AN ASSESSMENT OF SCATTERED RADIATION DURING FLUOROSCOPIC PROCEDURES IN DIAGNOSTIC RADIOLOGY

by

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The results of measurements of scattered radiation in the vicinity of a fluoroscopic X-ray facility are presented in this paper. Two different fluoroscopic systems, one with an undercouch tube and one with an overcouch tube, were compared. The dose rate was measured during the simulation of a fluoroscopy procedure, using an ionization chamber as a dosemeter. The distribution of scattered radiation has been determined and results show a much higher dose rate in cases of an overcouch tube arrangement. When X-ray units with an undercouch tube are concerned, under same exposure conditions, the dose rate is higher in cases of a vertical beam. Prior to the measurements, the ionization chamber was examined in order to evaluate its suitability as a survey meter used in diagnostic radiology. Measurements show that below 1.2 s, the ionization chamber gives an underestimation of dose rates. Therefore, in order to perform accurate measurements using this instrument, exposure times should be above 1.2 s.

Key words: fluoroscopy, scattered radiation, ionization chamber, dose

INTRODUCTION

Fluoroscopy is used worldwide for diagnostic purposes in medicine. The doses to the medical staff performing the procedure can vary depending on the type and duration of the procedure [1, 2]. When radiation protection of the medical staff involved in diagnostic procedures is concerned, two main courses of action are in play. Those in which the equipment is controlled remotely, *e. g.* general radiography where the radiographer is usually situated behind a protective screen, and those in which the medical staff has to be close to the patient's coach. If the latter is the case, the radiation hazard to the staff is mainly affected by the overall design of the X-ray equipment, working habits of the staff and the location of the X-ray tubes [3]. There are two geometries of fluoroscopic equipment determined by the position of the X-ray tube: the one with an undercouch tube and that with an overcouch tube arrangement. On the whole, overcouch X-ray tube arrangements provide better flexibility, due to the greater focus-table top distance and the possibility to perform routine radiography using the same equipment. Also, this equipment is intended to be used remotely, so that the protection of the staff from radiation can be solved by an appropriate protective barrier design.

When medical staff has to be close to the patient's coach, it is desirable to be able to assess the dose levels in order to propose necessary radiation protection measures. Staff doses can be estimated from the results of measurements of scattered radiation doses in the vicinity of the coach. This requires the knowledge of typical technique factors, fluoroscopy times and the approximate position of the staff during the procedure [4-6].

The ionization chamber survey meter is the most desirable instrument for a radiation protection survey in conventional diagnostic radiology. The most important factor making this instrument the most suitable for these purposes is mainly its flat energy response [7, 8]. The measurement of scattered radiation is based on

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dose measurements in terms of the dose equivalent rate or air kerma rate [9]. Due to the nature of these quantities, it should not depend on exposure time. However, there is some influence of exposure time on the dose rate, due to the finite response time of each instrument [7]. Therefore, in order to perform accurate measurements, a proper instrument must be chosen and adequately used [8].

The aim of this experiment was: (1) to examine whether an ionization chamber used as a survey meter is independent of different exposure times selectable on a conventional radiology generator, (2) to determine the distribution of scattered radiation around the X-ray unit during standard fluoroscopic procedures in diagnostic radiology, and (3) to assess the effect of the design of fluoroscopic X-ray equipment on scattered radiation distributions.

The results presented here were obtained by measuring the dose equivalent rate in the vicinity of the patient's bed, using the ionization chamber as a survey meter. They can also be used in dose assessment to the medical staff. Similar results have already been published [4, 5], but using a different approach: analytical methods or Monte Carlo simulations.

METHODS AND PROCEDURES

Two different types of measurements were used. One to assess the suitability of the ionization chamber as a survey meter in diagnostic radiology, the other to determine the distribution of scattered radiation around a typical fluoroscopy X-ray unit. Scattered radiation was measured using a pressurized ionization chamber, INOVISION 451P (INOVISION, USA), calibrated in terms of the ambient dose equivalent rate (H*(10)).

