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OPTIMISATION OF RADIOGRAPHIC PROCEDURES – LUMBAR SPINE IMAGING IN GENERAL RADIOGRAPHY

RADIOSURGERY FOR MULTIPLE BRAIN METASTASES IN NON-SMALL CELL LUNG CANCER – PARADIGM SHIFT

ESTIMATION OF CEREBROVASCULAR INSULT FREQUENCY IN EMERGENCY PATIENTS AT THE CLINICAL HOSPITAL CENTRE RIJEKA

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This is an official journal of the Slovenian Society of Radiographers with external reviews. The purpose is to publish articles from all areas of diagnostic imaging (diagnostic radiologic technology, CT, MR, US and nuclear medicine), therapeutic radiologic technology and oncology.
The articles are professional and scientific: results of research, technological assessments, descriptions of cases, etc.

Dear colleagues,

We are introducing the first issue of the Medical Imaging and Radiotherapy journal, volume 38 (2021). The journal's editorial board is proud and happy that a good word about our journal was spread and that we are receiving manuscripts from different countries and different topics. We are publishing three manuscripts, of which two are from foreign authors from Portugal and Croatia. The journal remains free and freely available to all readers on the journal's website and in the databases that index the journal.

We invite you to view the journal's website, which is available at http://mirtjournal.net. All the necessary information to prepare and submit the manuscripts can be found on the mentioned website. Besides that, a complete archive of the journal from its very beginning.

Nejc Mekis
Editor-in-chief of MIRTJ

Spoštovane kolegice in kolegi!

Pred Vami je prva številka revije Medical imaging and Radiotherapy journal, letnik 38 (leto izdaje 2021). V tokratni izdaji so objavljeni trije članki. V veliko veselje nam je, da se je dobro ime o naši reviji razširilo in da redno pridobivamo članke iz različnih držav na različne tematike. Tudi tokrat imamo v reviji dva članka tujih avtorjev, iz Portugalske in Hrvaške. Revija še vedno ostaja brezplačna in prosto dostopna vsem bralcem na spletni strani revije in v bazah, ki revijo indeksirajo.

Vabimo vas, da si ogledate spletno stran revije, ki je dostopna na povezavi http://mirtjournal.net/index.php/home. Na omenjeni spletni strani najdete vse potrebne informacije za pripravo in oddajo člankov in prav tako celotno bazo vseh objavljenih člankov od začetka izdaje revije.

Nejc Mekiš
Glavni urednik MIRTJ

Review article

OPTIMISATION OF RADIOGRAPHIC PROCEDURES – LUMBAR SPINE IMAGING IN GENERAL RADIOGRAPHY

OPTIMIZACIJA POSEGOV V RADIOLOŠKI TEHNOLOGIJI – SLIKANJE LEDVENE HRBTENICE V SPLOŠNI RADIOLOGIJI

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ABSTRACT

Purpose: Any use of ionizing radiation must be justified and the benefit must be greater than the harm it causes. Imaging must be performed with the lowest possible dose received by the patient, while maintaining optimal radiographic image quality. Imaging of the lumbar spine is a relatively high dose imaging procedure. This systematic review aims to explore optimisation options to reduce patient exposure, while maintaining radiographic quality during plain lumbar spine imaging.

Methods: A systematic review of the literature from the databases Pub Med Central, EBSCOhost including CINAHL, Cochrane Library, Web of Science, Science Direct, DiKUL and Springer Link was conducted. The documents were fully accessible and in the English language.

Results: 26 experimental studies were included in the analysis. There are many optimisation methods: changing the tube potential, comparison of different projections, use of shielding, primary beam collimation, increasing the source-to-image receptor distance, compression of the imaged area, using the air gap technique, evaluation of the need for additional projections, and rotating the patient depending on the tube side. On average, the dose is reduced by 44%. Studies that also evaluated the quality of radiographs found all radiographs to be diagnostically acceptable.

Conclusion: The results confirm a reasonable use of methods to optimize radiation exposure and to maintain an optimal image quality of radiographs. A systematic review for each specific area in general radiography should be conducted in the future.

Keywords: lumbar spine imaging, optimisation, dose reduction, low dose, image quality

IZVLEČEK

Namen: Vsaka raba virov sevanja mora biti upravičena, korist, ki jo dosežemo z uporabo ionizirajočih virov pa mora biti večja od škode, ki jo povzroči. Postopke slikanja moramo izvajati tako, da pacient pri slikanju prejme najnižjo dozo, ki je še razumno dosegljiva ob optimalni kakovosti rentgenograma. Slikanje ledvene hrbtenice spada med preiskave z relativno visoko dozo ionizirajočega sevanja. Namen sistematičnega pregleda je raziskati možnosti optimizacije v smislu zniževanja doze na paciente in hkratni ohranitvi kakovosti rentgenogramov na področju slikanja ledvene hrbtenice v splošni radiologiji.

Metode: Narejen je bil sistematični pregled literature s pregledom podatkovnih baz Pub Med Central, EBSCOhost preko CINAHL, Cochrane Library, Web of Science, Science Direct, DiKUL in Springer Link. Dokumenti so bili iskani v polnem besedilu in v angleškem jeziku.

Rezultati: V analizo je bilo vključenih 26 eksperimentalnih raziskav. Kot možnosti za optimizacijo so bile uporabljene različne metode spreminjanja napetosti, primerjava različnih projekcij, uporaba svinčenih zaščit, zaslanjanje primarnega polja, povečanje razdalje od izvora do slikovnega sprejemnika, kompresija slikanega področja, ocenjevanje potrebe po dodatni projekciji slikanja ter obračanje pacienta glede na postavitev rentgenske cevi. Povprečna doza ionizirajočega sevanja se zmanjša za 44 %. Raziskave, v katerih so poleg doze ocenjevali še kakovost rengenogramov, med ocenami niso opazili statistično značilnih razlik oz. rentgenogrami so bili diagnostično sprejemljivi.

Zaključek: Rezultati potrjujejo smiselno uporabo metod za optimizacijo tako na področju zniževanja doze kot tudi ohranjanja optimalne kakovosti rentgenogramov. V prihodnje bi bilo smiselno narediti sistematični pregled za vsako posamezno področje v splošni radiologiji.

Ključne besede: slikanje ledvene hrbtenice, optimizacija, zniževanje doze, kakovost rengenograma

INTRODUCTION

In the last century, population exposure has increased with the use of man-made radioactive sources. Despite the harmful effects of ionising radiation, its use in medicine has significant diagnostic and therapeutic benefits, increasing the frequency of X-ray examinations. Any use of radiation sources must be justified, and the benefit of the use must be greater than the harm it causes (1,2).

Radiation protection results in avoiding unnecessary or unproductive irradiation, which is achieved by general principles of radiation protection. The first principle is the justification principle. The procedure may be performed if it is clinically indicated and if a greater benefit can be expected than the harm caused by the radiation. The referring physician and the radiologist are responsible for the procedure, and they must be familiar with the radiation exposures involved in certain radiologic procedures. The goal is to assess whether the radiological procedure will improve diagnosis or treatment and provide the necessary information. The second principle is the principle of optimisation. Radiation doses and the frequency of patients irradiated must be as low as possible, considering the purpose of the radiation application. Quality and safety are essential characteristics for effective and successful medical treatment of patients. Radiation dose and radiographic image quality must be optimised for proper radiological procedures. Optimising means finding the lowest possible dose at which the purpose of the radiologic procedure is still achieved. By justifying the indication for the radiological procedure and optimising the equipment, techniques, and proper use of radiation sources, the procedure can be optimised. The third principle is the principle of applying dose limits. Departments and facilities may vary in their radiation doses. The causes of these differences must be identified and prevented (3). Radiographic procedures are used only when the diagnosis cannot be made by other methods that are not as risky for the patient (4). We must follow the ALARA principle (As Low As Reasonably Achievable), which means that the procedure must be performed at the lowest possible dose that still gives the optimal quality of the images or procedure (4,5). By reducing the radiation dose, patients are protected from genetic damage (2). According to the 2007 data from International Commission on Radiological Protection (ICRP) 103, the most radiosensitive organs with the highest weighting factor (0.12) are the breasts, lungs, stomach, colon, and bone marrow. The weighting factor of the specific organ represents the average of both sexes and all age groups (3).

Several optimisation studies have been conducted. They are all based on reducing patient exposure whilst still obtaining images of high diagnostic quality. There are no strict guidelines in the European guidelines for performing imaging, but they are supposed to present the basic criteria that have proved appropriate in the past (4). Dose limits do not exist for radiological procedures (6). However, reference values are established for each examination to aid and provide basic guidance in the optimisation of protocols (4). The establishment of reference values is one of the mechanisms by means of which patient overexposure is detected. Diagnostic reference levels (DRLs) represent dose values in diagnostic radiological procedures. They represent a dividing line between optimized and non-optimized radiological practice. DRLs are not expected to be exceeded during optimized procedures. The health authorities set the values in collaboration with the national health and radiation protection authorities (3).

Among the most common reasons for visiting a primary care physician is low back pain leading to imaging of the lumbar spine (7,8). Lumbar spine imaging is one of the examinations with the highest radiation exposure in plain radiography with a relatively high radiation dose (4,9–12). According to the European Commission (13), Slovenia is among the countries where patients receive the lowest dose area product (DAP) values for lumbar spine imaging. Many radiosensitive organs located near the lumbar spine (breasts, lungs, stomach, colon, gonads) must be protected (14).

General principles in accordance with the optimisation of the protocol (4):

- quality control of the radiographic equipment,
- correct positioning of the patient (the proper technique of patient positioning – as the lowest dose with the highest radiogram quality),
- imaging field collimation that leads to a better quality of the radiogram with lower doses,
- use of shielding (protective aprons for radiosensitive organ protection),
- proper exposition parameters (tube current, tube voltage and other parameters that influence the dose and quality of the radiograms) and
- proper image annotation;

Regular checks of the doses received and comparison with diagnostic reference values represent excellent radiological practice as the use of these methods has led to progressively lower exposure doses in many countries (15).

The aim of this systematic review was to investigate optimisation options to reduce the dose to patients while maintaining the quality of radiographic images in plain lumbar spine radiography. The focus was on the lumbar spine imaging, where the patient receives the highest dose in plain radiography. The aim was to investigate all optimisation possibilities in this area for easy transfer to clinical practice.

METHODS

We performed a systematic review and quantitative analysis. All studies that were included addressed lumbar spine radiography and optimisation, and were fully accessible. The literature search was conducted in English. Since radiography is a relatively new field in which new opportunities for protocol optimisation in terms of the ALARA principle are constantly emerging and new ways of performing examinations are being discovered as technology evolves, no additional restrictions were placed on the selection of studies.

Document references

Based on the research title, we selected key words that apply to the topic under study. First, we conducted the search in the Pub Med Central, EBSCOhost including CINAHL and Cochrane Library. Since few documents were found, the scope of the study was expanded to include sources found in Web of Science, Science Direct, DiKUL and Springer Link.

