Estimation of Entrance Surface Air Kerma (ESAK) and dose area product(DAP) for the patient examined by fluoroscopy apparatus[long term X-ray examination]

Raed Mohammed Kadhim
University of Kufa –College of medicine
Raed_medical@yahoo.com.

Abstract

Estimation of radiation absorbed dose in long term X-ray examination (Fluoroscopy) that the patient subjected to are of great value in the field of radiation protection. The aim of this project is to determine the amount of air kerma dose in air that can reflects the amount of the risk that the patient subjected to, also to calculate the dose area products (mGy/cm^2)and do comparison between EASK and DAP. The parameters that which are involved in this project are X-ray tube current (mA) , exposure time (sec.), focal film distance(FFD) and focal skin distance (FSD) in cm.ESAK and DAP are calculated using mathematical equation for different fluoroscopic examination of different patients. 35 cases were involved in this projects [15 male and 20 female].The results show that the ESAK are ranged between 54.438mGy and 120.27 mGy and the DAP ranged from 491.847 mGy.cm2 to 1086.639 mGy.cm2 .

الخلاصة

تخمين الجرعة الإشعاعية الممتصة أثناء الفحص بالأشعة السينية ولفترة زمنية طويلة بجهاز الفلوروسكوبي والتي يتعرض لها المريض لها أهمية كبيرة في حقل الوقاية من الإشعاع.الهدف من البحث هو لتحديد كمية جرعة الإشعاعية في الهواء (كيرما) والتي تعكس كمية الخطر الذي يتعرض له المريض وكذلك لحساب عامل ضرب الجرعة في المساحة(mGy.cm^2) إضافة إلى عمل مقارنة بين EASK و DAP. المتغيرات او العوامل التي تضمنها البحث هي تيار أنبوبة الأشعة و زمن التعرض الإشعاعي بوحدة الثانية والمسافة بين انبوبة الاشعة السينية و فلم التصوير ألشعاعي إضافة إلى المسافة بين انبوبة الاشعة السينية و سطح المرض(جلد المريض) بوحدة السينتميتر. EASK و DAP تم حسابهما باستخدام معادلة رياضية ولمختلف الفحوصات الإشعاعية ولمختلف المرضى. 35 حالة تم تضمينها في هذا البحث (20من الاناث و15 من الذكور).النتائج أوضحت بأن (EASK) تتراوح بين 54.438mGy و mGy 120.27 وان DAP تتراوح بين 491.847 mGy.cm2 و 1086.639 mGy.cm2 .

Introduction

Radiation exposures from diagnostic medical examinations are generally low and are almost always justified by the benefits of accurate diagnosis of possible disease conditions. There is no direct evidence of radiation ever causing any harm at the exposure levels encountered with diagnostic radiological examinations[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 International Atomic Energy Agency (IAEA) member states attending the International Conference on the Radiological Protection of Patients in Diagnostic and Interventional Radiology[2].

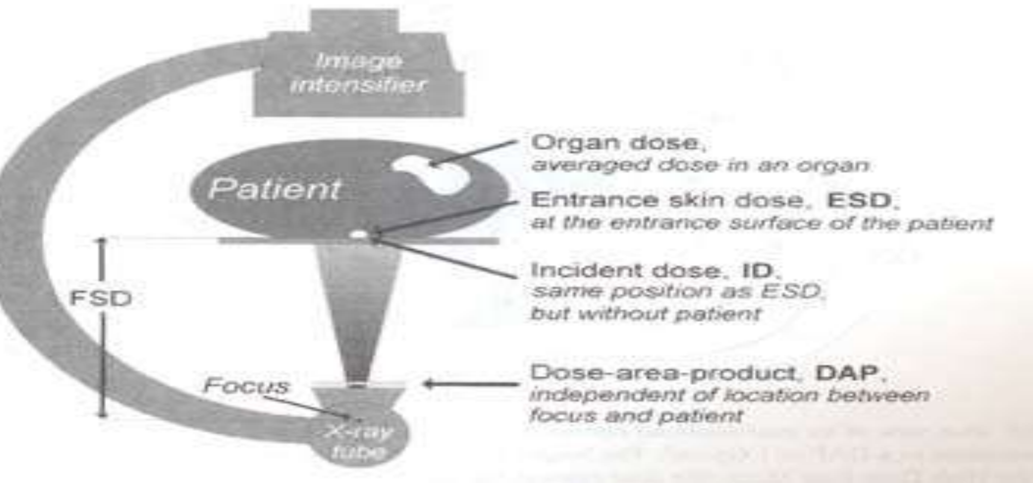
All radiological procedures involving X-rays deliver a radiation exposure to the patient table(1). In procedures where staff are present in the examination room, such as in interventional radiological procedures, also the staff receive a radiation exposure . Table(1):Show the mean of exposure time and 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)

