Static dosimetry space image in which urology diagnostics are performed

Milorad S. Banduka,[1] Dušan D. Vasić[2]

[1]Institute of Biophysics, Faculty of Medicine Sarajevo,
[2]General Hospital, Doboj, Bosnia and Herzegovina

Background. *The effects of the dispersed radiation described theoretically imply complex picture of interaction of the photon beam with the patient's body, as well as its dispersion on other structures. Basic theoretical laws of this phenomenon are highlighted, thus giving the opportunity to model the effect in total.*
Material and methods. *The measurements of the absorbed dose in the air give isodose curves that show distribution of the radiation dose. For the urological procedures standard urological diagnostic methods were being used.*
Results. *Through a large series of measuring, we got the distribution of the radiation dose in space, where urology diagnostics is being made using the X-ray. The parameters determining this picture are the most frequent ones in the total number of 20 random cases taken in General Hospital in Doboj, Bosnia and Herzegovina.*
Conclusions. *Static dosimetric picture of the space (radiation zone) in the general sense is useful before all for organisation of the diagnostic procedures utilising ionised radiation. Obtained in any way, this picture enables an insight into the three-dimensional distribution of the dosage on the basis of which it is possible to correct the organisation of the diagnostics being performed under these conditions. The values of the radiation dosage show it is necessary to use the protecting means prescribed by law. For more frequent exposure, it would be useful to make a dynamic dosimetric picture for professional exposure and assessment of the radiation risk of these persons.*

Key words: urology; radiation dosage; photons

Received 4 April 2002
Accepted 15 June 2002

Correspondence to: Prof. Milorad S. Banduka, Krfska 6, 78 000 Banja Luka, Bosnia and Herzegovina

Introduction

Within the frame of the general problem of electromagnetic interactions with the media, a problem of photon interaction is being considered. It can occur on the electron cloud as well as in the atom core. The probability of occurrence of these processes, however, shows that three effects [photo-effect, elastic dispersion on free electrons - (Compton and

Thompson effect), and pair effect] are highly dominating. All effects of interaction of photons with atomic core in the domain of the energies of photons in diagnostic radiology are excluded since the condition to start that process is not fulfilled. Contemplating the mechanism of photo-effect on the cloud electron directs to the significant component of absorbed energy spent to free the electron from the atom which, as a consequence, has an emission of characteristic radiation. This is particularly, the case, when dealing with the soft tissue or water (small ordinal number) whose K-electron connection energy, compared with the energy of incidental photon, is so small that practically all the energy that radiation brings in this way, is taken by the photo-electron.[1,2] On the other hand, applying the law on preservation of energy and impulse, it is easy to show that this effect cannot happen on free electron.

This is visible on the across section graph of this effect and energy of the incidental photon. The dependence shows a significant rise of across section in the area where energy of the incidental photon is close to the energy of K, L, M electrons. The analytical expression of this dependence is based on a quantum-electro-dynamical approach.[3,4]

In the effects of the elastic dispersion of photons there is a distinction between the effects when the dispersed photons have the same wave length as the incidental photons (Thompson-coherent dispersion), and when the photons change their wave length with elastic dispersion (Compton's effect). Both effects happen on free electron. The coherent dispersion is discussed in a classic way and the value of the cut for this effect is given with[2]

where $$r_0 = \frac{e^-}{mc^2}$$

is classic electron radius and it equals $r_0 = 2.8 \times 10^{-10}$ m.

In order to determine the radiation dose in space (outside primary beam), it is necessary to be familiar with the distribution of the dispersed photons presented by Johns and Cunningham.

Exploring the behaviour of the radiation dosage in the space (outside the primary beam), we can expect the influence of this effect. That is why it is important to say that the distribution of dispersed photons in this process is given by the expression.[2]

$$I_{(\varphi)} \cong \text{const}\,(1 + \cos^2\varphi) \qquad (2)$$

where $I_{(\varphi)}$ is an intensity of the photons dispersed under the angle φ.

With the second, Compton's effect, the dispersed photon changed its wave length depending on the dispersion angle

$$\Delta\lambda = \lambda' - \lambda = \Delta(1 - \cos^2\varphi) \qquad (3)$$

where λ is a wave length of the dispersed photon under the angle φ, while Δ is

$$\Delta = \frac{n}{m_e c} = 2.4 \times 10^{-12} m$$

This expression was also reached using the preservation laws starting from the fact that the dispersed photon and recoiled electron have mutually shared the energy of the incidental photon. The explanation of this mechanism leads to the confirmation of the particle characteristics of the photons (in classical approach the energy of the dispersed particle is a function of an angle of dispersion), which has its academic significance. Will this effect happen? And if it happens, what is the probability that photon will be dispersed under a specific angle? Here is a complex expression for across section based on a quantum-mechanic approach. This expression in the form of differential total section was given by Klein and Nishina as[5,2]

- where $\frac{d_e\sigma}{d\Omega}$ presents probability that pho-

ton will be dispersed on an electron in a unit of the solid angle Ω under the angle φ;
- m_e - mass of the electron in peace;
- c - speed of light in vacuum.