Methods of document identification

All documents were searched using the following keywords: radiography, lumbar spine and dose reduction. The keywords were selected based on the aim and objectives of this systematic review. The keyword for image quality assessment was not used. Nevertheless, this area was considered. The following exclusion criteria were also used: Magnetic Resonance, Computed Tomography, CT and MRI, as a large number of documents related to MR and CT appeared in the first search.

The retrieved documents were reviewed based on the title and the abstract. All documents that were not suitable for the research were excluded. All documents that did not relate to plain radiography of the lumbar spine and those that did not relate to the process of optimisation or dose reduction were also excluded. Then, all duplicate documents were eliminated. Finally, all articles were read and two documents were excluded because they were not fully accessible and one document did not refer to the study area.

The criteria for including the documents in the analysis were studies covering the topic of plain radiography, lumbar spine imaging, documents that examined dose reduction, documents with full accessibility and in English, as well as quantitative, qualitative, and experimental studies.

Exclusion criteria were all the documents that did not relate to plain radiography imaging, documents that covered other areas of general radiography and did not involve optimisation or dose reduction, and all documents in duplicate or without full accessibility.

Methods for quality evaluation of research

When evaluating the quality of research works included in this systematic review, a few main features were checked. The following features were taken into consideration:

- a country in which the study was performed,
- research design,
- subjects under investigation (participants),
- inspected area,
- inspected results,
- measurement tools,
- results.

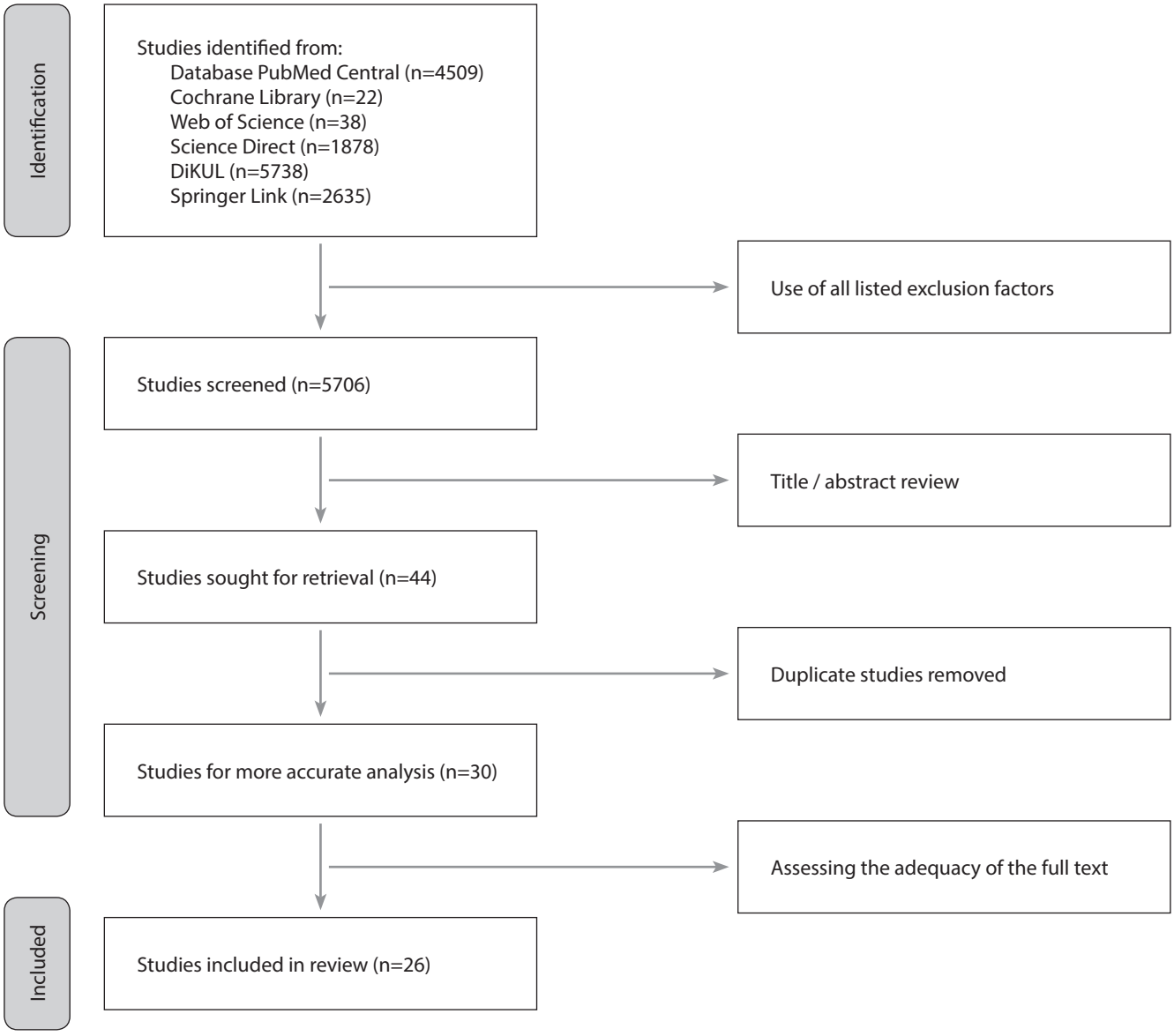

Figure 1: Flow chart of the included studies

RESULTS

The literature search in all seven previously mentioned databases yielded 14,832 results (articles). Based on this, exclusion factors were used for several search results. After using exclusion factors, all the articles were screened by title and abstract and all the articles that did not describe lumbar spine radiography or did not describe dose optimisation were excluded. Afterwards, duplicate documents were encountered. After all of the above exclusions had been made, all of the remaining articles were read and four of them were excluded; three were excluded because they were not consistent with the aim of the study and the fourth was excluded because it was not within the scope of general radiography. Figure 1 presents a flow chart of the studies selected.

Main characteristics of investigated papers

Twenty-six papers were included in our systematic literature review. All key data from our review are presented in Table 1. The data are ordered by year of publication, from the oldest to the most recent. The presented data include the country of research, the research methodology and the reviewed subjects on whom the research was conducted, the reviewed research area, which measurement devices were used, keywords, and finally, the results and conclusions of the research reviewed.

Result analysis

Papers describing optimisation techniques in lumbar spine radiography have been studied in several countries around the world. Those countries are Finland (16), Australia (17,34,39,41), Ireland (18,19,21,22,25), China (20), Sweden (24,26,33), Kuwait (23), United Kingdom (27,30,36), Slovenia (28,35,37), Iran (29,32), Israel (31), Croatia (38) and Malta (40).

The research methodology was experimental in almost all studies, except for three studies (16,32,39) in which the research methodology was a retrospective study of lumbar spine images. In most cases, the research was performed on an anthropomorphic phantom (17,20,34,41,22–25,29–31,33), in a few studies the research was performed on patients only (27,36–38), and some of them performed a combined study first on a phantom and then on patients (18,19,21,26,28,35,40). The sample size of the examined patient studies varied from study to study. The smallest sample size of patients studied was three (26), and the largest sample size was 110 (38). The investigators studied the radiation dose to the patient and/or phantom in all papers, but the measurement tool for the dose measurements varied from study to study. The dose was measured using TLDs (16,18–22,25,28,33), ionization chambers (17,26,30), with some mathematical formulas and using conversion factors (21,23,32), DAP meters (27,35,36,38,40), based on calculations with the PCXMC program and Monte Carlo simulation (24,29–31,35–38,41) and other ways (24,29,34). Image quality was not checked in a large number of the papers examined (17,20,34,37,25–29,31–33).

There were several ways to achieve dose optimisation in lumbar spine radiography. In 7 papers, the researchers used different tube potentials (kV) (21–24,34,39,41), different mAs (41), in 5 papers they used alternative positioning of the patient, in which the patient or phantom was rotated to different positions (19,27,29–31,35–37), and 2 studies used lead shielding as a method of radiation dose reduction (25,28). Four papers investigated increasing the distance (focus-film distance and source-to-image distance) on the radiation dose to the patient during lumbar spine radiography (17,18,22,41), and some of the papers evaluate the effect of proper collimation (32,33,38). Other methods described to reduce radiation dose include the need for additional image projection (16), changing the patient position on the cathode and anode sides of the X-ray tube (20), using a carbon fibre cassette and a faster film/screen combination (22), compression of the body part being examined (26), the effect of an additional copper filter (41), and replacing an antiscatter grid with an air-gap technique (40).

On average, the ESD decreased the most by 65% (18), dose to gonads by 42% (25), effective dose by 58% (29), DAP by 59% (27) and the dose to other inspected organs decreased the most by 80%, where they evaluate the use of lead shielding to reduce the radiation dose to breasts (28).

Of the 26 reviewed papers, 14 (16,18,38–41,19,21–24,30,35,36) examined the effect of the optimisation procedure on image quality. In eleven papers, the researchers found no statistically significant difference between image quality before and after optimisation (16,18,41,19,22,30,35,36,38–40). In three others (21,23,24), the researchers concluded that the optimisation procedure decreased image quality but the images were still diagnostically acceptable.

DISCUSSION

The aim of this systematic literature review was to investigate the options for radiation dose optimisation in lumbar spine radiography. This was selected because lumbar spine radiography is a procedure that delivers the highest radiation dose to the patient in general radiography. There are many ways to achieve dose optimisation in lumbar spine radiography, but all the inspected methods have their limitations. We did not limit our literature review according to the year of publication of the articles as we were interested in the trends of changing measuring equipment, the transition from the film/screen system, and CR and DR detectors.

All the 20 inspected papers offer a large variety of achieved dose reduction in lumbar spine radiography. The method used was mainly experimental. An experimental research method offers the researcher an inspection and testing of new methods for dose reduction and its comparison with previously established methods. In this way, the efficiency and safety of the new protocol can be evaluated. The disadvantage of the experimental method is mainly its ethical concerns; therefore, several researchers investigated their newly established methods on an anthropomorphic phantom (17,20,34,41,22–25,29–31,33) before carrying on with the study on the patients. The use of ionising radiation may negatively affect patients (1,2). However, the ethical concern can be avoided if the newly established research methodology is first performed on a phantom and results of the optimisation procedures are in that manner primarily investigated (18,19,21,26,28,35,40). Some of the investigated papers describe that the research was performed on patients, but many of them performed the primary analysis on a phantom before carrying on with the study on patients.

All the reviewed studies have proven that radiation dose in

Table 1: Main features of the studies included in the analysis.

