela sterilnosti (obleče zaščitna oblačila, razkuži roke, obvezna je uporaba maske in kape). Njegovo delo se začne že takrat, ko pacienta pripravljajo za operacijo; rentgenski aparat namesti v pravilni položaj, glede na položaj pacienta. Pri operaciji mora upoštevati navodila, ki mu jih daje operater. Poleg rutinskih posegov (standardno vstavljanje osteosintetskega materiala) se v operacijskem bloku srečujemo tudi z bolj specialnimi ortopedskimi posegi, ki pa niso rutinski in se jim moramo vedno znova prilagoditi. Prav pri teh posegih moramo uporabiti vse svoje znanje in iznajdljivost, da zagotovimo kvaliteten rentgenogram ob najmanjši izpostavljenosti (ekipe in pacienta) sevanju.

Rezultati: Kvaliteten radiogram, diaskopija in strokovno izkušen radiološki inženir, pripomorejo da operater delo opravi lažje in brezhibno. Zelo pomembna je prilagodljivost radiološkega inženirja, saj dela z različnimi operaterji, ki imajo vsak svoj način dela. Danes nam sodobna digitalna tehnologija omogoča lažje delo.

Razprava: Operacije kolka ni mogoče izvesti brez diaskopije, kar kaže na pomen vloge radiološkega inženirja.

Zaključek: Pri vsakdanjem delu v operacijskem bloku se radiološki inženir srečuje s standardnimi in tudi nepredvidljivimi okoliščinami, ne glede na to pa mora narediti projekcijsko in ekspozicijsko ustrezno sliko.

Ključne besede: operacijski blok, slikanje kolka, radiološki inženir.

Introduction: One of the tasks performed by the radiological engineer is taking x-ray images in the operating block. Our hospital (General Hospital Murska Sobota) uses Simens C-lok X-ray machine for taking x-ray images.

The machine is designed for taking x-ray images and fluoroscopy as well as processing and printing x-ray images. Engineer that works in the operating block has also other tasks. Taking x-ray images of lungs at the intensive units EIIT (Department of Internal Intensive Therapy) and REA (Department of Perioperative Medicine) as well as data input, accounting in BIRPIS as well as allocation of images to hospital units.

Purpose: Our aim is to show the complexity and importance of radiographers' tasks in the operation block.

Methods: Work of radiological engineer in the operating block depends on a schedule in the operating block, meaning that radiological engineer has to be available 24 hours a day. As all other staff in the operating block a radiological engineer must also follow the instructions and principles in the operating block (while entering filter zone wears filter clothes, use of masks and hats, etc.). A work of a radiological engineer is a team work. Radiological engineer represents important part of a team, because without x-ray images and fluoroscopy, surgeon cannot successfully perform the operation. Besides routine interventions (standard input of the osteosintetic material), radiological engineer encounters more specific procedures (discus hernia surgery, taking x-ray imaging in bile duct laparoscopic surgery, etc) in the operating block. During these practices radiological engineers have to use all their skills and ingenuity, to produce the highest quality x-ray image while using the lowest possible radiation. Besides this, radiological engineer has to be aware of his own safety too.

Results: Work in the operating block was much harder in the past than it is now. Today we have modern technology that allows us to perform our work much easier. Quality of surgeries depends on good fluoroscopical quality, which helps surgeon with his work.

Discussion: Hip operation can not be made without fluoroscopy which indicates the role of radiographer.

Conclusion: Radiological engineer meets unpredictable cases in his daily routine, but regardless to all circumstances radiological engineer has to perform his job according to his best efforts and use all his skills.

Key words: operating block, x-ray images, radiographer

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VPLIV KONCENTRACIJE JODA V KONTRASTNEM SREDSTVU NA KVALITETO SLIKE PRI RAČUNALNIŠKI TOMOGRAFIJI

EFFECT OF IODINE CONCENTRATION IN CONTRAST MEDIUM ON THE COMPUTED TOMOGRAPHY IMAGE QUALITY

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Uvod in namen: Med CT preiskavami zaradi večje kontrastnosti med tkivi pacientu intravenozno dodajamo kontrastno sredstvo. Kontrastna sredstva so različna, razlikujejo se glede na vsebnost joda. V krvnem obtoku se redči s krvjo, zaradi česar se manjša njegova koncentracija v tkivih. S poizkusom želimo odgovoriti na vprašanje ali koncentracija joda v kontrastnem sredstvu vpliva na kontrastnost slike. Cademartiri et al. (2005) so podobno raziskavo opravili na prostovoljcih, mi pa na fantomu.