. Radiation has long been known to be harmful to humans. The radiation exposure received in an X-ray examination is known to increase the risk of malignancy as well as, above a certain dose, the probability of skin damage and cataract.[3]

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[4].

Dose-Area-Product (DAP) meters are large-area, transmission ionization chambers and associated electronics. In use, the ionization chamber is placed perpendicular to the beam central axis and in a location to completely intercept the entire area of the x-ray beam. The DAP, in combination with information on x-ray field size can be used to determine the average dose produced by the x-ray beam at any distance downstream in the x-ray beam from the location of the ionization chamber fig.(1) [5].



Fig(1):Schematic diagram of the C arm fluoroscopic unit showing the DAP

The quantity kerma (K) (kinetic energy released in the medium) is defined as the quotient of dE_{tr} by dm, where dE_{tr} is the sum of the initial kinetic energies of all the charged ionizing particles (electrons and positrons) liberated by uncharged particles (photons) in a material of mass and dm is the mass of material :

$K= dE_{tr}/dm$ ….(1)

The unit for kerma is the same as for dose, that is, J/kg. The name of its SI unit is gray (Gy) and its special unit is rad

For a photon beam traversing a medium, kerma at a point is directly proportional to the photon energy fluence Ψ¨ and is given by:

$$K= \Psi(\left(\frac{\bar{\mu}}{\rho_{tr.}} \right)........1$$

Where

$\left(\frac{\bar{\mu}}{\rho_{tr.}} \right)$is the mass energy transfer coefficient for the medium averaged over the energy fluence spectrum of photons[6].