RESEARCH	COUNTRY	RESEARCH METHOD & SUBJECT	INSPECTED AREA	AIM OF THE STUDY	MEASURING EQUIPMENT	KEYNOTES	RESULTS AND COCNLUSION
Moilanen et al., 1983 (16)	Finland	Retrospective study - image evaluation n=250	Lumbar spine in AP, LAT projection and lumbo-sacral joint (LS) view in LAT projection	Evaluation of the necessity of LS joint imaging and the influence on gonadal dose.	Termoluminiscent dosimeters (TLD) were used to measure the dose. The images were retrospectively evaluated by radiologists.	Film/screen combination was used.	In 91% of the cases the third image (LS joint) does not contribute any diagnostic information. The dose was doubled, when three projections are used compared of two projections.
Dilger et al., 1997 (17)	Australia	Experimental research - Phantom study	Lumbar spine (AP and LAT projection)	Comparison of radiation dose to patient at different focus film distance (FFD was 100cm and 200cm).	A chamber dosimeter to measure entrance testicular dose.	Film/screen combination was used.	The increase of FFD decreases radiation dose for AP projection by approximately 30% and for LAT projection by 70%.
Brennan and Nash, 1998 (18)	Ireland	Experimental research - Phantom and patient study (n=21; females between 55 and 65 kg)	Lumbar spine in LAT projection	Comparison of radiation dose to patient at different focus film distance (FFD was 100cm, 130cm and 200cm) and influence on image quality.	Entrance surface dose (ESD) was measured using TLDs. Image quality assessment was performed by two radiographers and one radiologist based on quality criteria by the European Commission.	Film/screen combination was used. entrance surface dose and dose to ovaries were measured.	The larger FFD resulted in 65.5% of ESD reduction in the phantom and 44.1% reduction in the patient study. 63-69% dose reduction to ovaries when a larger FFD was used. There were no statistically significant difference in image quality.
Brennan in Madigan, 2000 (19)	Ireland	Experimental research – Phantom and patient study (n=30; 70 ± 5kg, 1,55-1,75m)	Lumbar spine in AP and PA projection	The influence of PA projection on ESD and image quality.	ESD was measured with TLDs. The diameter of the investigated part was measured to determine the compression in PA projection. Image quality assessment was performed by three clinicians based on quality criteria by the European Commission.	In PA projection the diameter of the investigated part was decreased by 9.6%. That has influenced the AEC to terminate the exposure sooner than in AP projection.	Decrease of ESD in PA projection by 38.9% in phantom study and by 38.6% in patient study. There was no statistically significant difference in image quality.
Fung in Gilboy, 2000 (20)	China	Experimental research - Phantom study	Lumbar spine in AP and LAT projection	Radiation dose to selected radiosensitive organs (ovaries, testicles, breasts, thyroid and eyes) based on position of the patient regarding the tube side (cathode-anode).	ESD was measured using TLDs.	Known fact based on the literature review is that there is higher intensity of radiation on the cathode side of the tube.	When the patient's head is orientated towards the anode side of the x-ray tube, the ovaries and testicles received 17% and 12% higher dose on average, respectively, in LAT projection and 17% and 12% higher, respectively, in AP projection.

RESEARCH	COUNTRY	RESEARCH METHOD & SUBJECT	INSPECTED AREA	AIM OF THE STUDY	MEASURING EQUIPMENT	KEYNOTES	RESULTS AND COCNLUSION
Doherty et al., 2003 (21)	Ireland	Experimental research - Phantom and patient study (n=59; 70±10kg, 1.65±0.1m)	Lumbar spine in AP and LAT projection	Increase of the anode voltage (kV) and its influence on ESD, effective dose (ED) and image quality.	The ESD was measured using TLDs, ED was calculated, and image quality assessment was performed by three radiologists based on quality criteria by the European Commission.	The increase of tube voltage results in faster termination of AEC due to higher energy of the photons. The comparison of tube voltage in the patient study was 81 kV and 96 kV in the AP and 90 kV and 102 kV in the LAT projection.	Decrease of ESD by 40.4% in AP and 34.8% in LAT projection. Decrease of ED for 29.9% in AP and 24.6% in LAT projection. The reduction of image quality in the AP projection was 18.3% and 10.1% in LAT but all images were still diagnostically acceptable.
Grondin et al., 2004 (22)	Ireland	Experimental research - Phantom study	Lumbar spine in AP and LAT projection	Increase of anode voltage (kV), FFD, c carbon fibre cassette, a faster film/ screen combination and their influence on radiation dose and image quality	ESD was measured using TLDs Image quality assessment was performed by two radiographers and one physicist based on quality criteria by the European Commission.	Increase of tube voltage in the AP projection from 66 kV to 96 kV and in LAT projection from 81 kV to 102 kV and the increase of SID from 100 cm to 130 cm	Dose reduction with the use of optimised procedure (higher kV, FFD, faster film/screen combination and use of carbon fibre cassette) has decreased by 66% with no significant changes of image quality
Brindhaban et al., 2005 (23)	Kuwait	Experimental research - Phantom study	Lumbar spine in AP projection	The effect of increased tube voltage on radiation dose and image quality in two CR systems.	A chamber dosimeter was used for ESD, ovary dose and effective dose were calculated using conversion factors. Image quality was assessed using visual grading scale (VGS) based on quality criteria by the European Commission and the SNR was calculated.	Three different tube voltages were used. 9 evaluators = 5 radiologists, 1 physicist and 3 radiographers	The decrease of ESD, ovary dose and effective dose between 25% and 50% depending on the used CR system. Significant decrease of image quality, however the images were still diagnostically acceptable.
Geijer and Persliden, 2005 (24)	Sweden	Experimental research - Phantom study	Lumbar spine in AP projection	To evaluate the relation between kV and image quality at the constant effective dose.	Entrance dose was recorded with a solid-state detector, while organ doses and effective dose were calculated with PCXMC program (Monte Carlo simulation). Image quality was assessed using VGS bases on quality criteria by the European Commission by eight radiologists.	The tube voltage (kV) was changed between 48 and 125 and the tube load (mAs) was adjusted to keep a constant effective dose.	At the constant effective dose, a lower tube voltage delivers better image quality than higher tube voltage. But due to the use of AEC which is set for a constant detector dose this cannot be done.

RESEARCH	COUNTRY	RESEARCH METHOD & SUBJECT	INSPECTED AREA	AIM OF THE STUDY	MEASURING EQUIPMENT	KEYNOTES	RESULTS AND COCNLUSION
Clancy et al., 2010 (25)	Ireland	Experimental research - Phantom study	Lumbar spine in AP and LAT projection	To determine the effect of the use and different positioning of lead shielding on dose to ovaries, uterus and testicles in lumbar spine radiography.	Dose to the mentioned organs was measured using TLDs.	They used different positioning of lead shielding (no shield, tube side, wrap-around and Bucky side).	In the AP projection dose to the testicles was decreased by 42% when a tube side apron was used and for 36% when the wrap-around apron was used. In the LAT projection, the observed dose reduction to the testicles was 12% with the use of wrap-around apron. No reduction to other inspected organs was observed.
Olsson et al., 2010 (26)	Sweden	Experimental research - Phantom and patient study (n=3)	Lumbar spine in AP projection	To determine the effect of compression technique to obtain the optimal image quality and radiation dose.	Kerma-area product (KAP) was measured with a ionisation chamber.	Compression for three volunteers to determine the effect of compression was simulated with Comp-X (carbon fibre plate)	With the use of compression dose reduction of up to 50% or more can be obtained.
Davis in Hopkins, 2013 (27)	UK	Experimental research - Patient study (n=30)	Lumbar spine in LAT projection	Comparison of radiation dose received by the patient in LAT projection of lumbar spine when the patient Is lying on the side and on the back with the horizontal x-ray beam and its influence on image quality.	They measured DAP using a DAP meter.	Rotating the patients from their side to their back caused an increase in tissue thickness. The simulations of different lateral thickness were carried out using PMMA.	59% of DAP decrease was found when the patient was lying on the side rather than on the back. With the use of horizontal central ray position, the tube voltage should be increased to decrease the radiation dose.
Mekiš et al., 2013 (28)	Slovenia	Experimental research - Phantom and patient study (n=100 female patients)	Lumbar spine in AP and LAT projection	To evaluate the influence of lead shielding on dose to breasts in lumbar spine radiography.	Dose was measured using TLDs for both projections.	The use of tube voltage used in clinical environment was not in accordance with European guidelines.	The use of lead shielding has decreased the radiation dose to breasts by approximately 80%.
Chaparian et al., 2014 (29)	Iran	Experimental research - Phantom study	Lumbar spine in different projections	The aim of the study was to determine the ED, dose to radiosensitive organs and effective risk.	The measurements of entrance skin exposure were performed using solid-state dosimeter, while effective dose and risk of exposure induced cancer death were calculated using PCXMC program (Monte Carlo simulation).	The use of different projections has a different effect on radiosensitive organs as they lie closer or further from the primary field.	Lower effective dose in PA projection by 51% and effective dose and risk by 58% in comparison to AP projection. Lower effective dose in LLAT projection by 53% and effective dose and risk by 58% in comparison to RLAT projection.

RESEARCH	COUNTRY	RESEARCH METHOD & SUBJECT	INSPECTED AREA	AIM OF THE STUDY	MEASURING EQUIPMENT	KEYNOTES	RESULTS AND COCNLUSION
Davey in England, 2015 (30)	United Kingdom	Experimental research - Phantom study	Lumbar spine imaging in AP and PA projection	Comparing AP and PA projection at various tube voltage (kV) using CR and compare effective dose, dose to organs and image quality	ESD was measured using an ion chambers in Mult-O-Meter. Effective dose and dose to selected organs was calculated using PCXMC program (Monte Carlo simulation). The image quality was assessed using VGA by 5 radiography students.	The use of PA projection has an effect of object magnification in comparison to the AP projection.	Magnification in the PA projection was 8%. The effective dose reduction was 19.7% and the organ that had the most dose reduction (74%) was the stomach. There were no significant differences between the images made in AP and PA projection.
Ben-Shlomo et al., 2016 (31)	Israel	Experimental research - Phantom study	Lumbar spine in four different projections AP, PA, LLAT, RLAT	To calculate and compare the effective dose for lumbar spine radiography for adults and 10-year-old children.	The calculations were made using PCXMC program (Monte Carlo simulation).	The authors want to determine the less radiosensitive side of the body for lumbar spine imaging.	RLAT projection has been proven to deliver 28% lower ED in comparison to LLAT projection. PA projection has been proven to deliver 48% lower ED in comparison to the AP projection.
Karami, in Zabihzadeh 2017 (32)	Iran	Retrospective study - 830 images of lumbar spine in the AP projection	Lumbar spine in AP projection	To evaluate the collimation protocol in two Iranian general hospitals.	A mathematical formula to determine the oversized primary field was used.	The authors state that this has happened due to implementation of digital detectors.	The area of diagnostic interest was 1.26 times higher than it is supposed to be – this cause higher dose too. In 62% of radiographs evaluated, ovaries were included in the primary beam.
Robinson et al., 2017 (33)	Sweden	Experimental research - Phantom study	Thoraco-lumbar spine (scoliosis protocol)	The aim was to determine the differences to organ dose, effective dose and effective risk comparing tight and loose collimation in thoraco-lumbar spine imaging.	The TLDs were used to measure ESD, organ doses and the effective risk were calculated using a mathematical formula.	The patients that suffer from scoliosis usually get imaged quite frequently and because they are at a young age a tight collimation protocol should be used to protect as many organs.	The organ dose with the use of loose collimation protocol increased from 31 to 571% The effective risk vas 3.3 times higher when using a loose collimation.
Shanahan, 2017 (34)	Australia	Phantom study	Lumbar spine in AP projection	To compare the ESD based on the 15% kVp rule and simplified 10 kVp rule for CR and DR systems (system 1 and 2), and for Projection VR - virtual radiography simulation (system 3).	The ESD was measured using NanoDOT, single point dosimeters .	The 15% rule states that if you increase the tube voltage for 15%, then the tube time current product has to be decreased by 50% to get the same exposure. The exposure maintenance formula uses the increase in SID.	Increasing kVp resulted in reduction of ESD by 59,5% (system1), 60,8% (system2) and 60,3% (system 3). Increasing SID resulted in reduction of ESD by 22,3% (system1), 18,8% (system2) and 23,5% (system 3).
Alukić et al., 2018 (35)	Slovenia	Experimental research - Phantom and patient study (n=100)	Lumbar spine, AP and PA projection	Compare patient radiation dose and image quality using AP and PA projection.	DAP meter was used to measure DAP and effective dose was calculated using PCXMC program (Monte Carlo simulation). image quality was evaluate by three radiologists using criteria in European guidelines.	Body mass index (BMI), DAP, exposure index (EXI), mAs, image field size and source to patient distance were acquired.	No significant difference in image field size, DAP and image quality but in a PA projection a significant reduction of thickness of abdomen by 10%, DAP by 27% and effective dose by 53% compared to AP projection. No significant difference in image quality between AP and PA projection.