$h\nu \rightarrow 0$ In the extreme case for low energies of the incidental photon when

$$h\nu \rightarrow 0$$

or

$$\alpha \rightarrow 0$$

$\alpha \rightarrow 0$ and the complex equation (4) transforms into the classical one (Thompson's case), that is

$$\frac{a_e\sigma}{d\Omega} = \frac{e}{2m_0^2c^4}(1 + \cos^2\varphi) \qquad (5)$$

which means that, with low energies, (soft Roentgen radiation-if the beam was not filtered), the contribution of coherent radiation will be significant, while with strongly filtered beam Compton's effect is more probable. In the soft tissue this process may occur on any electron of the atom since all electrons can be considered free - comparing their bound energy with the energy of incidental photon, which is the basic precondition for the development of this effect.

$h\nu \rightarrow 0$ Presenting the graphic equation of Klein-Nishina in the function of dispersion angle, it is evident that the distribution of dispersed photons differs in the energies of incidental photon from Thompson $h\nu \rightarrow 0$ distribution from the line at 10 MeV, when there is no photon dispersing back.[5,2] By integrating the equation on all angles using the substitution

$$d\Omega = 2\sin\varphi\, d\varphi$$

we get the total section of the Compton's effect as a number whose value is expressed as a function of the incidental photon energy. Theoretical conclusion is that the total cross section of the Compton's effect decreases with the increase of energy.

The component of the section that at Compton's process relates to the dispersion σ_R can be found by multiplying Klein-Nishina equation with the relation hν'/hν that is T_e/hν, for the component that relates to the absorption of σ_a.

By integrating according to the dispersion angles, we get

$$\sigma = \sigma_a + \sigma_R$$

$$\sigma = \sigma_R$$

for low energies because, with Thompson's process, a coherent radiation occurs and there is no absorption.[5]

The presented essence of these effects directs to the complexity of the mechanism of interaction of photon radiation with the matter. The consequence of these effects are photons dispersed in the space outside the primary beam of the source. In this work, we will present the way of determining the level of the radiation dosage in the space around the X-ray source as a consequence of the dispersion of the radiation in the patient during the examination and in other structures the beam encounters to.

Material and methods

Dosimetric methods

A certain level of radiation is detected in every point of this space (structures encountered by the radiation beam as well as walls of the room where the source is installed) with the effects of the dispersion. This value mostly exceeds the value, which could, in a dynamic picture, exceed the limited dosage (the limited dosage is the level prescribed by law). We determined the absorbed dosage in air for distant points by large series of measuring, which secured reliable results. Experimental methods for standard dosage measuring were used.

The following equipment was used:

- standard water phantom 200 x 200 x 150 mm with plastic walls;
- dosage measuring system Ionex with appropriate chambers by Nuclear Enterprises
- the radiation source was X-ray Telestatic used for urology diagnostics with possible scopia and graphia.

Methods applied in urology

In order to have a completely objective review of urological conditions of individual parts of uro-system, invasive x-ray diagnostic methods are applied in urology. Depending on the part of the uro-system to show, standard urological practice in General Hospital Doboj requires the presence of urologist, next to the patient (in radiation zone), during some testing - x-ray scopia or x-ray graphia. These methods are applied in the following conditions:

- retrograde urethrography
- retrograde cystoscopy
- retrograde uretheropyelography (Chevass method)
- retrograde (ascendant) pyelography.

The objective of the listed diagnostic procedures is the evaluation of morphological situation of the uro-system by visualising pathological changes as well as their consequences on the channel system. Apart from morphological data, there are also data of precious value for the estimation of functional condition, treatment and disease prognosis.

Pathologic changes that we were detecting by these methods might occur in any part of the uro-system: in urethra, urinary bladder, ureter, pyelocalix of kidney system. If the clinical, laboratory and echotomographic testing - extratornally and urographically - do not allow us to set the correct diagnosis, we apply the invasive diagnostic urological-radiological methods.

