Original Article

ปริมาณรังสีที่ผิวหนังผู้ป่วยที่ได้รับจากการวินิจฉัยทั่วไปด้วยเอกซเรย์ที่โรงพยาบาลสงขลานครินทร์

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Entrance Surface Dose Level of Common Diagnostic X-ray Examinations at Songklanagarind Hospital.

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บทคัดย่อ:
วัตถุประสงค์: เพื่อศึกษาปริมาณรังสีที่ผิวหนังของผู้ป่วยที่มารับการตรวจที่ห้องเอกซเรย์ สาขารังสีวินิจฉัย ภาควิชารังสีวิทยา คณะแพทยศาสตร์ มหาวิทยาลัยสงขลานครินทร์
วัสดุและวิธีการ: เครื่องเอกซเรย์ผลิตภัณฑ์ TOSHIBA รุ่น KXO-60 G/DT-BTH และเครื่องวัดรังสีชนิดไอออนไนเซชันแชมเบอร์ ผลิตภัณฑ์แรดแคล รุ่น 9095 ใช้วัดปริมาณรังสีในอากาศเพื่อนำค่าที่ได้มาประเมินปริมาณรังสีที่ผิวหนังของผู้ป่วย โดยตั้งเทคนิคการฉายรังสี (exposure technique) สำหรับผู้ป่วยผู้ใหญ่ที่มีรูปร่างขนาดกลางของท่าถ่ายรังสี ประกอบด้วย ภาพรังสีทรวงอกในท่า posterior-anterior (PA) กระดูกสันหลังส่วนบั้นเอวในท่า anterior-posterior (AP) และ lateral กระดูกเชิงกรานในท่า AP ช่องท้องในท่า AP กะโหลกศีรษะในท่า AP/PA และ lateral โดยศึกษาระหว่างเดือนมกราคม พ.ศ. 2551 - มกราคม พ.ศ. 2552 นำปริมาณรังสีที่ได้ไปเปรียบเทียบกับระดับปริมาณรังสีอ้างอิงของทบวงการพลังงานปรมาณูระหว่างประเทศ ในผู้ป่วยจำนวน 80 ราย
ผลการศึกษา: ปริมาณรังสีเฉลี่ยและระดับปริมาณรังสีควอไทล์ที่ 3 ซึ่งใช้เป็นปริมาณรังสีอ้างอิงของสถาบันจากการตั้งเทคนิคการฉายรังสีของท่าต่างๆ เท่ากับ 0.29, 2.98, 10.30, 1.62, 2.86, 4.40, 3.28 และ 0.36, 3.16, 12.69, 2.06, 3.68, 5.22, 3.57 มิลลิเกรย์ ตามลำดับ เปรียบเทียบกับระดับปริมาณรังสีอ้างอิงของทบวงการพลังงานปรมาณูระหว่างประเทศที่มีค่าคือ 2, 0.4, 10, 30, 10, 10, 5, 3 มิลลิเกรย์ ตามลำดับ

สาขารังสีวินิจฉัย ภาควิชารังสีวิทยา คณะแพทยศาสตร์ มหาวิทยาลัยสงขลานครินทร์ อ.หาดใหญ่ จ.สงขลา 90110
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สรุป: การตรวจทางรังสีที่ห้องเอกซเรย์ สาขารังสีวินิจฉัย ภาครังสีวิทยา โรงพยาบาลสงขลานครินทร์ ปริมาณรังสีเฉลี่ยที่ผิวของกะโหลกศีรษะในท่า lateral มีค่าเท่ากับ 3.28 มิลลิเกรย์ สูงกว่าระดับปริมาณรังสีอ้างอิง 3 มิลลิเกรย์ สาเหตุมาจากการตั้งค่าเทคนิคการถ่ายที่ไม่เหมาะสม ส่วนท่าการตรวจอย่างอื่นมีระดับต่ำกว่าปริมาณรังสีอ้างอิงของทบวงการพลังงานปรมาณูระหว่างประเทศ

คำสำคัญ: ปริมาณรังสีที่ผิว, ปริมาณรังสีอ้างอิง, การวินิจฉัยด้วยรังสี

Abstract:

Objective: To determine the entrance surface dose level in common diagnostic x-ray examinations at Songklanagarind Hospital.