RESEARCH	COUNTRY	RESEARCH METHOD & SUBJECT	INSPECTED AREA	AIM OF THE STUDY	MEASURING EQUIPMENT	KEYNOTES	RESULTS AND COCNLUSION
Green et al., 2019 (36)	United Kingdom	Experimental research - Patient study (n=80; 60-100 kg)	Lumbar spine, AP and PA projection	Evaluate dose and image quality in both projections and survey current UK practice	DAP meter was used to measure the DAP and effective dose was calculated using PCXMC program (Monte Carlo simulation). Image quality was evaluate by two radiologist using criteria in European guidelines.	BMI, DAP and mAs were acquired	Effective dose was reduced by 41% when PA projection was used with no difference in image quality.
Alukić et al., 2019 (37)	Slovenia	Experimental research - Patient study (n=100)	Lumbar spine, AP and PA projection	Determine the effect of the PA projection on effective dose and the absorbed organ dose	Calculation with PCXMC program (Monte Carlo simulation).	Image quality was not measured.	Significant reduction of ESD by 33% and, effective dose by 53% and 64% average reduction of the absorbed organ doses when the PA projection was used.
Pazanin et al., 2020 (38)	Croatia	Experimental research – Patient study (n=110)	Lumbar spine, AP and LAT projection	Determine the influence of optimal and standard (non-optimal) collimation on radiation dose and image quality	DAP meter was used to measure the DAP, absorbed and effective dose were calculated using PCXMC program (Monte Carlo simulation). Image quality was evaluate by two radiologist and a radiographer using criteria in European guidelines.	BMI, exposure conditions, image field size and DAP were acquired.	Optimal collimation reduced image field size by 40%, effective dose by 48% and absorbed dose by 41% for the AP and effective dose by 48% and absorbed dose by 10% for the LAT projection. Image quality improves by 24% in the LAT projection, and showed no statistically significant difference for AP projection with the use of optimal collimation.
Peacock et al., 2020 (39)	Australia	Retrospective study - 91 images of lumbar spine in the LAT projection	Lumbar spine in LAT projection	To assess the effects of the high tube potential on image quality using DR system and validate effect on dose saving technique	Collection of data from PACS system. Image quality was assessed by five senior radiographers using a 15-point visual grading analysis.	kV, mAs, deviation index and DAP were acquired.	The reduction of DAP with the use of higher kVp was shown for 40 lateral lumbar spine radiographs with no statistically significant difference in image quality.
Bellizzi et al., 2020 (40)	Malta	Experimental research – Phantom and patient study (n=50)	Lumbar spine in LAT projection	To investigate the possibility of replacing an antiscatter grid with an air gap technique to reduce dose.	DAP meter was used to measure the DAP. Image quality was assessed by five radiologists using a 15-point visual grading analysis.	/	Application of air gap technique resulted in a statistically significant reduction in DAP by 72%, image quality between the two techniques was not significant.
Lai et al., 2020 (41)	Australia	Experimental research - Phantom study	Lumbar spine in LAT projection	Determine the influence of different exposure parameters – source to detector distance, tube potential, tube time current and additional copper filter for reduction of effective dose.	Effective dose was calculated using PCXMC program (Monte Carlo simulation). Contrast-to-noise ratio and magnification were calculated using ImageJ.	Exposure factors, SSD, focal-skin distance, collimation field and additional filtration parameters were acquired for each image acquisition.	The highest effective dose was found with the use of lowest SSD, lowest tube potential, highest tube time current and without additional copper filter.

the lumbar spine can be optimised based on their proposed methodology. The results cannot be generalised due to the uniqueness of each study methodology and measurement technique.

With the lowering of tube voltage (kV), the patient's dose can be reduced (21–24,34,39,41). It has already been proven that the increase of tube voltage increases the penetration of x-rays, and as a consequence, the automatic exposure control terminates exposure earlier due to more x-rays hitting the ionising chamber of AEC. The negative effect of tube voltage increase is its influence on image quality. The use of modern materials and digital technology that offers image postprocessing, such as changing the window centre and level, can reduce the negative effect of tube voltage increase on image quality (24). In the past, the increase of tube voltage in screen-film technology has led to a decrease of image contrast (4). The inspected papers investigated the influence of tube voltage increase performed on different imaging systems (screen-film and digital). Therefore, the results between studies differ. A film-screen system was in use in research until 2004. The research on two CR detectors was firstly mentioned in 2005 (23).

Therefore, in the literature review, it could be observed how measurement equipment for dose has changed over the years and where they first used TLDs and chamber dosimeters (16–23,25,26). In 2013, Davis and Hopkins first mentioned the use of the DAP meter (27).

In the early years, dose on organs could not be measured. The record of organ dose was first mentioned in 2005 (24), and then again nine years later in 2014 (29). Since 2014, the Monte Carlo simulation has been used in eight different articles (29–31,35–38,41). For calculations of an effective dose, organ dose weight and height of the patient, imaging field size, DAP, and total filtration are needed (42).

In studies that investigate an alternative projection in lumbar spine radiography (19,27,29–31,35–37), researchers should be careful that the radiograph's quality remains optimal and that the changing of the position does not result in excessive magnification of the inspected object. As described in the reviewed papers, the magnification of the inspected object can be enlarged up to the point that it still does not interfere with the diagnostically important information and radiologist's perception. The further away the inspected object is from the image receptor, the greater the magnification is (19). The use of alternative projections is limited in its use since it cannot be used in all diagnostic departments due to the patient's status or mobility. Changing the projection from AP to PA projection in lumbar spine radiography greatly influences dose reduction to different organs in the patient's body. Due to anatomy, some bones in the human body (pelvis) can work as a shield for some organs that lie behind the bone structure. Another advantage of the PA projection is that some radiosensitive organs lie further from the irradiation source and, due to the inverse square law, those organs receive a lower radiation dose than in the AP projection.

Lead shielding has proven to be an effective dose reduction technique when used inside or outside the primary field. The use of lead protection over the radiosensitive organs can decrease the dose received by those organs (25,28). Proper collimation of the primary beam also has a considerable effect on the patient's radiation dose (32,33,38). When deciding which organs to shield or put outside the primary field, the ICRP document must be considered to determine which organs have the highest tissue weighting factors (3). However, tissue weighting factors change over time based on the results of studies investigating the ionising radiation effect on the human body, the organs, and cells. For example, before the year 2007, the gonads were the organ with the highest tissue weighting factor (6), so the research was mainly focused on dose reduction to the gonads. After the new publication from the ICRP in 2007, the gonads are now the sixth organ based on tissue weighting factor (3). The organs with the highest tissue weighting factor of 0.12 are now the breast, lungs, bone marrow, stomach, and colon, so the research of dose reduction has nowadays changed to described (most radiosensitive) organs.

Along with the most frequently described research methods, other reviewed methods have also been proven to be effective as a dose reduction technique, such as the change of the patient position based on the tube side (cathode-anode) (20). It has been proven that the radiation intensity is lower on the anode side; therefore, the part of the body with a smaller diameter (legs) has to be on that side of the x-ray tube and the larger diameter (head) on the cathode side (14). Also, a well-known example of the compression of the body part is in daily use in mammography since the dose reduction to the patient and improved image quality were proven. That kind of dose reduction technique can also be implemented to other positioning in radiography (26). The ALARA principle states that even with a minimum dose, if receiving that dose has no benefit, it should be avoided. This was indicated in a study that examined the necessity for a third projection (lumbosacral joint in lateral view). It was found that the use of the third projection doubled the dose compared to two projections (AP and lateral) (16). Finally, a significant manner of optimising the dose is by using the air gap technique instead of the anti-scatter grid (40). The reduction in scattered radiation reaching the detector is achieved by increasing the distance between the effective scatter point source and the image receptor. This increased distance increases the chance that the scatter radiations path will not reach the receptor and; therefore, not reduce image contrast.

We recommend that the studies that were performed only on an anthropomorphic phantom be conducted also on patients in order to determine their influence on dose reduction on actual patients before using them in the clinical environment. In dose optimisation, image quality cannot be decreased to the extent that the diagnostically important information is lost. If diagnostically important information was missed, this would result in even greater harm to the patient in comparison to the damage that would result due to ionising radiation. In a large variety of the reviewed papers, the influence of dose optimisation on image quality has not been inspected (17,20,34,37,25–29,31–33). When the image quality was inspected, all three groups of experts were used, but not all together. We propose that all three groups of experts (radiographer, radiologist, and medical physicist) evaluate the image quality to obtain the optimal results due to their different backgrounds. Radiologists would inspect the diagnostic part of the image, radiographers the technical part of the image and the medical physicists would give an objective quality of the image.

Due to rapid changes in technology, new ideas and methods of dose reduction techniques will surely appear. The researchers should remember to inspect the effects of the optimisation technique on image quality and not only on radiation dose.

Limitations of the systematic review

This review has screened a variety of research papers in the field of dose reduction in lumbar spine radiography that may lead to easier implication in a clinical setting. Based on the reviewed literature, this type of qualitative study was not found in this field.
Limitations of our review are that only articles in English were included in the review and that not all papers examined the effects of dose optimisation on image quality.

