Mathematical assessment of entrance surface dose(ESD) for patients examined by long term X-ray examination (fluoroscopy).

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Assessment of radiation absorbed dose by patient in medical X-rays examinations are of great values in the radiation protection field. Fluoroscopic procedures (particularly prolonged interventional procedures) may involve high patient radiation doses .ESD were calculated for patients who are examined by fluoroscopy apparatus (long term X-ray examination) that used to visualize the dynamic movement of different movable organs .Parameters that involved in this projects are X-ray tube voltage(KV peak),X-ray exposure factors(mA.s) and distance between X-ray tube and patients skin.35 cases were involved in this projects [15 male and 20 female].mathematical equation was used to assess the ESD .The results show that ESD ranged from 257.742 mGy to 1142.814mGy and of mean 571.2846mGy.

التقييم بالمعادلة الرياضية للجرعة الممتصة في سطح المرضى الذين تم فحصهم بالأشعة السينية ولفترة زمنية طويلة (التصوير التألقي).

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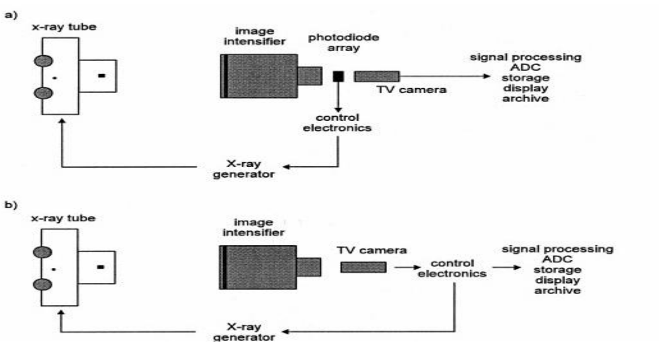
عملية تقييم الجرعة الإشعاعية الممتصة للمرضى الذين يتم فحصهم بالأشعة السينية الطبية له اهمية كبيرة في حقل الوقاية من الإشعاع .عمليات الفحص بجهاز الفلوروسكوبي (بالخصوص العمليات الداخلية الطويلة) قد تتضمن تعرض المريض لإشعاع عالي.جرعة سطح الدخول حسبت للمرضى الذين يتم فحصهم بجهاز الفلوروسكوبي [الفحص لفترة زمنية طويلة بالأشعة السينية] والذي يستخدم لمشاهدة الحركة الديناميكية لمختلف أعضاء الجسم .المتغيرات المضمنة في البحث هي فولتية أنبوبة الأشعة السينية ،عامل التعرض الإشعاعي والمسافة بين أنبوبة الأشعة وجلد المريض .٣٥ حالة تم تسجيلها في هذا البحث [٢٠ إناث و ١٥ ذكور] .معادلة رياضية استخدمت لتقييم جرعة سطح الدخول . أوضحت النتائج بأن جرعة سطح الدخول للمرضى تتراوح بين 257.742 mGy و 1142.814 mGy بمعدل 571.2846. mGy

1-Introduction

Diagnostic radiology utilizing ionizing radiation has played a very major part in health care delivery since the discovery of X-rays and its application to imaging. This is without bias to the known deleterious effects of ionizing radiation. Concerns about radiation dose to patients have been a major issue in the radiology service delivery. The United Nations has recommended modalities for radiation protection of patients undergoing diagnostic radiology. For all imaging modalities that employ ionizing radiation, international ecommendations require that the principles of justification and optimization be met[1]. Medical applications of ionizing radiation are accepted worldwide as essential tools for protecting and improving human health. However, they also represent by far the largest man-made source of radiation exposure for the population. There is a worldwide overwhelming interest in patient exposure, which has clearly been demonstrated by about 1000 senior officers and scientists from 88 IAEA(International Atomic Energy Agency) member states attending the International Conference on the Radiological Protection of Patients in Diagnostic and Interventional Radiology[2]. Fluoroscopy is used to create real-time images for diagnosis and to guide other medical procedures fig(1). Modern fluoroscopic x-ray equipment is subject to strict governmental regulations, but these regulations do not guarantee that radiation is safely used on patients nor that the physician operators and support staff are protected from risk of radiation-induced injury[3].