Materials and methods: The air kerma was measured by ionization chamber at the x-ray equipment manufactured by Toshiba Model KXO-60 G/DT-BTH in this study. Skin dose was determined in 80 medium-sized patients during January 2008 - January 2009 in different projections: chest posterior-anterior (PA), lumbar spine anterior-posterior (AP) and lateral, pelvis AP, abdomen AP, skull AP/PA and lateral. Compare the average dose value with IAEA dose reference level (DRL).

Results: The average entrance surface dose (ESD) of 7 different positions were 0.29, 2.98, 10.30, 1.62, 2.86, 4.40 and 3.28 mGy. The third quartile doses were 0.36, 3.16, 12.69, 2.06, 3.68, 5.22 and 3.57 mGy compared with the reference level (IAEA BSS) were 2, 0.4, 10, 30, 10, 10, 5, 3 mGy.

Conclusion: Most of the entrance surface dose levels were generally within the IAEA dose reference level (DRL). However, the skull lateral ESD was 3.28 mGy was higher than the DRL was 3 mGy according to improper radiographic technique.

Key words: entrance surface dose (ESD), dose reference level (DRL), common diagnostic x-ray examination

Introduction

Diagnostic imaging has an increasing role in medicine with approximately 5% growth per year with worldwide annual per capita effective dose of 0.4 mSv.[1] The development of practical methods for patient dose assessment in radiology is desirable since Quality Assurance Programs (QAPs), including patient dosimetry, are a legal requirement now-a-days in most countries. These QAPs of radiographic images based on the operating conditions of x-ray equipment is essential for good image quality, accurate medical diagnostics and for the prevention of health professionals and patients to unnecessary doses of ionizing radiation. Patient dose in radiography primarily depends on the entrance surface dose (ESD) and the organ dose which depends on the sensitivity of the organs and tissues irradiated during the radiographic examination. Many studies have proposed the measurement of the

ESD in different countries and their results were compared with dose levels recommended by relevant organizations. Also, the organizations such as the National Radiological Protection Board (NRPB) and International Atomic Energy agency (IAEA)[2,3] recommended the dose constraints or investigation levels to provide guidance for medical exposures. In Brazil[4] and Malaysia[5] the investigations showed that patients dose from common x-ray examinations were below the reference doses. In contrast, Iran[6] researchers reported that the average entrance surface doses were comparatively high for x-ray examination.

In the past, the ESD from common diagnostic x-ray examinations at Faculty of Medicine, Songklanagarind Hospital, Prince of Songkla University, has not been fully determined. The aim of this work is to estimate the ESD of common diagnostic x-ray at Division of Diagnostic Radiology, Department of Radiology, Songklanagarind Hospital, Faculty of Medicine, Prince of Songkla University.

Materials and methods

This research has been considered and approved by the Board of Directors of care ethics, research on patient specimens and Social Sciences. Faculty of Medicine, Prince of Songkla University No. EC 51/365-005.

Patients involved in this study were selected by the age of above 15 years and the weight ranging of 40-90 kg. All patients who fulfilled these criteria underwent a particular patient dose survey at the time of the study. For good statistical analysis, at least 10 patients per projection were studied. The collected patient information (i.e. age, weight) and exposure technique were: tube potential (kVp) and tube current-time product (mAs), focus-to-skin distance (FSD).

The digital x-ray equipment was manufactured by Toshiba, model KXO-60 G/DT-BTH, serial number B 7562106. Quality Control test were performed on x-ray equipment of the hospital, before start of patient dose survey, established measurements base on a well-defined protocol prepared by the National Council on Radiation Protection[7] to check for the reliability of voltage and time settings. The calibrated ionization chamber was: RADCAL model 9095.