CONCLUSION

Regardless of the many uses and advantages of ionising radiation in X-ray diagnostics, it has a negative effect on the human body, so the ALARA principle must be observed. This means that the patient is imaged with the lowest possible radiation dose with optimal image quality based on the expected pathology. Based on the inspected studies, it can be concluded that there are many different ways to achieve dose reduction in lumbar spine radiography, while keeping the quality of the images in the diagnostically acceptable range. The methods studied for dose optimisation are different lead shield positioning, proper collimation, alternative patient positioning, patient positioning based on the orientation of the X-ray tube, increasing the source-to-image receptor distance, and changing the exposure factors, among others. All the methods studied were found to be effective in dose optimisation as the average dose reduction in all the studies was 44%. The studies that investigated the effect of dose optimisation on image quality concluded that there was no significant reduction in image quality and that all images were still diagnostically acceptable. We did not find a large systematic review examining dose optimisation techniques and image quality in lumbar spine radiography. Due to a wide variety of procedures, techniques, and modalities in radiology, this cannot be generalised to all diagnostic procedures. Therefore, a targeted review should be performed separately for each procedure and modality.

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Case report

RADIOSURGERY FOR MULTIPLE BRAIN METASTASES IN NON-SMALL CELL LUNG CANCER – PARADIGM SHIFT

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ABSTRACT

Purpose: The purpose of this paper is to present a case of multiple brain metastases treated with LINAC-based radiosurgery (SRS).

Materials and methods: Case report and a summary review of pertinent literature regarding SRS for multiple brain metastases.

Results / Case Study: This case presents a patient with non-small cell lung cancer diagnosed with nine brain metastases who was treated with SRS. During follow-up, all brain lesions showed complete response with minimal impact on the patient's quality of life.

Discussion and Conclusion: The role of SRS is expanding, and recent published trials have showed promising results supporting its use in patients with more than four brain metastases. As our case suggests, SRS can be an effective and safe treatment for these patients and should be considered by physicians when they are presented with a similar case.

Keywords: Stereotactic; Radiotherapy; Radiosurgery; Brain metastases

INTRODUCTION

Brain metastases (BM) from non-small cell lung cancer (NSCLC) occur in approximately 10% of patients at the time of diagnosis, and this proportion is even higher in patients with advanced-stage disease (approximately 30%) (1). BM can lead to serious complications related to neurological deterioration and a diminished quality of life (QoL).

Treatment options include surgical resection, radiotherapy (RT) (whole-brain radiotherapy (WBRT) and, in selected patients, stereotactic radiosurgery (SRS)) or a combination of both. Historically, SRS has been reserved for patients with one to four BMs. However, over the last decade, this treatment modality has become more widely available, and evidence from recent clinical investigations has shown promising results supporting the use of SRS in patients with more than four BM (2,3,4).

The authors present a clinical case report of a patient with NSCLC treated with SRS for nine BM, with a complete clinical response in all brain lesions.

MATERIALS AND METHODS

All the clinical information was based on medical records, imagiologic findings, patient interview and physical examination.

A Linear accelerator TrueBeam™ STx with 120 HD multileaf collimator was used for SRS delivery.

The authors conducted a brief search on Pubmed, SCOPUS and Clinical Key database, with MESH terms: "Stereotacic radiosurgery" and "multiple brain metastases". The authors reviewed publications since 2010.

CASE STUDY

A 62-year-old man with a Karnofsky Performance Status (KPS) score of 100% was diagnosed in September 2012 with lung adenocarcinoma stage III-B according to the TNM staging system, 7th edition (5). The patient underwent concomitant chemoradiotherapy until October 2012. The chemotherapy regimen consisted of paclitaxel and carboplatin, and radiation therapy was administered at a dose of 66 Gy for the primary

tumour and regional lymph nodes. One month after RT, a follow-up CT showed disease progression in the lung, and the patient was treated with systemic chemotherapy with cisplatin and pemetrexed, followed by maintenance with pemetrexed until January 2014. Due to the local progression of the pulmonary lesions, pemetrexed was stopped and docetaxel was initiated until June 2014.

In December 2018, the patient developed neurological symptoms (syncope, tremor, and speech disorders). After admission to the emergency room, he underwent brain computed tomography (CT), which revealed two ring-enhancing lesions with surrounding oedema in the occipital and frontoparietal lobes.

An additional brain Magnetic Resonance Imaging (MRI) was performed that revealed nine suspected lesions (shown in Fig. 1, right column images): lesion 1 was 6 mm in the left side of the precentral gyrus; lesion 2 was 4 mm in the left side of the precentral gyrus; lesion 3 was 17.4 mm in the anterior left frontal lobe; lesion 4 was 20.8 mm in the left paramedian parietal-occipital region; lesion 5 was 5 mm in the right paramedian occipital region; lesion 6 was a millimetric lesion in the right cerebellar hemisphere; lesions 7, 8, and 9 were millimetric lesions in the left cerebellar hemisphere. Lesions 1 through 5 were associated with extensive surrounding oedema, causing a mass effect. MRI findings, along with patient clinical history, were considered highly suggestive of BM. Steroid therapy was immediately initiated, and the patient was scheduled for SRS.

For SRS treatment planning, a CT without contrast (slices of 1 mm thickness), along with a brain gadolinium-enhanced MRI (1 mm slice thickness) were requested. All lesions were treated with LINAC-based SRS using a commercial stereotactic mask fixation system in conjunction with the iPlan 4.1.1, Brainlab treatment planning system. Target volumes – Gross tumour volume (GTV), clinical target volume (CTV), planning target volume (PTV), and organs at risk were contoured on thin-slice (1 mm) gadolinium-enhanced T1-weighted axial MR imaging obtained 10 days prior to SRS and fused to the treatment planning CT. The GTVs were delineated as contrast-enhancing tumours demonstrated on MRI scans without CTV expansion. For all lesions, a 1 mm geometric expansion was created around the GTVs to generate the PTV. Linear accelerator TrueBeam™ STx with 120 HD multileaf collimator was used for treatment delivery, and all the lesions were treated using flattening filter-free 6 MV photons (plan details are described

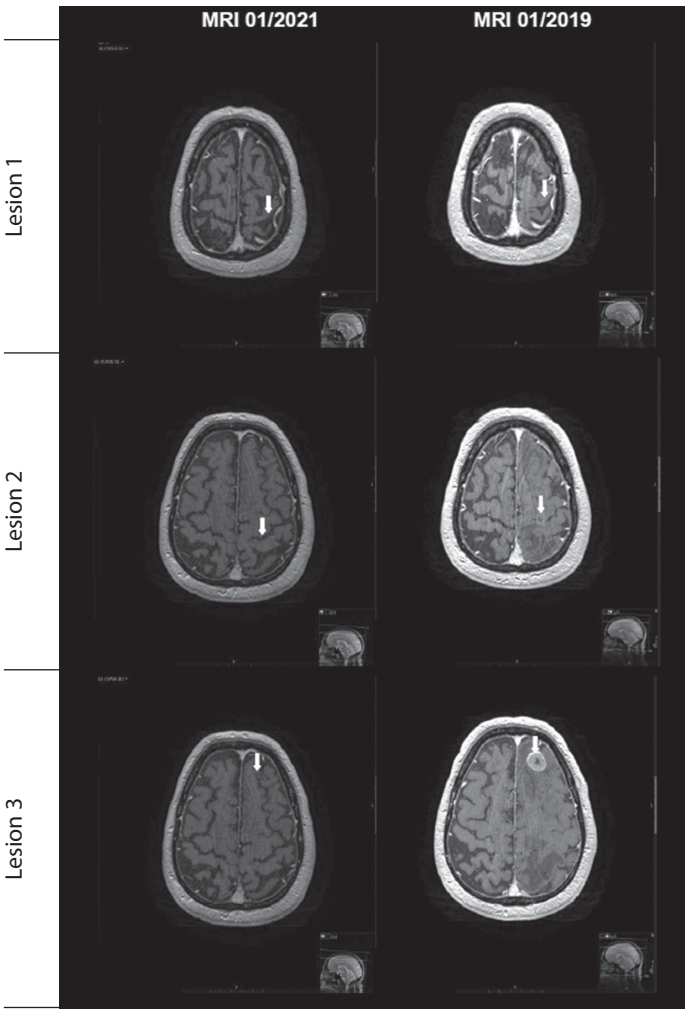

Figure 1: Brain MRI images - lesions 1, 2 and 3. On the left MRI from January 2019 (before radiotherapy treatment) and on right the MRI from January 2021 (last imagiologic follow-up)

Table 1 – Radiotherapy plan description

	Volume (cm³)	***Total Dose / Fractions***	***Technique***	***$D_{98\%}$***	***CI***	***GI***	***Normal Brain***
PTV lesion 1 and 2	1,4	24Gy / 1fr	DA	23,3 Gy	1,35	5,36	V_{12Gy} = 5,6 cm³
PTV lesion 3	5,82	27Gy /3 fr 1fr / day	VMAT	26,4 Gy	0,97	4,43	V_{18Gy} = 7,7 cm³
PTV lesion 4	7,23	27Gy /3 fr 1fr / day	VMAT	26,3Gy	1,03	4,11	V_{18Gy} = 11,8 cm³
PTV lesion 5	0,46	24Gy / 1fr	DA	21,7Gy	0,43	5,58	V_{12Gy} = 3,8 cm³
PTV lesion 7	0,39	24Gy / 1fr	DA	22,8 Gy	0,77	5,9	
PTV lesion 6	0,41	24Gy / 1fr	DA	23,2 Gy	0,85	6,34	V_{12Gy} = 8,0 cm³
PTV lesion 8	0,38	24Gy / 1fr	DA	23,4 Gy	1,00	7,89	
PTV lesion 9	0,36	24Gy / 1fr	DA	22,0 Gy	0,47	6,67	
	Total 16,45						

PTV: Planning target volume; fr: fraction; DA: Dynamic arcs; VMAT: Volumetric modulated arc therapy; CI: Conformity index; GI: Gradient index

in Table 1). This treatment ended in January 2019, was well tolerated, and the patient did not experience headaches nor did he have any other neurological complaints.

The patient was then followed-up with periodic physical examinations and MRI imaging according to the protocols of our institution (3-4 month intervals for the first year, 6 months for the second year, and then annually). At each visit, the neurological status and the severity of complications were scored according to the National Cancer Institute Common Toxicity Criteria for Adverse Events version 4.03 (6), and MRI scans were also performed and analysed by the same radiologist.

In April 2019, three months after SRS, all the cerebral lesions were smaller, as well as the surrounding oedema; however, there was disease progression in the lung and the patient began treatment. In September 2020, nine months after SRS, MRI showed complete radiologic response in all the nine brain lesions despite small residual gliosis.

As of January 2021 (24 months after SRS), the patient had remained with complete response on brain MRI (shown in Fig. 1-3, left images). At this time, the lung lesion had remained stable under pembrolizumab treatment, and the patient had remained highly functional (KPS 100%) without significant neurological symptoms or other treatment toxicities detected.