Material in metode: Za poizkus smo naredili fantom ožilja, ki je sestavljen iz cevk, po katerih kroži voda, kar predstavlja tok krvi. Cevke so oblite z želirno maso, ki ponazarja okolno tkivo. Narejen je tudi dovod za kontrastno sredstvo. Fantom smo vsakokrat eksponirali z istimi ekspozicijskimi pogoji, in sicer 120 kV in 100 mAs. Prav tako so bili vedno enaki pogoji na avtomatskem injektorju: 80 ml kontrastnega sredstva smo injicirali s hitrostjo 4 ml/s. Meritve smo izvedli s štirimi različnimi kontrastnimi sredstvi, in sicer Visipaque 320, Iomeron 350, Iomeron 400 ter Ultravist 370. Poizkus smo izvedli tako, da smo sledilec kontrasta (bolus tracking) pri vsaki ekspoziciji postavili na isto mesto na fantomu. Ko je sledilec zaznal vrednost 80 HU se je sprožila ekspozicija. Na slikah smo nato za vsako kontrastno sredstvo na istem mestu fantoma izmerili vrednost HU enot. Tako smo razredčenja posameznih vrst kontrastnih sredstev lahko primerjali med seboj.

Rezultati: Izmerili smo naslednje vrednosti HU: Visipaque 320 – 2517 HU, Iomeron 350 – 2634 HU, Ultravist 370 – 2810 HU, Iomeron 400 – 2942 HU. Iz rezultatov vidimo, da se kontrast, ki vsebuje večjo koncentracijo joda, manj razredči, zato je slika bolj kontrastna

Razprava: Kontrastno sredstvo, ki vsebuje večjo koncentracijo joda, se manj razredči. Slika je zato bolj kontrastna, kar je pri nekaterih preiskavah za diagnostiko ključnega pomena.

Zaključek: Koncentracija joda v kontrastnem sredstvu vpliva na kontrast slike. Če je koncentracija joda v kontrastnem sredstvu večja, se jod v krvi redči počasneje, zato je kontrastnost slike večja. Enake rezultate so z meritvami na prostovoljcih prikazali tudi Cademartiri et al. (2005). Zato pri preiskavah, pri katerih mora biti kontrastna ločljivost visoka, izberemo kontrastno sredstvo z visoko vsebnostjo joda.

Ključne besede: HU lestvica, koncentacija joda, kontrastno sredstvo

Introduction and purpose: During CT examinations the patients are given contrast agents intravenously for better tissue differentiation. Contrast agents differ by iodine concentration. When applied intravenously, iodine dilutes in blood and its concentration gradually fades in tissue. This experiment will answer the question if different iodine concentrations in contrast agents affect the image contrast resolution. Similar experiment on volunteers was performed by Cademartiri et al. (2005), while our experiment was made with a phantom.

Methods and material: For purposes of experiment, we constructed a system of tubes filled with circling water to mimic blood flow. Tubes were encased in gelling mass which represented the surrounding tissues.

Each time, the phantom was exposed with the same exposure factors, 120 kV and 100 mAs. Through the supply line, the phantom was injected with the same injecting conditions, 80 mL of the contrast agent with flow velocity of 4 mL/s. Measurements were made with four different contrast agents: Visipaque 320, Iomeron 350, Iomeron 400 and Ultravist 370.

We placed the bolus tracking slice each time on the same place on the phantom. The scanning started when the tracker picked up 80 HU or higher on selected slice. We measured values of HU on obtained images for each contrast agent and compared the dilution.

Results: We measured the following HU values: Visipaque 320 – 2517 HU, Iomeron 350 – 2634 HU, Ultravist 370 – 2810 HU, Iomeron 400 – 2942 HU. The results reveal that the contrast agent with higher iodine concentration dilutes less and thus improves the contrast of the image.

Discussion: The results reveal that contrast agent with higher iodine concentration dilutes less. This improves contrast resolution of the image, which is of crucial importance for diagnosis.

Conclusion: Iodine concentration in contrast agent affects the contrast of the image. When the iodine concentration is higher, its dilution is slower, which improves the contrast of the image. In comparison, Cademartiri et al. (2005) got the same results with measurements on volunteers. That indicates the usage of higher iodine concentration contrast agents in investigations, when high contrast is required.

Key words: HU scale, iodine concentration, contrast agent

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