In order to estimate the dependence of the dose rate against exposure time, scattered radiation was measured. So as to mimic a scattering medium, a water phantom (dimensions 15 cm 30 cm 30 cm) was used. The phantom was set up at 2 meters from the X--ray tube in the primary beam. Scattered radiation was measured at 2.4 meters from the edge of the phantom and at an angle of 90º. Due to technical problems associated with the stability of laboratory's high voltage supply, a divider DYNALYZER III (RADCAL, USA) was used in order to measure the true values of tube parameters. Also, correction factors were applied to measured dose rates, in order to diminish the differences between nominal and true tube current values.

Measurements of scattered radiation around the fluoroscopy units were performed on both overcouch and undercouch X-ray tube geometry. A rectangular shape water phantom with rounded corners (25 cm 25 cm 15 cm), placed in the center of the X-ray beam, was used to simulate a standard patient. The measurements were performed in the plane perpendicular to the cathode-anode axis of the couch in a horizontal position and parallel to the cathode-anode axis of the vertical couch orientation. So as to choose the appropriate tube voltage and tube current values, an automatic brightness control setting was used for the specified focus-table top distance.

RESULTS AND DISSCUSION

The results for ion chamber response dependence on exposure times are shown in figs. 1 and 2.

In the first set of measurements, the actual values of the tube current were less than the nominal value of 80 mA, so that the dose rates had to be corrected. The correction factor was estimated by dividing each actual tube current value by the average value. The plot of dose rates against exposure time depicts a continuous rise of the dose rate until it reaches a plateau (flat region) above the value of 1.2 s. Thus, measurements below the exposure time of 1.2 s indicate an underestimation of the true dose rate.

In order to verify this finding, a second set of measurements was performed using a different approach. In this case, the tube current was changed and the measured dose rates normalized by dividing them with the actual value of the tube current. Again, the

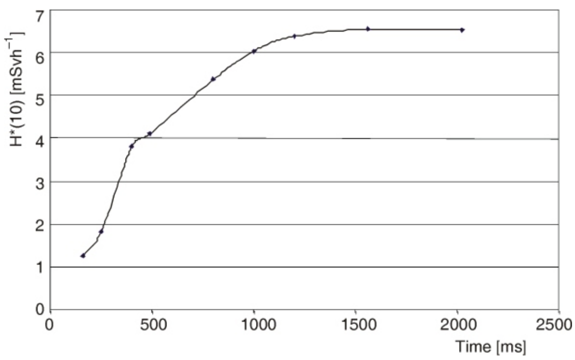

Figure1. Ion chamber response dependence on exposure time for u = 90 kVp and i = 80 mA

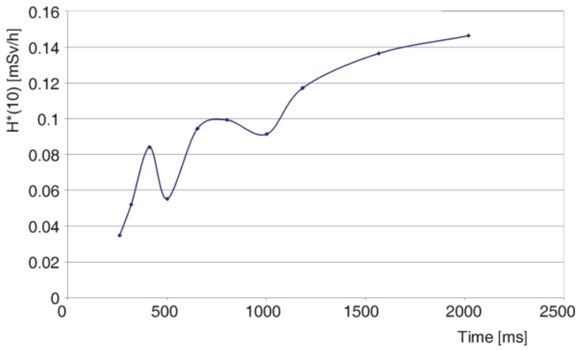

Figure 2. Ion chamber response dependence on exposure time for u = 90 kVp and $i{\cdot}t$ = 100 mAs

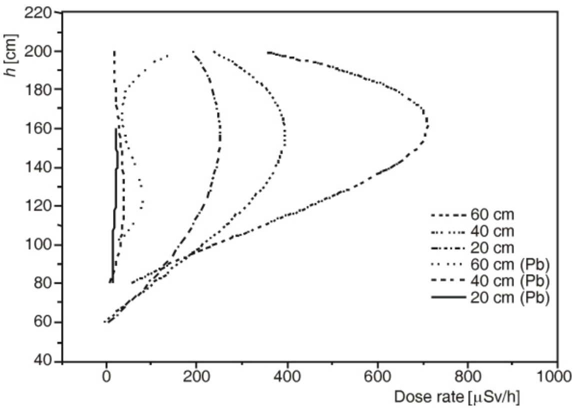

Figure 3. Vertical radiation profiles per unit X-ray tube current and u = 80 kV, in a vertical plane for an overcoach X-ray fluoroscopic installation; Pb indicates the presence of protective screens