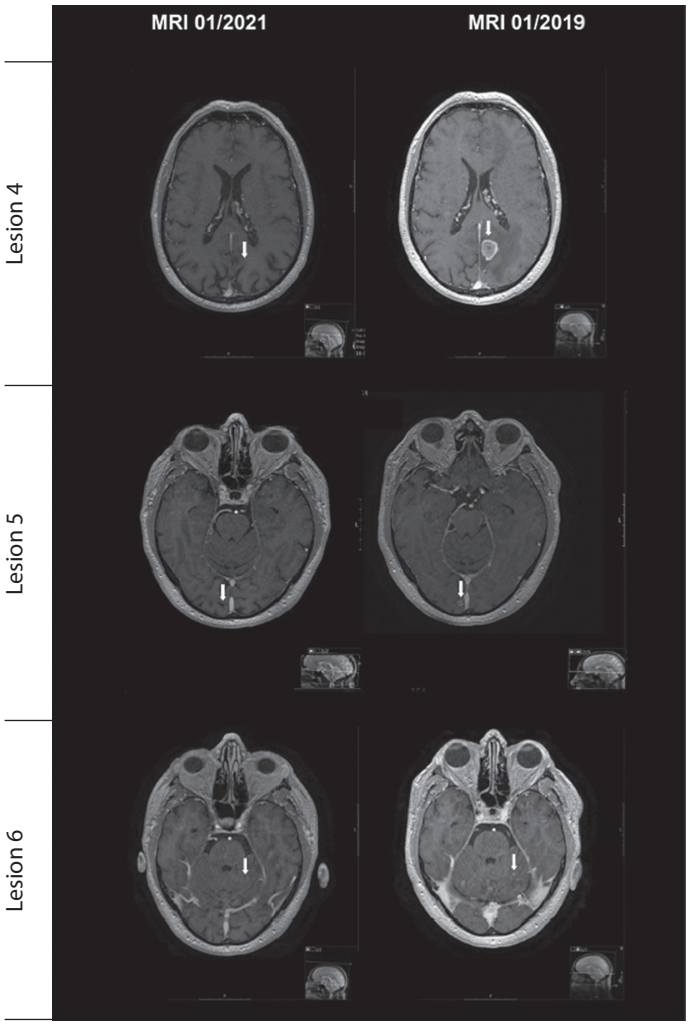

Figure 2: Brain MRI images - lesions 4, 5 and 6. On the left MRI from January 2019 (before radiotherapy treatment) and on right the MRI from January 2021 (last imagiologic follow)

DISCUSSION

The incidence of BM diagnosed in NSCLC patients has risen in recent years as a result of developments in imaging modalities, such as MRI, along with advances in systemic therapies, such as immunotherapy or targeted therapy (4). These refinements increased the sensitivity of detecting smaller lesions during screening examinations and improved survival rates. Locoregional treatment options for BM have never been as diverse as they are now (WBRT, surgical resection, SRS, or a combination of treatment modalities) (1).

The first investigations evaluating SRS were performed in patients with single lesion metastatic disease, either in combination with WBRT or as an alternative therapy to surgical resection. These results showed a lasting response to BM local control with minimal impact on the patients' QoL (1,3). With recent awareness of the neurocognitive effects of WBRT, multiple studies have evaluated SRS combined with WBRT versus SRS alone for intracranial metastatic tumours. The results have been in favour of SRS as they have shown minimal neurocognitive decline and improved QoL, with no differences in overall survival (OS) (7). Current investigations confirmed previous results and showed several other advantages of SRS over WBRT, including sparing healthy brain tissue, decreased time of treatment, improved tolerance to treatment, and reduced acute treatment-related toxicity (8).

Traditionally, SRS was used for patients with up to four BM, each lesion smaller than 3-4 cm, and it was usually performed in a single session (up to a maximum of five sessions) under the guidance of real-time imaging (9). In fact, most of the previous studies used these values as reference cut-offs; however, current evidence in the literature has suggested a benefit for patients with five or more BM (4,10). A Japanese prospective study (11,12) included more than 1 000 patients

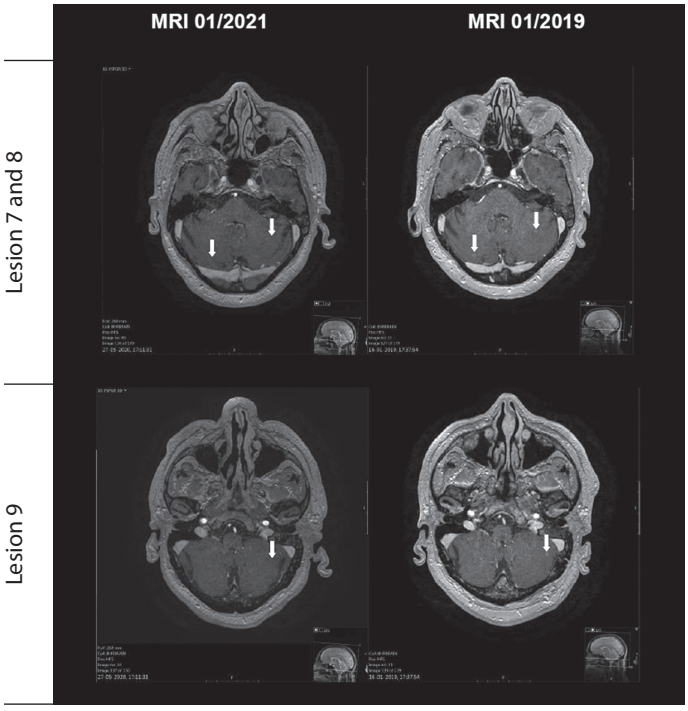

Figure 3: Brain MRI images - lesions 7, 8 and 39. On the left MRI from January 2019 (before radiotherapy treatment) and on right the MRI from January 2021 (last imagiologic follow-up)

divided into two groups of 2-4 and 5-10 brain metastases. Both groups were treated with SRS alone. In this non-inferiority study, overall survival, local failure, distant in-brain recurrences, neurological death, and toxicity were found to be similar in both arms. A retrospective cohort study showed no difference in survival between patients with > 10 and those with 2–9 brain metastases, all of whom underwent SRS monotherapy for all lesions (3).

Regarding the factors that influence survival, studies suggested that the rate of new BM development, total brain tumour volume, and the number of metastases should be considered as survival predictors in patients treated with SRS (13,14).

A multicenter retrospective study reported that patients treated with single-fraction SRS for > 4 BM, smaller total tumour volume, higher total dose, and lower volume of normal brain receiving >12 Gy were associated with increased survival (15). A single institutional retrospective study (16) included 1 017 patients with 1-10 BM treated with SRS and showed that tumour volume, KPS, and histology remained significant for OS on multivariate analysis, whereas lesion number did not. In this study, regarding histology, NSCLC and the group "Other" (including small-cell lung cancer, colorectal, ovarian, and prostate cancer) had a worse outcome than breast cancer, melanoma, and renal cell carcinoma. However, a clear definition of survival predictors in this setting must be supported by a stronger level of evidence (17).

Another significant issue that is related to survival rate is the cost at which the patient's survival is extended. One very recent study addressed this question by comparing health-related QoL between patients treated with SRS with 1-4 BM or 5-10 BM. Health-related QoL was assessed using the Functional Assessment of Cancer Therapy-Brain, a self-report questionnaire specific to patients with brain tumours. The results showed no statistical differences between the two groups, suggesting that SRS could be a useful tool for these patients when balancing disease control and QoL (18).

CONCLUSION

The present case describes a successful approach for a patient with multiple BMs treated with SRS. Patients with multiple lesions, but a low overall disease volume, might be suitable candidates for SRS. When presented with a similar clinical case, all treatment options should be considered by physicians and they should also be individually analysed considering numerous specific factors such as patient's performance status, comorbidities, lesion specificities (such as number and size of the BM), histopathologic features, and the extracranial tumour burden. Nevertheless, the authors believe that SRS should always be considered as a successful and effective approach with a few collateral effects.

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Original article

ESTIMATION OF CEREBROVASCULAR INSULT FREQUENCY IN EMERGENCY PATIENTS AT THE CLINICAL HOSPITAL CENTRE RIJEKA

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ABSTRACT

Purpose: Cerebrovascular stroke is defined as a sudden focal neurologic deficit caused by cerebrovascular disease lasting longer than 24 hours. Cerebrovascular insult (CVI) is divided into ischemic and hemorrhagic. Along with heart disease and malignancies, cerebrovascular disease is the most common cause of mortality and disability in the modern world, attributing to this disease being the leading cause of disability across the globe. Diagnosis and identification of the type of stroke requires imaging examination with computed tomography. A detailed history and imaging usually rule out the impersonation of a stroke. Computed tomography (CT) is one of the first diagnostic modalities used to image the brain to identify the difference between ischemic and hemorrhagic stroke. The aim of this retrospective analysis was to estimate the incidence of cerebrovascular insult in patients who underwent CT brain examination in the Clinical Department of Radiology at Clinical Hospital Centre (CHC) Rijeka in the period from January 1, 2020, to December 31, 2020.

Materials and methods: During this period, 255 data sets from patients' medical records were anonymously collected. The data search included patients who underwent CT of the brain with a clinical question about CVI.

Results: The data analysis at CHC Rijeka showed that the incidence of CVI is slightly higher in the male population. It is commonly diagnosed in the population of 81-90 years. About half of the patients with suspected CVI had normal CT findings.

Conclusion: These results could serve as a guideline for targeting groups in preventive healthcare interventions and education.

Keywords: computed tomography, cerebrovascular insult, ischemic stroke, hemorrhagic stroke

INTRODUCTION

The World Health Organization has defined stroke as „a clinical syndrome of vascular etiology manifested by the sudden onset of a focal or global brain defect lasting more than 24 hours or leading to death" (1). The severity of disability of the survivors is a major and very difficult problem, not only in medical terms but also in socioeconomic terms. The mortality rate ranges from 63.5 to 273.4 deaths per 100,000 population per year (2). Therefore, it is crucial to detect stroke early and treat it quickly to reduce morbidity and mortality. In preventing morbidity and mortality, rapid and accurate diagnosis through various modalities plays an important role. One of them is computed tomography (CT). CT imaging is widely available, accessible, noninvasive, and the relatively most accurate investigation used in stroke, and the modality of choice is the initial investigation in a stroke patient. The purpose of CT is to differentiate ischemic stroke from intracranial hemorrhage and to rule out other pathologic processes, such as tumors and vascular malformations that may clinically mimic stroke (1).
A stroke occurs when certain areas of the brain suddenly lose blood flow, depriving brain tissue of oxygen and nutrients. The brain cells begin to die within minutes. There are two main causes of stroke: occluded artery (ischemic stroke, Figure 1) or intraparenchymal bleeding (hemorrhagic stroke, Figure 2). A temporary disturbance of blood flow to the brain that leaves no permanent consequences is also called a transient ischemic attack (TIA) (3). Ischemic stroke is the most common type of stroke. It occurs when the blood vessels of the brain are blocked. This condition is caused by fatty deposits that accumulate in the blood vessels, blood clots, or other debris that travels through the bloodstream and accumulates in the blood vessels of the brain (3). Inadequate blood flow in a cerebral artery can often be compensated by an effective collateral system, particularly between the carotid and vertebral arteries via anastomoses in the ring of Willis and, to a

lesser extent, between the great arteries supplying the cerebral hemispheres. However, normal variations in the ring of Willis and the caliber of various collateral vessels, atherosclerosis, and other acquired arterial lesions can impair collateral vessel flow, increasing the possibility of occlusion of an artery, leading to cerebral ischemia (4). Hemorrhagic stroke occurs when an artery within the brain parenchyma ruptures. Bleeding in the brain can result from a variety of causes that involve blood vessels. Factors associated with hemorrhagic stroke include uncontrolled hypertension, excessive anticoagulant treatment, aneurysms, trauma, cerebral amyloid angiopathy, etc. (3). A transient ischemic attack, sometimes called a „mini-stroke," is a transient episode with symptoms that resemble a stroke. A TIA causes no permanent damage and is caused by a temporary interruption of blood flow to the brain that can last up to five minutes. Like an ischemic stroke, TIA occurs when a clot or debris reduces or blocks blood flow to a specific part of the central nervous system (3).