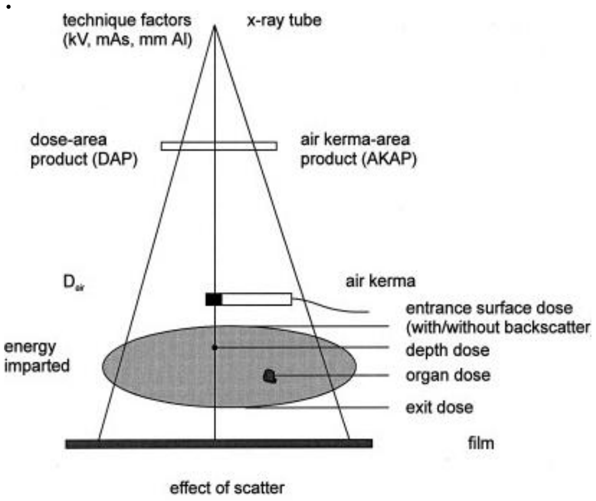
Fig(1):(a and b)

Show the schematic diagram of the fluoroscopic units of different structure.

Since the early 20th century, fluoroscopy has been integral to the practice of diagnostic radiology. For the most part, fluoroscopic procedures were primarily diagnostic and involved relatively small risks to patients and personnel. The number of prolonged fluoroscopic procedures performed in the United States has increased dramatically over the past 10 years. This phenomenon is partially driven by the preference of managed care to use methods that are less invasive and less costly than surgery[4]. Fluoroscopy is an x-ray-based medical imaging technique that is used when viewing a real-time process within the human body is important. Examples of use for fluoroscopy include swallowing studies, upper and lower astrointestinal imaging, angiography, as well as device placements such as stents, needles, lines, and tubes. Because of its widespread applications, fluoroscopy is found in many areas of modern hospitals. Areas often using fluoroscopy include radiology, gastroenterology, surgery, pain management, cardiology, and others fig(2)p[5].

Fig:(2)show the complete fluoroscopy apparatus system.

The entrance dose, also known as the incident dose, is the air kerma (kinetic energy released per mass unit) at the focus to skin distance without the patient presence (International committee for Radiation Protection 2000). It does not include back-scattered radiation from the patient[6].Entrance surface dose (ESD) is the absorbed dose in the skin at a given location on the patient. It includes back-scattered radiation from the patient. Entrance dose can be converted to ESD by multiplying with a backscatter factor and converting from air to tissue as shown in fig(3)[7].



Fig(3):Schematic diagram shows the location of entrance surface dose in the patient.

Patient doses depend on a number of factors such as machine factors; age, size, and body composition of the patient; and user setup, such as collimation, source-to-skin distance, and so on. The dose rate to the patient is greatest at the skin where the x-ray beam enters the patient. The typical fluoroscopic entrance exposure rate for a medium-sized adult is approximately 30 mGy/min (3 rad/min) (since 10 mGy = 1 rad) but is typically higher in image-recording modes. Diagnostic procedures performed under fluoroscopic control have significantly shorter fluoroscopic times and lower entrance skin doses compared with those of interventional procedures. Mean fluoroscopic times for interventional procedures are significantly longer[8]

2-Material and methods

The present work was performed to evaluate the ESDs of patients undergoing fluoroscopic examinations to determine the site of renal stone of patient in ESWL unit in Al-Sadder teaching hospital.. The dependence of ESD on SSD should follow the inverse square relationship because the SSD is much greater than the focal spot of the anode. the following formula is proposed for the ESD of a three phase generator as follow:[9].

$$ESD(mGy)= C\,(Kvp/100)^2(mA.s/1000)(2.5/mmAl)(100/SSD)^2 \ldots\ldots\ldots\ldots\ldots 1$$

where kvp, mA.s, mm Al and SSD are, respectively, the peak voltage, the tube current(it is the product of tube current(mA) by time of exposure in second), the aluminum filtration, and the SSD in cm. C is constant(X-ray output factor) and it's equal to about 111 mGy/mA.s at 80 kVp at 1 meter from X-ray tube, X-ray tube of Ziehm 8000 product family , Ziehm Imaging , manufactured by Zeihm imaging GHM 2007 .

* (kVp and mA.s) had been taken from practical work in the ESWL unit in Al-sadder teaching hospital.

*SSD (source to skin distance in cm)which is 50cm in this project.

*mm Al the total filtration in unit of (mm) of aluminum of X-ray tube[4mm Al].

*35 cases were involved in this project (15 males and 20 females).

3-Results

The results of this study concerning the recorded fluoroscopy times, exposure factors and estimated patient doses for the various cases given in Table 1. It should be noted that the maximum ESD estimate for the patient's skin dose was 0.81 Gy, much less than the threshold of 2 Gy

required for the onset of early transient erythema insensitive patient.
The frequency of ESDs calculated and kVp and mA.s involved in this project are given in tables (2,3 and 4).
*The relationship between the ESDs calculated and both KVp , mA.s used in this project are shown in fig. 1 and 2 .

Table (1):Shows the calculated values of ESDs, X-ray tube voltage (kv) and exposure factor(mA.s)

Item	Upper limit	Lower limit	mean
ESD (mGy)	1142.814	257.742	571.2846
KVp (kV)	92	59	72.7428
mA.s (mA*S.)	570	258	378.1714
Time of exposure(second)	43	100	71.5

Table(2):Shows the frequency of the calculated values of the ESDs in (mGy).