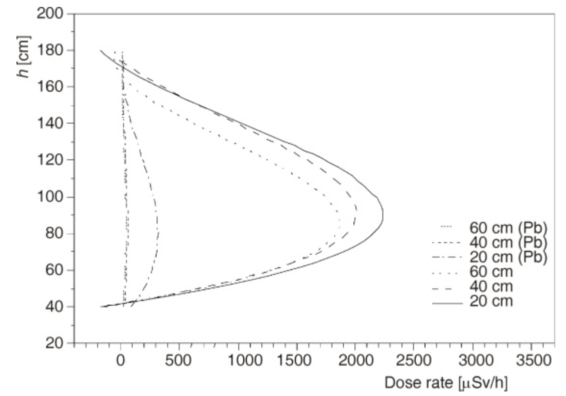

Figure 4. Vertical radiation profiles per unit X-ray tube current and u = 85 kV, in a vertical plane for an undercoach X-ray fluoroscopic installation; Pb indicates the presence of protective screens

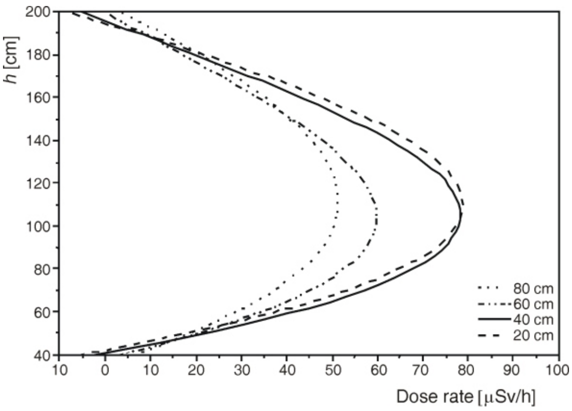

Figure 5. Vertical radiation profiles per unit X-ray tube current and u = 90 kV, in a vertical plane for an undercoach X-ray fluoroscopic installation; coach in horizontal position

dose rates for tube current fluctuations were corrected, using a correction factor, as previously described. The

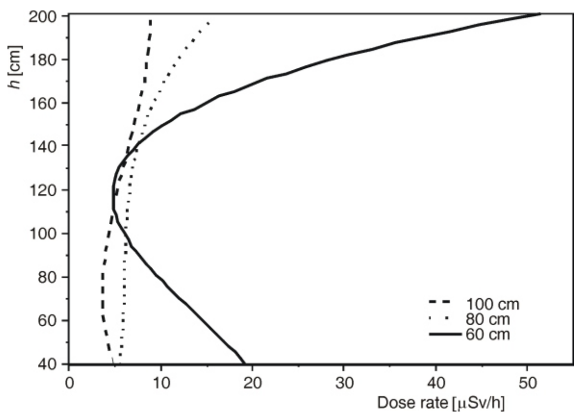

Figure 6. Vertical radiation profiles per unit X-ray tube current and u = 90 kV, in a vertical plane for an undercoach X-ray fluoroscopic installation; coach in vertical position

dose rate measured by the ion chamber reaches a plateau after an exposure time of 1.2 s, verifying the previous results. Radiation profiles (given in μSv/h) are shown in figs. 3-6. Dose rate contours were obtained by the interpolation of measured values at specified data points. The sampling was carried out in steps of 20 cm from 40 cm to 200 cm from the floor.

The situation where the lead protective screens of the intensifier or the X-ray tube housing were in position, as opposed to the one when they had been removed, was clearly distinguished. In most cases, the spatial variation in the dose rate is particularly large in the region of the eyes. It can, thus, be deduced that the staff standing back as far as possible, may achieve a significant reduction in the dose rate received.