Patient Doses in Fluoroscopy

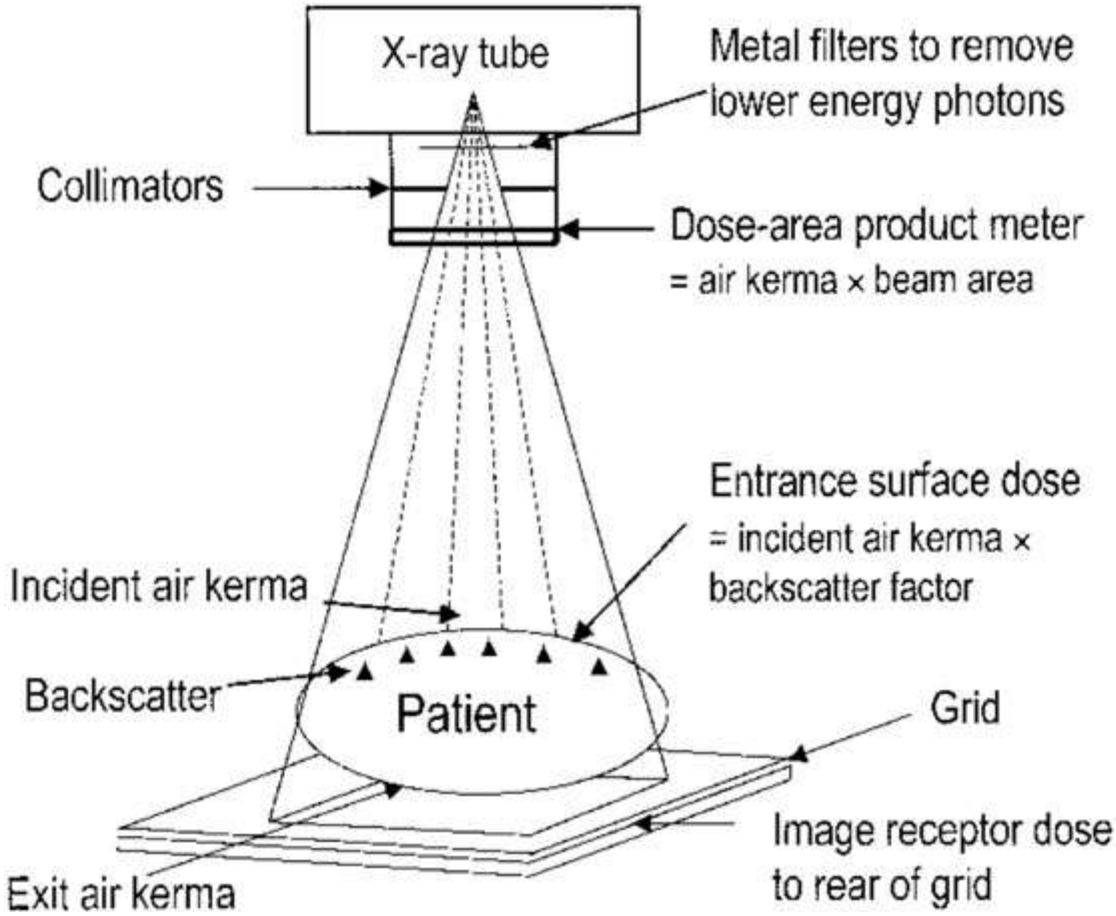
The dose rate to the patient is greatest at the skin where the x-ray beam first enters the patient. Although most literature has begun to report dose rate in milligray per minute, existing regulations still specify limits in terms of an exposure rate (roentgen per minute). The entrance exposure limit for standard operation of a fluoroscope is 10 R/min (100 mGy/min) . Some fluoroscopes are equipped with a high-output or "boost" mode, and the limit for operation in this mode on state-of-the-art equipment is 20 R/min (200 mGy/min) . There is no limit on entrance exposure rate during any type of recorded fluoroscopy, such as cinefluorography or digital acquisitions[7]

Material and Method

- The present work was performed to evaluate the Entrance Air Surface Kerma (EASK) of patients undergoing fluoroscopic Fig.(2) examinations to determine the site of renal stone of patient. The dependence of ESD on FSD 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 ESAK:[8].

$$ESAK = \left(output(mGy/mA.s) \times (100/FSD)^2 \times mA.s \right) mGy ....(2)$$

Where the (output) in mGy/mA.s is calculated using a windows based computer program ,called Pad Pro software was used in this study .This software has gained popularity with many other nuclear professionals in medical engineering, medical physics and other nuclear physics disciplines. The x-ray machine/device calculator allows the choice of empirical data or the use of known x-ray tube output. Software developed by Ray Mc Ginnis ,last update Augst,6,2007.[9], (mA.s) represents the products of X-ray tube current(mA) and time of exposure(Sec.) and FSD represents the focal to surface of the patient distance in cm .



Fig(2): A schematic diagram show the air kerma and DAP with patient position.

- DAP was calculated using the following equation[8]

$$DAP = ESAK \times A_{FFD} \left(\frac{FSD}{FFD}\right)^2 \quad ....(3)$$

Where ESAK are the entrance skin air kerma(mGy) and FFD was the focal film distance in cm.

- (mA.s) had been taken from practical work in the ESWL unit in Al-sadder teaching hospital.
- mm Al the total filtration in unit of (mm) of aluminum of X-ray tube[4mm Al] that which input to the software to calculate the X-ray out put.
- 35 cases were involved in this project (15 males and 20 females)

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 ESAK estimate for the patient's skin dose was much less than the threshold of 2 Gy required for the onset of early transient erythema insensitive patient..
*The frequency of (mA.s) , (ESAK) , time of exposure and (DAP) calculated involved in this project given in tables (1,2,3 and 4)
* The relationship between mAs and DAP are shown in fig(1) , relationship between mAs and DAP are shown in fig(2) and EASK and DAP are shown in Fig(3) respectively.

Table (2): Show the values (range) for ESAKs calculated DAP calculated , exposure factor(mA.s) and time of exposure.