ESDs interval(mGy)	Frequency
200-399	7
400-599	16
600-799	7
800-999	2
	3

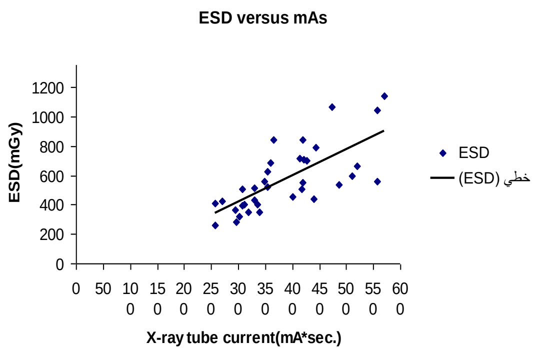
Table(3):
Shows the frequency of X-ray tube voltage (kVp) used in this project

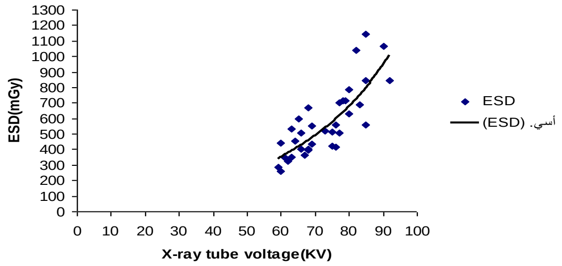
kVp interval(kV)	Frequency
50-59	1
60-69	16
70-79	9
80-89	7
90-99	2

Table(4):Shows the frequency of X-ray tube exposure factor(mA.s) used in this project

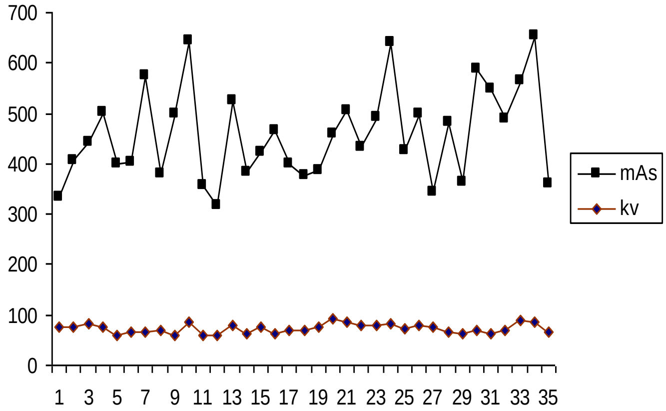
mA.s interval(mA*S.)	Frequency
200-300	6
300-400	14
400-500	11
500-600	4

Fig(1):
Shows the calculated entrance surface dose (mGy) against X-ray tube voltage(kv).

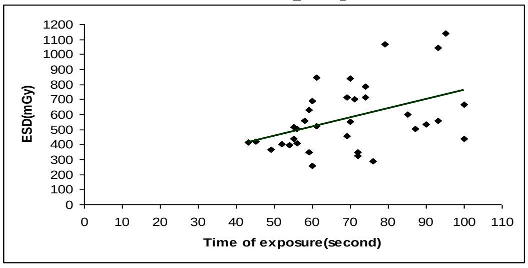




Fig(2):Show the relationship between the calculated ESDs versus X-ray exposure factor(mA.s) .



Fig(3):
Shows the relationship between KVp and mA.s used in this project.



Fig(4):
Shows the relationship between the exposure time and the calculated ESD.

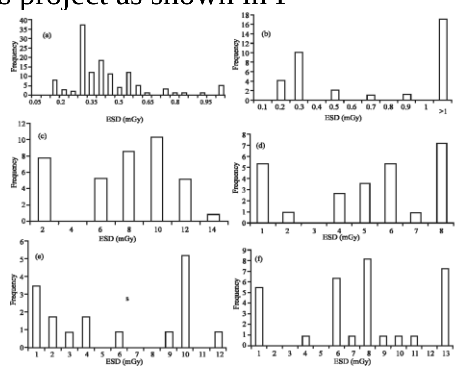
Discussion:

Medical clinics and hospitals which utilize ionizing radiation have been searching to be in compliance with the radiological protection and quality control requirements of the Order (Portaria) No. 453/98 (“Radiological protection guidelines in medical and odontological radiodiagnosis”).The method outlined here to conduct surface dose assessment has proved useful in assisting X-ray departments. ESD was calculated for 35 case show significantly high dose with mean 571.2846 mGy (0.5 Gy) Table(1) for patient examined flouscopically , high dose are due to high exposure time which is comparable to results obtained by[Mahadevappa ;10] whose it's ESD mentioned in the table below:

Table(5):Show the mean of exposure time and ESD measured by (Mahadevappa ,10)

Procedure	Mean Fluoroscopic Exposure Time (min)	Mean Entrance Skin Dose (mGy)*
Barium enema study (18)	3.3 (<1–5)	44 (23–59)
Barium swallow study (18)	3.8 (2.5–6.1)	66 (41–150)
Renal angiography (20,21)	5.1 (2.9–7.6)	100 (80–220)
Cerebral angiography (20,21)	12.1 (2.9–36)	220 (60–590)
Hepatic angiography (20,21)	12.1 (3.6–42)	340 (100–580)
Percutaneous transhepatic cholangiography (20,21)	14.6 (2.9–44)	210 (30–520)

Our results show large variety in radiographic techniques(kVp and mA.s) table 1 and 2 that reflex the variety in patient weight and size ,so as patient get larger ,it required high KVp to produce high energy X-ray that can penetrate through ,where the high frequent value for KVp ranged (60-69 and 70-79) that means the weight of most of the patients examined are in range(65-85 kg) table(3) and high frequent values of mA.s are ranged from(300-400 mA.s) as shown in table(4) ,where the high frequent values for ESD calculated are ranged between (300-400 mGy) as shown in table(2)
, literature dealing with determination of ESD for patient examined radiologiacally(11 and 12] also concentrate on the frequency of ESD mentioned above in this project as shown in F

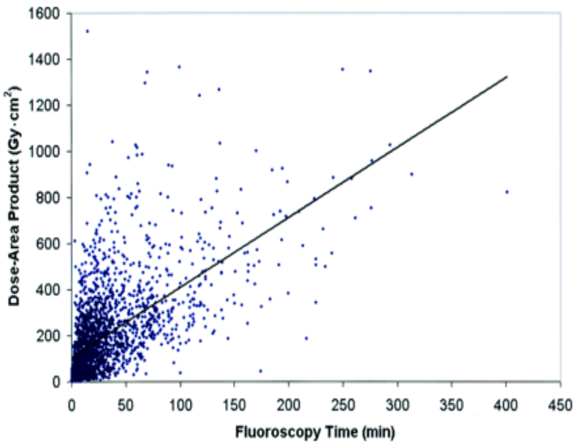


Fig(5):shows the frequency of ESDs against measured in [11].

Where [11] calculatde the ESD for different radiographic examination that done for the patients, using TLD dosimeter and mathematical equation where the ESD values calculated range from 0.6 – 6.9 mGy(mean). And Mean ESD calculated by [12]ranged from[.28-18.60 mGy] with kVp and mA.s mean(66-89 kVp) and (9-72 mA.s).

The results show that the relationship between both the kVp and mA.s with ESD are exponential and linear respectively that approved also by [9] and [13] that using other mathematical equation of the same principles .

The effect of the time of the exposure(including in mA.*s*) on the ESD Fig(5) are significantly clear and considered many research involving[14] and [15] as shown in fig(6).



Fig(6) Scatter plot of fluoroscopy time and dose area product done [15] .

Fig (3) show the relationship between the both(kVp and mA.s) and ESD calculated in this project and clarify that the(kVp and mA.s) parallel with acute variations in (mA.s) more than KVp that reflect the exposure time variation from case to other depending on the ability of visualization of organ examined by fluoroscopy that result in increasing patient ESD,[16] studied the relationship between kVp and mA.s in his study on fluoroscopy, and[17] studiedthe effect of (kVp and mA.s) on image quality and patient dose in fluoroscopic examination .

Other recent and comparable literature dealing with calculating and measurement of ESD from conventional X-ray and fluoroscopic examination such as [18, Suliman] who calculated the ESD for paediatrics for different X-ray position and ranged from(52-264 μGy) and it's very low comparing with our results due to small exposure time.[19] also calculated the ESD for Patient examined by conventional X-ray and it's ranged between (0.3-38.3 mGy) and it's also low comparing with our results.

Finally when we have to compare our results with those international reference dose ,we found that the time of exposure are comparable ranged between (1.9-9.2min) [20].

Conclusion

1. Dose monitoring helps to ensure that the best possible protection of the patient is maintained at all times and provides an immediate indication of incorrect use of technical parameters or equipment malfunction. During fluoroscopy ,the kV and mA are very important parameters which controls the quality of X-ray picture on the screen .
2. The entrance surface(ESD) dose can be maintained to minimum value by reducing the exposure time where the relation-ship between the entrance dose and time is linear.
3. Estimation of the entrance surface dose could be an alternative reliable and cheap method for patients dose monitoring in the every day routine of a diagnostic radiology department.

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