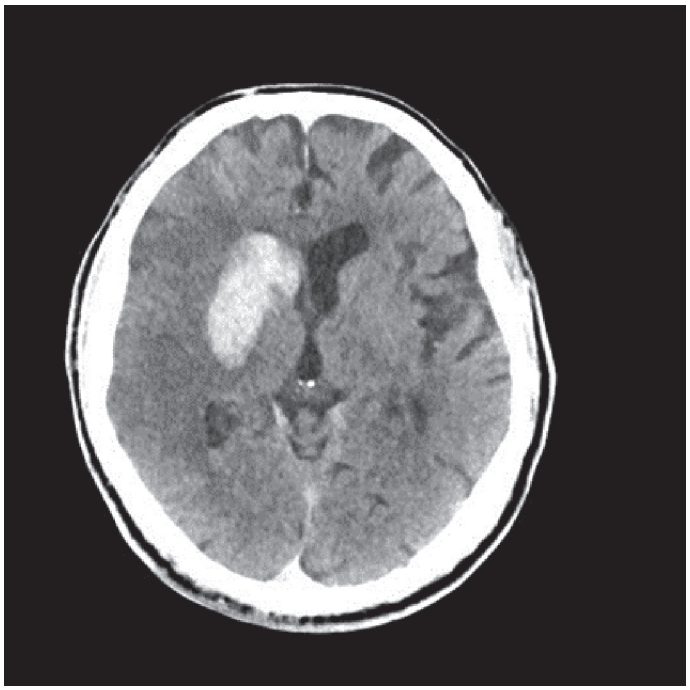

Figure 1: CT of the brain, axial section, view of hemorrhagic stroke. Source: CHC Rijeka database (retrieved June 30, 2021)

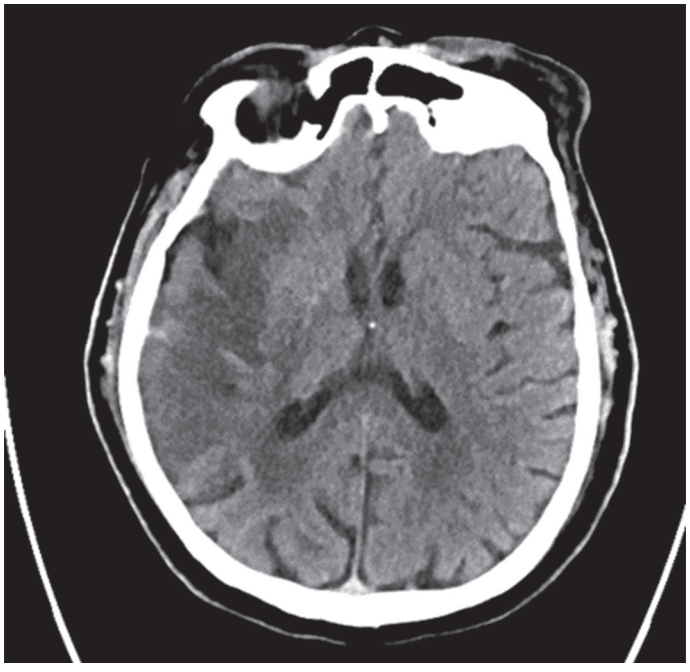

Figure 2: CT of the brain, axial section, view of ischemic stroke. Source: CHC Rijeka database (retrieved June 30, 2021)

Risk factors for stroke are divided into variable factors and biological factors such as sex, age, race, and genetic inheritance. People above 55 years of age, men, black and Asian race have a higher risk of stroke. The first and most important factor that can be controlled is hypertension. A person with high blood pressure is three times more likely to have a stroke, and successful treatment reduces the likelihood of stroke by 50%. Heart fibrillation, which is another cause, increases the risk of stroke by 30% in people over the age of eighty. Taking anticoagulants reduces the risk by 70%. Other risk factors that are influenced by human behavior are cardiovascular disease, diabetes, smoking, dyslipidemia, etc. (4).

In patients with a clinical suspicion of stroke, rapid and accurate diagnosis is required, so several steps are taken. All patients with suspected acute cerebral infarction who are admitted to the hospital must undergo a physical examination, which includes taking a medical history or heteroanamnesis, determining neurological status, and performing laboratory tests. The patient then undergoes one of the radiological diagnostic imaging modalities to assess the stroke and determine its nature and duration (5).

One of the most important aspects in the evaluation of patients with acute ischemic stroke is CT (6). The CT description of stroke defines three main phases: acute (less than 24 hours), subacute (24 hours to 5 days), and chronic (after 5 days) (7). Acute stroke is cytotoxic edema, and the changes can be subtle but significant. In addition to the term acute stroke, terms such as „early ischemic change" are also used, and it used to be called „hyperacute". Cytotoxic edema is an intracellular edema and results in the loss of the normal interface between gray and white matter (differentiation) and depletion of cortical furrows. Subacute stroke is a vasogenic edema with greater fat effect, hypoattenuation, and well-defined margins. The fat effect and risk of herniation are greatest at this stage. Chronic strokes are characterized by loss of brain tissue and hypoattenuation (8).

The aim of the study was to determine the frequency of cerebrovascular insults in patients who underwent a CT brain examination at the Clinical Department of Radiology at CHC Rijeka in the period from January 1, 2020 to December 31, 2020. In addition to the frequency, the incidence of cerebrovascular insult by gender and age, as well as the type of cerebrovascular insult based on the radiological findings were also investigated.

MATERIALS AND METHODS

The data required to conduct the study were collected in the CHC Rijeka by analyzing the data in PACS (Picture Archiving Communication Systems). The study included 225 patients who underwent CT at the Clinical Department of Radiology in Rijeka for suspected cerebrovascular insult between January 1, 2020 and December 31, 2020. The data search included

patients who underwent CT of the brain with a clinical question about CVI.

The data analysis refers to referral diagnoses and clinical questions exclusively under the keywords "CVI" and cerebrovascular insult. All other instructions for diagnoses and clinical questions were excluded from the analysis. Data on patient acquisition and gender were also collected in the same way. Based on the data obtained and to assess the difference in the incidence of CVI according to sex and age, the patients were divided into 10 age groups and the age of the youngest and oldest patients was determined. In the study of CT findings in 225 patients, the number of detected pathological changes of the brain and normal findings without signs of CVI were analyzed. The obtained data were divided according to gender and age.

RESULTS

Of the total of 225 patients, 126 or 56% were men and 99 or 44% were women (Figure 3).

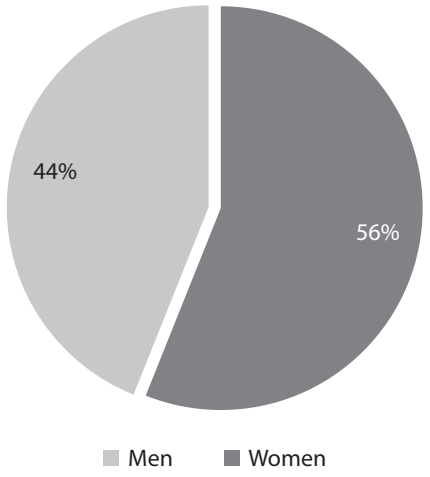

Figure 3: Gender distribution of patients who underwent CT -examination of the brain with clinical suspicion of CVI in the Clinical Department of Radiology in Rijeka in the period from January 1, 2020 to December 31, 2020

Patients included in this study were divided into age groups in addition to gender. The average age of the patients is 72 years, with the youngest patient being 13 years old and the oldest 96 years old. The largest proportion consists of patients in the age group of 81 to 90 years, 72 or 32.0% of them, then 58 or 25.8% in the age group of 61 to 70 years and 51 patients or 22.7% of them, aged 71 to 80 years. As for gender, the largest proportion in the group of women is 81 to 90 years old, with 43.4% (43 women), while in the group of men the largest number of patients is in the age group of 61 to 70 years, with a total of 38 patients or 30,2%. In the younger age groups, a much smaller number of patients was expected, so in the group of 51 to 60 years there were 27 patients or 12.0%, with twice as many men as women in the group. In the 41 to 50 age group, there were 6 patients or 2.7%, most of whom were also men. In the 31 to 40 age group, all patients treated were male and accounted for 1.8%. The youngest patients, up to 30 years old, were 2 or 0.9% (Figure 4).

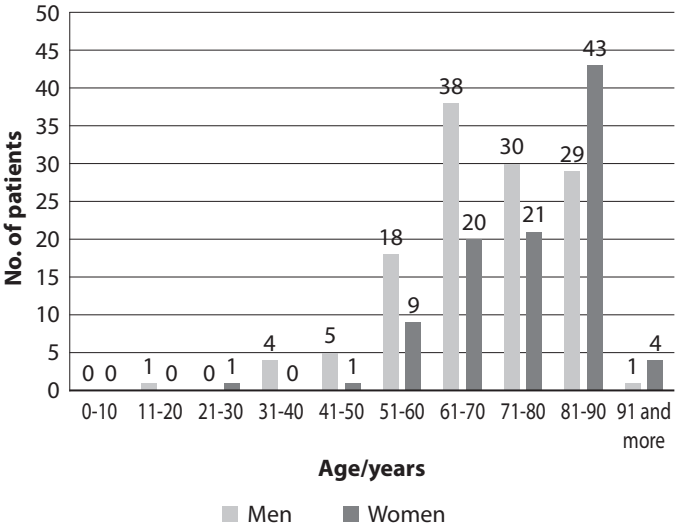

Figure 4: Representation of patients by age and gender who underwent CT examination of the brain with clinical suspicion of CVI in the Clinical Department of Radiology in Rijeka in the period from January 1, 2020 to December 31, 2020

Of the total patients examined for suspected cerebrovascular insult who underwent CT, 101 or 44.9% had normal morphologic CT findings without evidence of ischemic stroke or without definite ischemic or hemorrhagic changes and without the presence of a tumor mass. There were 54 patients or 24.0% diagnosed with a chronic ischemic lesion on CT. 30 patients or 13.3% were diagnosed with an acute ischemic lesion. Intracerebral hemorrhage was diagnosed in 20 patients or 8.9%. 20 patients or 8.9% were categorized as others (patients diagnosed with a tumor who underwent CT examination for control) (Figure 5).