Item	Upper limit	Lower limit	Mean
ESAK (mGy)	120.27	54.438	571.2846
DAP($mGy.cm^2$)	1086.639	491.847	72.7428
mA.s (mA*Sec)	570	258	378.1714
Time of exposure(second)	43	100	71.5

Table(3): Show the frequency of mA.s used in this study

mA.s	Frequency
250-	6
300-	10
350-	4
400-	9
450-	2
500-	2
550-600	2
Total	35

Table(4): Show the frequency of ESAK values calculated in this study in(mGy)

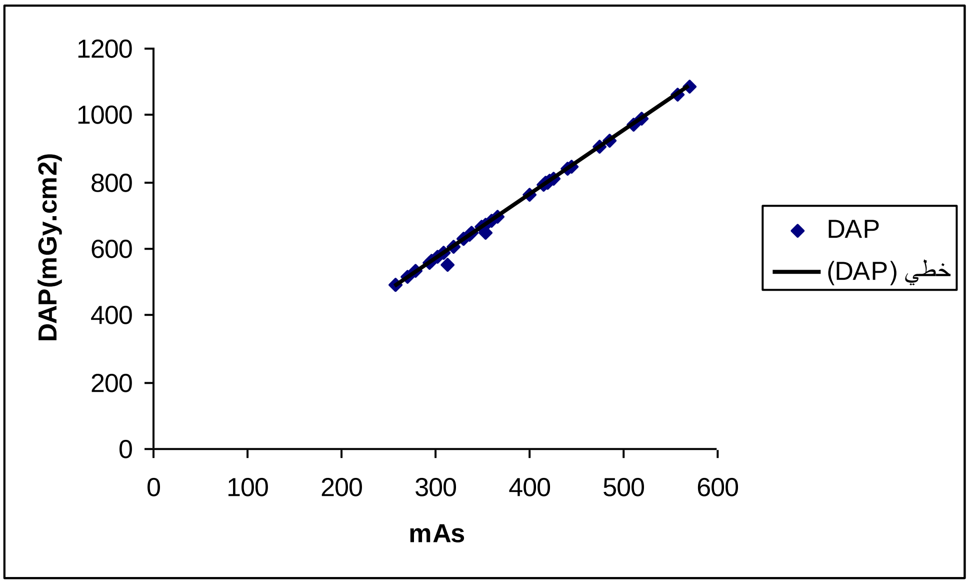
ESAK(mGy)	Frequency
50-	9
65-	11
80-	9
95-	4
110-125	2
Total	35

Table(5): Show the frequency of time of exposure used in this study in(Second)

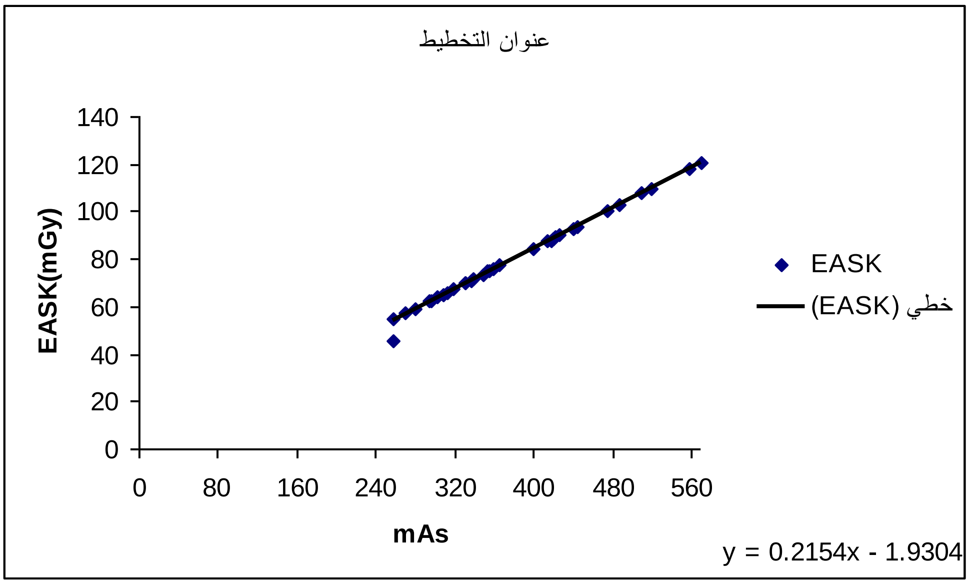
Time(Sec.)	Frequency
40-49	3
50-59	9
60-69	6
70-79	9
80-89	2
90-100	6
Total	35

Table(6): Show the frequency of dose area product calculated in this study in(mGy.cm^2).