The basic principles should necessarily be followed for every single listed procedures that will be briefly explained:

- In retrograde urethrography, contrasting substances are injected by a rubber attachment and special syringes. Imaging is performed in AP and oblique positions of the patient during the injection of diluted contrasting substance.
- In retrograde cystography, urinary bladder imagining in AP and oblique projection of the patient is performed after the injection of diluted iodine solution, air as a negative means or combination of both means in two-component cystography.
- Contrasting substance intake may be direct - by the insertion of catheter under control or by the infusion system through the catheter installed in the urinary bladder. In such case, the liquid is 50 - 75 cm above urinary bladder level, and the gravity force helps fill it into the organ. The contrasting substance concentration ranges 10 - 30% (mostly 17%). The contrasting substance quantity is determined by the above stated conditions (it ranges from 20 - 120 ml in children, and 250 - 300 ml in adults). The contrasting substance quantity is usually determined individually per patient.
- The retrograde cystography and uretrocistography are, in most cases, simultaneously performed. They are separated in practice only when we are sure that there is a pathological process in the urinary bladder, without any repercussion on the other organ.
- In case of mictial cystourethrography, imaging is performed immediately after urinating, and in case of polycystography, fractional intake of contrasting substance is simultaneously followed by imagining in the same film, without changing of the patient's position.
- In retrograde ureteropyelography (Chevass method), retrograde pyelography and endoscopic setting of ureteral stents, the urologists control the performance personally and monitors the radioscopias.
- Having performed endoscopy of ureteral opening, an ureteral sonda with conal peak

of 4-6 Ch in diameter is inserted. Thus, the Chevass method applied in retrograde ureterocystography blocks the return of contrasting substance into the urinary bladder. By injecting the contrasting substance, a proximal ureter and pyelocalix system of the kidney are shown. This is monitored by scopia and recorded by graphia.

Results of measuring

The aim of work is to determine the static picture of the radiation dosage outside the primary beam, which is generated as a consequence of dispersion in the patient during radiological diagnostics.

The static picture was obtained for the parameters that were most commonly utilised in 20 cases of diagnostics. These parameters are:

- Voltage 90 kV
- Current 250 mA
- FKD 1 m
- Field 0.25 m x 0.25m

We measured the absorbed dosage in the air for the points that lay in the plain 1.1m above the floor. The obtained results were distributed in columns and rows, which enabled constructing the iso-dosage trajectories in that plain. The values of the strength of the absorbed dosage pointed in the picture are:

A - 2.5 10^{-3} Gy/h
B - 2 10^{-3} Gy/h
C - 1.5 10^{-3} Gy/h
D - 1 10^{-3} Gy/h
E - 0.5 10^{-3} Gy/h

Monitoring the position of the operator during the diagnostics, we can see that his/her body is in the radiation field whose minimal value ranges from 2.5 10^{-3} Gy/h up to 10 10^{-3} Gy/h.

In the immediate vicinity of the workdesk, the aforementioned chamber did not give reliable results so this area was controlled with a TL dosage-meter. It is expected that this picture will be useful for the assessment of the dosage that the patient receives during the examination (dynamic picture).

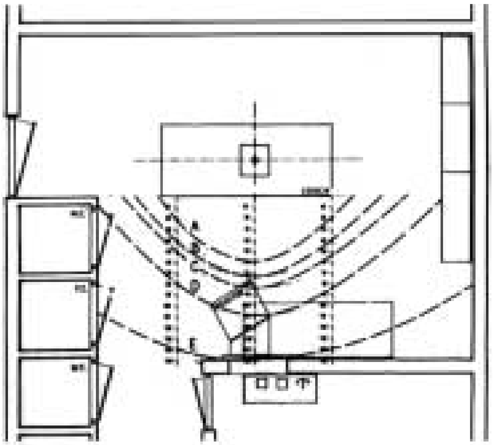

Figure 1. Distribution of the radiation dose in space in which urology diagnostics are performed.

Discussion

The problem of dispersion as a complex phenomenon is discussed today from experimental and theoretical view. Since experimental procedures are very long, avoiding certain phases can be done by modelling certain relations as a part of the overall procedure.

In today's literature, different theoretical approaches, based on nuclear across section as statistical values helping to assess some physical values, such as the intensity of the energy flux, exposition dosage, and similar, are offered. For the purpose of calculating the section, Klein-Nishina's equations of differential section as function of the energy of incidental photon and angle of dispersion are used today. On the basis of these analytical approaches, several computer programs are used today with the ambition to cover this problem in the general picture. The differences in the results gained through these programs and via experimental measuring are sometimes unacceptable. Besides, in the premise of the analytical calculations a lot of assumptions are introduced, which sometimes do not correspond with reality. However, we can be satisfied with the developments and occurrence of improved programs related to this problem.[6]

Conclusions

Static dosimetric picture of the space (radiation zone) in the general sense is above all useful for the organisation of the diagnostic procedures utilising ionised radiation. Obtained in any way, this picture enables an insight into the three-dimensional distribution of the dosage on the basis of which it is possible to correct organisation of the diagnostics being performed under these conditions. The values of the radiation dosage show that it is necessary to use the protecting means prescribed by law (appropriate clothing and glasses). For more frequent exposures, it would be useful to make a dynamic dosimetric picture for professional exposure and assessment of the radiation risk of these persons.

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