Entrance surface dose is the absorbed dose to the entrance skin of the patient at the central point of the irradiated area. The indirect dosimetry[8] method for radiographic examinations involves a measurement of x-ray tube output, e.g. air kerma at defined geometry for a range of tube voltage. The air kerma (AK) was measured by the ionization chamber using American Association of Physicists in Medicine (AAPM) protocol which the focus to chamber distance (FCD) was at 100 cm, the air kerma, mGy per tube current-time, mAs, was determined. The patient entrance surface doses were calculated using the air kerma per mAs at the proper tube voltage multiplied by the selected current-time product and the inverse square laws of the FSD and FCD (equation1) for different positions: chest posterior- anterior (PA), lumbar spine anterior-posterior (AP) and lateral, pelvis AP, abdomen AP, skull AP/PA and lateral. Only diagnostically acceptable images were included in this study.

The ESAK (Entrance surface air kerma) was calculated using AK by the following equation:

ESAK=AK x mAs (FCD/FSD)^2 —— (1)

ESD can be calculated from equation:

ESD=ESAK x BSF ———— (2)

Where BSF is the back scatter factor[9] for a particular examination at the required potential, field of view and the filters.

The third quartile values for each projection were calculated and established as the institute dose reference level.

Results

The patient information (i.e. weight, age) and the exposure parameters such as the tube potential (kVp), tube current-time product (mAs), FSD, FCD for the 7 x-ray projections and filtration half value layer (HVL) in the beam at 80 kVp established measurements base on a well-defined protocol prepared by the National Council on Radiation Protection and Measurements[7] and BSF used are shown in Table 1.

A total of 80 patients were included and both sexes were included in the research. The average ESD and third quartile dose level for all routine x-ray examinations compared with guidance levels, the results were generally within the range of the diagnostic reference levels except the average ESD of skull lateral projection was a little higher than DRL are shown in Table 2.

Average ESD, third quartile dose level compared to the dose reference level were displayed as a bar graph in Figure 1, average ESD for skull lateral projection and third quartiles for two of seven examination types (skull AP/PA and lateral) are higher than DRL.

Table 1 Patient information and mean exposure parameters on 7 projections

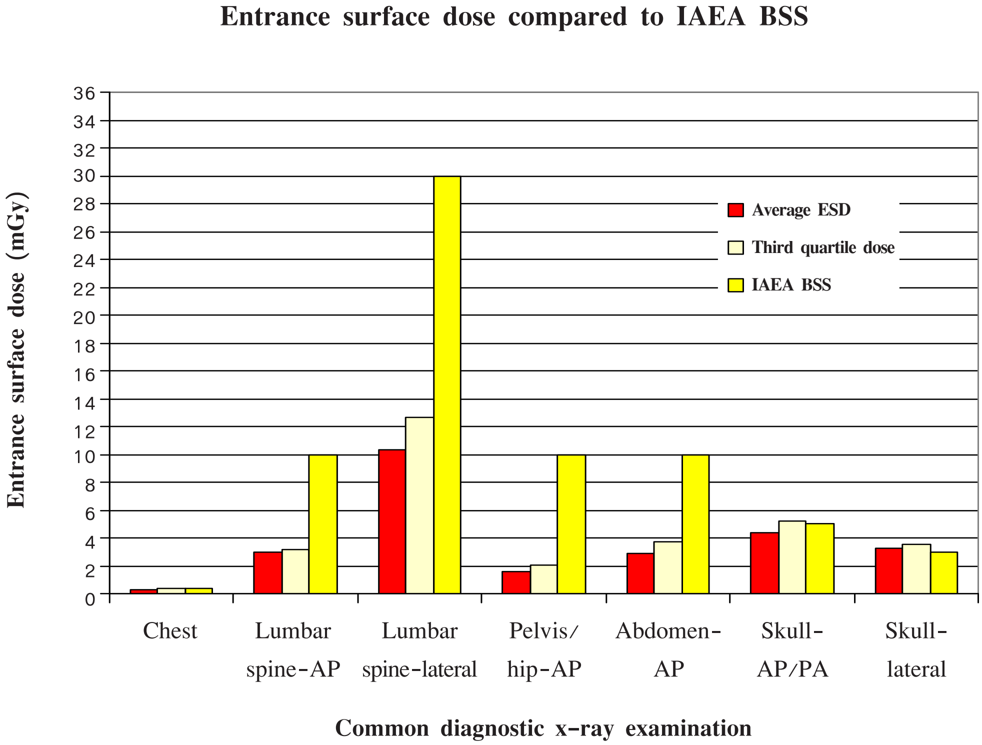
Projections / Parameters	Chest	Lumbar spine		Pelvis	Abdomen	Skull	
	PA	**AP**	**Lateral**	**AP**	**AP**	**PA**	**Lateral**
Tube potential (kVp)	100.00	80.00	85.00	74.70	79.00	78.00	75.90
Tube current-time (mAs)	3.40	18.50	30.50	8.30	7.20	23.20	20.40
FCD (cm)	180.00	100.00	100.00	100.00	100.00	100.00	100.00
FSD (cm)	156.10	73.03	65.63	74.10	74.37	74.15	76.00
Weight (kg)	56.90	57.60	57.40	57.50	58.80	57050	62.40
Age (years)	53.50	53.00	53.00	55.60	56.80	43.80	55.40
BSF[9]	1.53	1.41	1.41	1.38	1.38	1.37	1.37
HVL	3.70 mm of Al.						