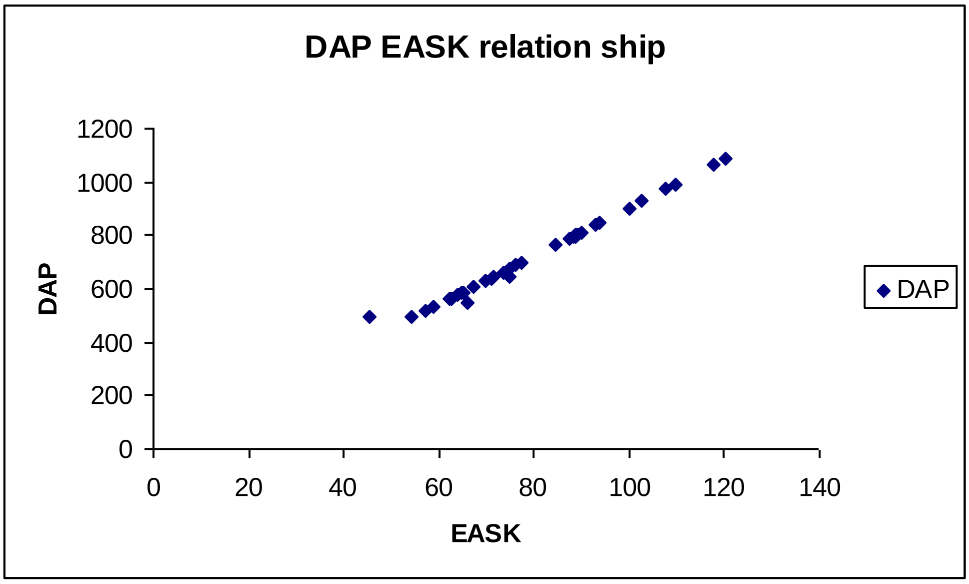
DAP(mGy.cm^2)	Frequency
400-	5
550-	15
700-	9
850-	4
1000-1150	2
Total	35



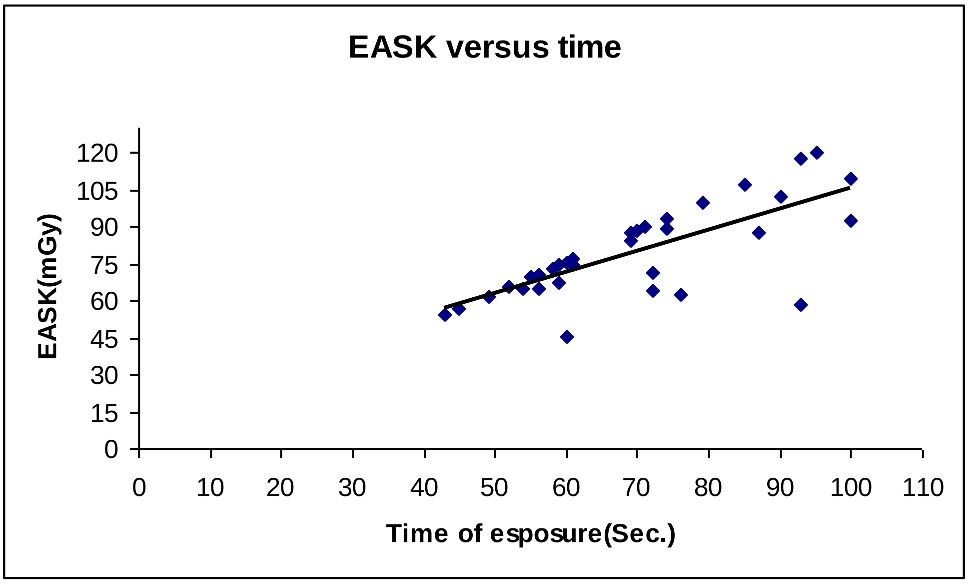
Fig(3):Show the relationship(linear) between the exposure factor and dose area product(mGy/cm^2).