The essential difference in radiation safety between the two types of fluoroscopic units lies in the scattered radiation aspects of the two systems. In the undercouch-tube arrangement, the X-ray tube is in a shielded enclosure that attenuates the leakage and scattered radiation. The overcouch-tube fluoroscopy arrangement, on the other hand, produces a scattered radiation distribution, with a peak coinciding with the position of the staff. This scattered radiation must be intercepted sufficiently in advance, before it reaches the staff. If adequate protective devices are not applied, an overbearing workload, combined with extended fluoroscopy times, may result in the radiologist receiving a high eye dose. When radiation protection is concerned, this is more prominent in cases of overcouch-tube fluoroscopy equipment and insufficient staff training. The figures presented here demonstrate that the screens have a considerable effect; when removed, the curves are flattened in shape. Upon the removal of the screens, dose rates increase by more than tenfold. Vertical radiation profiles along the mid-line of the undercouch X-ray tube position illustrate the effect of the Bucky slot cover on isodose contours (figs. 5 and 6). Upon the removal of the Bucky slot cover, the radiologist is irradiated by leakage and scattered radiation from the tube housing. The measure of this increase depends on the distance from the couch. Resulting body exposures turned out to be extremely non-uniform. Under such conditions, partially unshielded organs in the trunk, along with the tissues and organs in the region of the head and neck, will influence the effective dose [4].

CONCLUSIONS

As presented, the ionization chamber has a flat energy response which makes it a suitable instrument for radiation protection purposes. Nevertheless, our results show that this instrument requires special attention regarding the selection of exposure times. In order to perform accurate measurements using the said instrument as a survey meter in diagnostic radiology, the exposure times used for the purpose had to be above 1.2 s. As shown in our research, the ionization chamber tends to give an underestimation of dose rates when they are below 1.2 s, meaning that , if possible, exposure times should be higher during the radiation protection survey.

Our dose measurements using a suitable ionization chamber have demonstrated that scattered radiation levels around fluoroscopy equipment can be quite high, depending on the type of the fluoroscopic procedure and equipment. In overcouch-tube fluoroscopy arrangements, with the radiologist present at the couch side, a significant dose to the eye may result from even a modest number of procedures. Under these circumstances, protective measures needed to be implemented, with the eye dose received requiring special consideration.

In order to evaluate the risk and assess the efficiency of personal shielding in cases of extremely non-uniform exposures to radiation, said exposures had to be measured at specific anatomical locations. It is, therefore, advisable to consider personal monitoring arrangements for each of these types of procedures and equipment. Using the data at hand, an educated guess as to the different diagnostics techniques with respect to the differences in the workload, screening times, loading factors and field size, should be made.

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МЕРЕЊЕ РАСЕЈАНОГ ЗРАЧЕЊА У ОКОЛИНИ ДИЈАГНОСТИЧКОГ РЕНДГЕН-АПАРАТА ТОКОМ ПРОСВЕТЉАВАЊА

У раду су приказани резултати одређивања расподеле расејаног зрачења у околини дијагностичког рендген-апарата. Мерена је јачина амбијенталне дозе у ваздуху на дефинисаним растојањима од ивице носача пацијента. Резултати су приказани у форми зависности дозе од растојања, за различите висине од пода. Мерења су вршена током симулације просветљавања у присуству воденог фантома за две геометрије, рендгенску цев испод и изнад носача пацијента, и у обзир су узета оба случаја, вертикални и хоризонтални сноп. Коришћени су различити параметри експозиције, а мерења су извршена јонизационом комором. Пре самог мерења проверена је адекватност овог инструмента за мерење расејаног зрачења у дијагностичкој радиологији. Утврђено је да за време експозиције испод 1,2 секунде овај инструмент показује мање дозне вредности од стварних. На основу измерених вредности јачине амбијенталног дозног еквивалента, уочене су знатно веће дозне вредности за случај цеви изнад носача пацијента. За рендгенску цев испод носача пацијента, при истим факторима оптерећења, вредности су веће у случају вертикалног снопа.

Кључне речи: просветљавање, расејано зрачење, јонизациона комора, доза