kVp = kilovoltage, mAs = milli ampere second, FCD = x-ray tube focus-to-chamber distance, FSD = x-ray tube focus-to-skin distance, BSF = back scatter factor, HVL = half value layer, PA = posterior- anterior, AP = anterior-posterior

Table 2 Comparison of the average ESD (mGy) with the dose reference level (DRL) of International Atomic Energy Agency

Projection	Number of patients	Average ESD+S.D. (mGy)	Third quartile dose level (mGy)	DRL (mGy)
Chest-PA	20	0.29+0.08	0.36	0.40
Lumbar spine-AP	10	2.98+1.49	3.16	10.00
Lumbar spine-lateral	10	10.30+3.27	12.69	30.00
Pelvis/hip-AP	10	1.62+0.80	2.06	10.00
Abdomen-AP	10	2.86+1.55	3.68	10.00
Skull-AP/PA	10	4.40+1.02	5.22	5.00
Skull-lateral	10	3.28+1.04	3.57	3.00

S.D. = standard deviation, PA = posterior-anterior, AP = anterior-posterior



BSS = basic safety standards, PA = posterior-anterior, AP = anterior-posterior

Figure 1 The average entrance surface dose, the third quartile and the dose reference level, DRL (IAEA) for different x-ray projections

Discussion

The average ESD of 7 projections of chest PA, lumbar spine AP and lateral, pelvis AP, abdomen AP, skull AP/PA and lateral were 0.29, 2.98, 10.30, 1.62, 2.86, 4.40 and 3.28 mGy respectively. The third quartile doses were 0.36, 3.16, 12.69, 2.06, 3.68, 5.22 and 3.57 mGy, respectively. In comparison to the DRL as recommended by International Atomic Energy Agency, the results were generally within the range of the diagnostic reference levels. However, the average ESD of skull lateral projection was 3.2 mGy which was a little higher than DRL of 3.0 mGy. In order to reduce the ESD, the exposure technique such as tube voltage should be increased in the range of 70-85; the automatic exposure control should be used in order to reduce the tube current-time and ESD.

The comparison of radiation dose could be accomplished at many levels such as national or international levels using the standard institutes such as IAEA, European Union (EU) and American Association of Physicists in Medicine (AAPM). IAEA established the DRL by collecting data from different regions and analyzed by professional and experienced persons to produce reliable results and could be global applicable. Basic Safety Standards (BSS), for example, seems to be more acceptable than other institutes in the country.