Fig(4):Show the relationship(linear) between the exposure factor(mAs) and entrance air skin kerma(EASK) calculated in this project(mGy)



Fig(5):Show the relationship(linear) between the entrance air skin kerma(EASK) and dose area product(mGy/cm^2)



Fig(6):Show the relationship(linear) between the time of exposure(sec) and EASK(mGy/cm^2).

Discussion:

It is necessary to keep the exposure doses from fluoroscopy as low as is reasonably achievable to avoid radiation skin injuries in patients undergoing fluoroscopic examination. The method outlined here to conduct surface dose assessment has proved useful in assisting X-ray departments.

ESAK was calculated for 35 case show significantly high dose with mean 87.354 mGy for patient examined flouscopically ,those high dose are due to high exposure time which is comparable to results obtained by[Mahadevappa ;10] whose it's ESD mentioned in below table(2)

DAP in mGy/cm^2 are also calculated in this project for 35 cases mentioned above with mean of about 789.243 mGy/cm^2 which is significantly high due high exposure time that the examination need to visualize the renal stone fluoroscopically and destructed shock wave lithotripsy.

Our results show large variety in radiographic exposure(mA.s) table 1 that reflex the variety in patient weight and size, where the high frequent values are in 300-350 as shown table(2).

The high frequent values for ESAK are range between 50-65 mGy as shown in table(4) and for the time of exposure ranged between 50-59 sec. as shown in table(5)

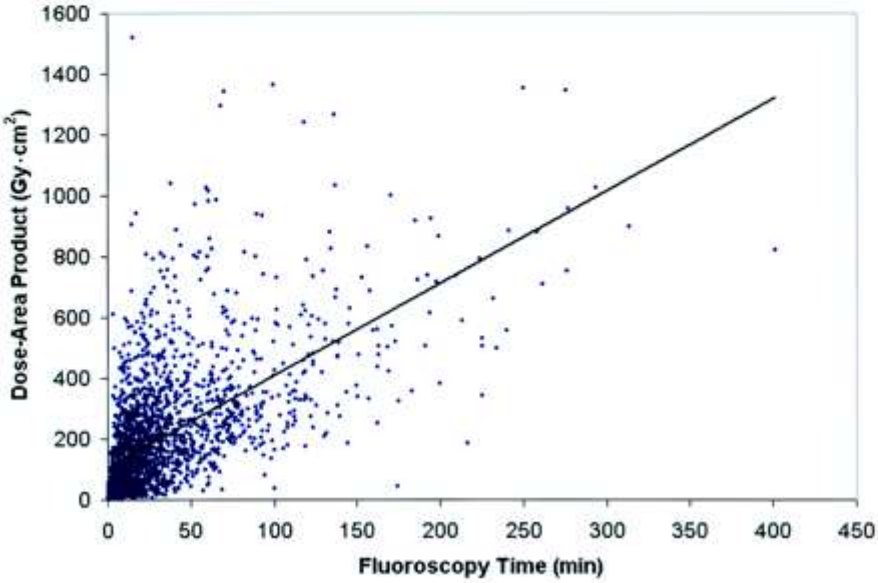
The high frequent values for the Dap cakculated are in range between 770-850 mGy.cm^2 as shown in table(6)

Previous literature dealing with determination of ESD(mGy) for patient examined radiologiacally(11 and 12] also concentrate on the frequency of ESD as we mentioned to the frequency of ESAK and DAP mentioned above in this project.

[13] calculate the ESAK for the patient undergoing routine X-ray examination depending on mathematical equation ,but theX-ray output measured using a calibrated

1 cm3 PTW-Freiburg TM77334 ionization chamber connected to a PTW UNIDOS E electrometer,in time that we using a calculating software guess the X-ray output ,where the the ESAK rnaged between (0.1-5.30 mGy) which is low compared with our results due to very short exposure time that X-ray examination required.

The effect of the time of the exposure(including in mA.s) on the ESD Fig(7) are significantly clear and considered many research involving[14] and [15] as shown in fig(5).