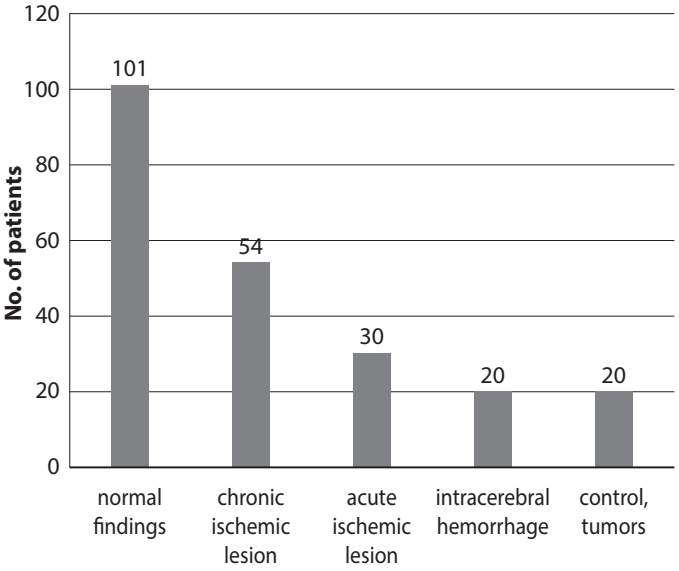

Figure 5: Frequency of pathological changes in the radiological findings of the brain CT in patients investigated in the Clinical Department of Radiology, locality of Rijeka, in the period from January 1, 2020 to December 31, 2020

Of the total number of patients (99), 44 or 44.4% had no detectable signs of acute stroke on CT scan, 25 or 25.3% had signs of chronic ischemia, and 16 or 16.2% had signs of acute ischemic lesion. We found 7 patients with intracerebral hemorrhage, and 14 patients with a tumor or follow up scans (Figure 6).
In the group of treated male patients (126), 57 or 45.2% were normal, 29 or 23.0% had the described chronic ischemia, and 14 or 11.1% had the described acute ischemic lesion. There were 13 or 10.3% of patients with an intracerebral hemorrhage, and 13 or 10.3% of patients were diagnosed with a tumor or were undergoing control (Figure 7).

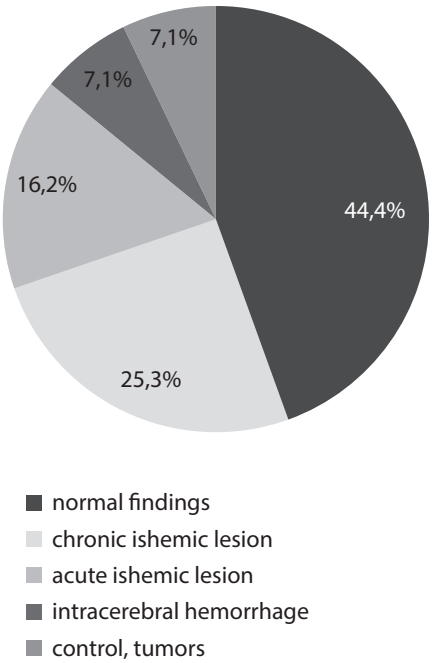

Figure 6: Frequency of pathological changes in radiological findings of the brain CT in female patients who were in the Clinical Department of Radiology in Rijeka in the period from January 1, 2020 to December 31, 2020

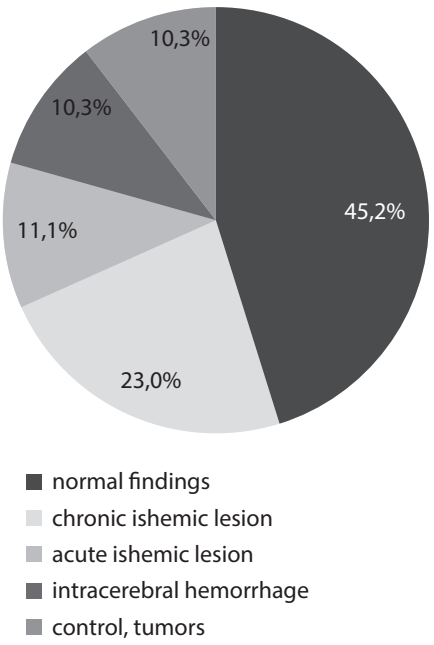

Figure 7: Incidence of pathological changes in radiological findings of the brain CT in male patients who were in the Clinical Department of Radiology, Rijeka, in the period from January 1, 2020 to December 31, 2020

There were more male patients with no evidence of CVI, 57 or 56.4%. Of the total number of patients with described ischemia (chronic and acute) and intracerebral hemorrhage, 56 or 53.8% were male patients and 48 or 46.2% were female patients, while 13 or 65% were male patients with a diagnosed tumor or were undergoing a follow-up scan (Figure 8).

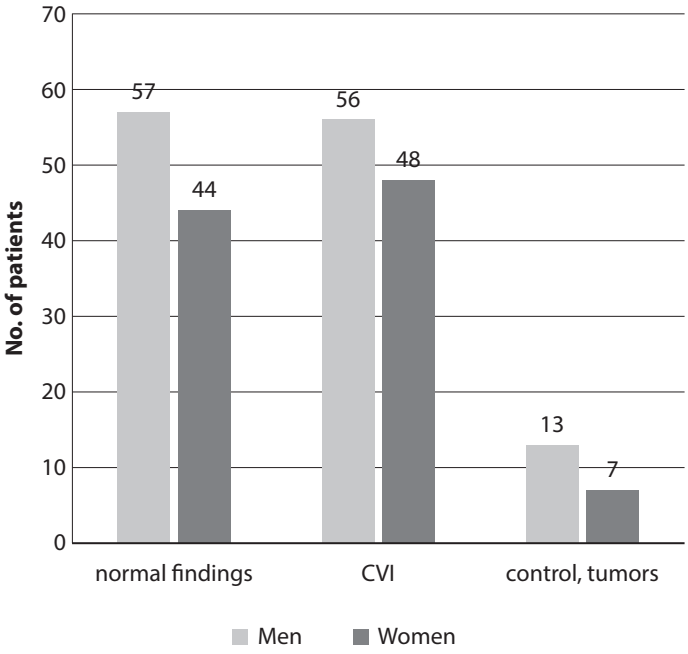

Figure 8: Gender representation of patients with pathological changes in the radiological findings of the brain CT who underwent CT at the Clinical Department of Radiology, Rijeka, in the period from January 1, 2020 to December 31, 2020

Among the patients with ischemia (acute and chronic) and intracerebral hemorrhage described in the CT report, the largest number is in the age group 81 to 90 years (45 or 43.3%), patients in the age group 61 to 70 years (25 or 24.0%), and patients aged 71 to 80 years (23 or 22.1%). The proportion of females with ischemia and intracerebral hemorrhage depends on the age. In older age groups, the proportion of women increases, while in the younger groups the majority are men (Figure 9).

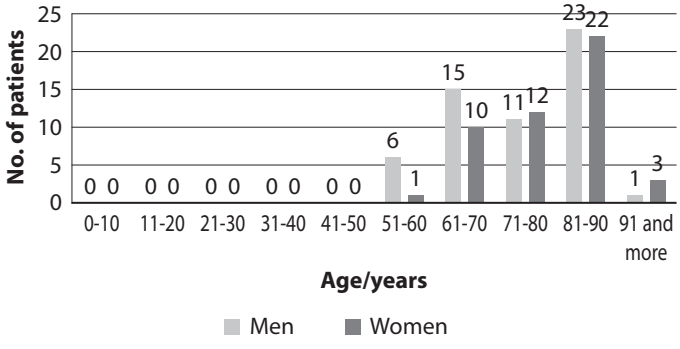

Figure 9: Representation of patients by age and gender with the findings of ischemia (chronic, acute) and intracerebral hemorrhage who underwent CT in the Clinical Department of Radiology in Rijeka, in the period from January 1, 2020 to December 31, 2020

DISCUSSION

The results of the analysis of patients with a finding of ischemia (chronic, acute) and intracerebral hemorrhage in suspected cerebrovascular insult cases (CVI) at the CT examination of the brain showed a slightly higher representation of male patients - 56 patients or 53.8%. Considering the very small difference between males and females, we can determine that it is an equal ratio of representation. According to a survey conducted in 2012 by the Department of Radiodiagnosis, College of Medical Sciences - Teaching Hospital, Bharatpur, out of 100 patients with a confirmed diagnosis, 72 (72%) were men and only 28 (28%) were women (9). In a study published in 2016 to assess stroke subtypes and risk factors in patients admitted to Sayad Shirazi Hospital, Gorgan, 218 (58.19%) males and 157 females (41.90%) with a confirmed diagnosis were recorded (10).

Amongst the age groups of patients with a confirmed diagnosis of cerebrovascular insult, most of them (45 or 43.2%) were between 81 and 90 years of age. However, some studies show that the mean of years with a positive finding is 57.29 years. A 2020 study showed that the most common age group affected by stroke is between 43 and 62 years (11). Furthermore, the results of a study conducted in 2015 at the Department of Radiology in the Nigerian Tertiary Hospital showed that the mean age was 55 years (12).

In addition to the analysis of gender and age, a statistical analysis of the frequency of morphologically ordinary findings without CVI was also performed in patients who were examined for suspected cerebrovascular insult with the CT scan. Out of a total of 225 patients, 101 showed no CT signs of CVI. This result confirms that the largest number of patients in whom CVI was suspected due to a clinical question, had CT with normal findings, i.e., it showed no changes in the morphology of the brain. In patients referred to the brain CT, the clinical findings are generally suggestive of stroke, but early CT scans often do not show the parenchymal changes that would define ischemic stroke. In a 2020 study, of the 100 cases examined, ischemic infarction was the most common (56%), followed by intracerebral hemorrhage (27%), and brain tumor and subdural hematoma (1%) were the least common. A normal CT finding accounted for only 5% of the total population (12). However, the results of the 2015 study show that of the 271 patients who underwent a CT brain scan for suspected cerebrovascular insult, 188 had normal findings or early ischemic changes, while 83 patients met the criteria for the study to be conducted. In it they were categorized as ischemic infarction and hemorrhagic infarction (12).

CONCLUSION

One of the most important aspects in the evaluation of patients with acute ischemic stroke is the CT scan. The data analysis at CHC Rijeka showed that CVI has a slightly higher incidence in the male population. It is commonly diagnosed in the population aged 81-90 years. About half of the patients with suspected CVI had normal CT findings. These results could serve as a guideline for targeting groups in preventive healthcare interventions and education.

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