Fig(7) Scatter plot of fluoroscopy time and dose area product done [15]

The results show that the relationship between the mAs and DAP ,ESAK and time of exposure respectively linear as shown fig(2),(3),(4) .
Many literature con concentrate on calculation of DAP either using special instrument or mathematically, so [16] measuring DAP using VacuDAP 2000; VacuTec Mebtechnik, Dresden, Germany) in which the results was ranging from 0.04-150.5 Gy/cm^2 .
Other also calculate DAP in cGy.cm^2 [17] and obtained the that which is comparable to our results.

Conclusion

1.The entrance surface(ESAK) dose can be maintained to minimum value by reducing the exposure time where the relation-ship between the entrance dose and time linear.
2. 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
3. The entrance surface(ESAK) dose can be maintained to minimum value by reducing the exposure time where the relation-ship between the entrance dose and time linear.

Reference

1.Wall BF, Hart D. Revised radiation doses for typical X-ray examinations. The British Journal of Radiology;Vol. 70; P:437-439; (1997).

2.Dieter F. Regulla , and Heinrich Eder ; patient exposure in medical X-ray imaging in Europe ; Radiation Protection Dosimetry, Vol. 114, Nos 1-3, pp. 11–25(2005).

3. Håkan Geijer ; Radiation Dose and Image Quality in Diagnostic Radiology;
Department of Radiology, Örebro University Hospital, SE-701 85 Örebro
And Department of Medicine and Care Faculty of Health Sciences, Linköping University, (2001)

4. Robert A. Parry, MS, Sharon A. Glaze, MS and Benjamin R. Archer; Typical Patient Radiation Doses in Diagnostic Radiology; IMAGING & THERAPEUTIC TECHNOLOGY; Radiographics;Vol:19 ; PP:1289-1302. (1999).

5. Stephen Balter , et al ; Techniques to estimate radiation dose to skin during fluoroscopically guided procedures , Skin Dose Measurements AAPM July ;PP:1-10(2002).

6. Faiz M. Khan, Physics of Radiation Therapy; Third Edition;(2003).

7. Sprawls P, Jr. Physical principles of medical imaging 2nd ed. Gaithersburg, Md: PP:165-167 (1993).

8. Gyekye, P. K; et al , PATIENT DOSE ASSESSMENT DUE TO FLUOROSCOPIC EXPOSURE FOR SOME SELECTED FLUOROSCOPIC PROCEDURES IN GHANA; Radiation Protection Dosimetry ; Vol. 136 ; No. 3,(2009).

9. Newsletter; Ionactive-consulting for radiation protection; issues 1(2007). *(www.ionactive.co.uk.).*

10. Mahadevappa Mahesh; Fluoroscopy: Patient Radiation Exposure Issues; Imaging & Therapeutic Technology ; Radiographics.; Vol:21: PP:1033-1045. (2001).

11.Obed ;I.R et al ,dose to the patient in routine X-ray examination of chest ;skull ,,abdomen and pelvis in nine selected hospital in Nigeria ;Research journal of medical series,Vol:1, No:3 P:,209-214 (2007).

12.NJ ,K-H et al ; Dose to the patient in routine X-ray examination in Malaysia; the British journal of radiology; Vol:71; P :654-660(1989).

13. T Nyathi1 ,et al, Patient dose audit for patients undergoing six common radiography examinations: Potential dose reference levels,Vol:47,No:2(2009).

14 MCFADDEN; S L ,et al; X-ray dose and associated risks from radiofrequency catheter ablation procedures, The British Journal of Radiology, 75, 253–265 (2002).

15. Donald L. et al ; Radiation Doses in Interventional Radiology Procedures: The RAD-IR Study ; Journal of Vascular and Interventional Radiology,Vol:14: P:711-728 (2003).

16. Karthikesalingam, A ,et al , Radiation exposure during laparoscopic cholecystectomy with routine intraoperative cholangiography, Springer , Vol:23, PP: 1845–1848(2009).

17. Hollie Ruffles,et al , A comparison of fluoroscopy time and dose area product (DAP) readings for outpatient barium enema examinations, Radiography 15, 49e57(2009).