The mean value of ESD studied in Brazil were 0.19 mGy for chest PA, 2.37 mGy for lumbar spine AP, 4.75 mGy for lumbar spine lateral, 1.75 mGy for abdomen AP and 1.26 mGy for skull PA. All the ESD values of present work are higher than the ESD in Brazil.

In contrast, our ESD of 7 projections was significantly less than the ESD of Malaysian except skull lateral projection. In Malaysia the average ESD of 7 projections were 0.30, 6.40, -, 5.30, 9.20, 4.70 and 3.00 mGy respectively, which did not exceed the IAEA dose reference levels.

In practice, the image quality is expressed as the adequate contrast on radiographs by the combination of exposure factors such as tube voltage and tube-current time product. It is well known that the lower the voltage used for any examination, the higher the tube-current time product required to achieve better contrast on the image and hence the higher the patient dose. The selection of the tube-voltages for any examination depends on the anatomy being imaged and the contrast required. The optimal tube potential in chest radiography has received a considerable amount of discussion in the radiological literature.[10] Generally, a wide range of exposure levels has been observed due to the large variety of radiographic techniques. It has been estimated that increasing the tube potential from 60 kVp to 90 kVp will result in an ESD saving of 60%. In this study, a high tube potential technique (≥100 kV) for chest radiography was used. The Commission of the European Communities (CEC) has recommended a technique of 125 kV.[11] The low tube potential technique will probably be selected for the higher contrast chest radiographs. Martin et al.[12] found that increasing tube potentials by 8-13 kV with reduced the tube-current time in lumbar and thoracic spine examinations resulted in a dose reduction of 26-36%. In this study, the skull lateral projection demonstrated the over range of DRL by the improper radiographic exposure. As the voltage is increased, the contrast between different tissues diminishes, and hence, the selected voltage should provide a balance between contrast and patient dose. Very low filtration can cause unnecessary high dose. This can be excluded as the HVL of x-ray machine with single phase full waveform was 3.7 mm of Al which was higher than the value recommended by IAEA BSS of 2.5 mm. of Al.[8]

A significant dose reduction can further be achieved when adhering to the simple guidelines of good radiographic technique. On the other hand, it was observed that there was a wide variation in patient dose for the same type of examination. It was mostly caused by the lack of standardization on the radiographic technique and equipment performance. The results show the need for changes in the working procedures and equipments used. It is necessary to investigate the reason for higher dose levels in some projections so as to review and reduce it. Training facilities for the medical and technical staff are also necessary. These facts could be achieved if the radiology departments implement QAP and establish national and/or regional diagnostic reference levels. This would promote a reduction the variability of ESD as well as aid in the optimization of radiation protection so as to keep the patient doses as low as reasonably achievable (ALARA).

Conclusion

Entrance surface doses (ESD) of patients undergoing chest (PA), lumbar spine (AP and lateral), pelvis AP, abdomen AP, skull AP/PA and lateral examination at Division of Diagnostic Radiology, Department of Radiology, Songklanagarind Hospital have been monitored. In this work, the ESD values in 7 projections below the reference level (IAEA BSS, 1996) except for skull lateral examination. Higher kVp in skull lateral projection is recommended to lower the dose. The system AEC (Automatic Exposure Control) should be calibrated and applied for the patient dose optimization.

References

1. United Nation Scientific Committee on the Effects of Atomic Radiation. Sources and effects of ionizing radiation: UNSCEAR. 2000 report Vol I [monograph on the Internet]. Vienna: The Committee; 2002 [cited 2010 Feb 10]. Available from: http://www.unscear.org/unscear/en/publications/200_1.html
2. International Atomic Energy Agency. International basic safety standard for protection against ionizing radiation and for the safety of radiation sources [monograph on the Internet]. Vienna: The Agency; 1996. Safety series No.115 [cited 2010 Feb 10]. Available from: http://www.pub.org/mtcd/publications/pdf/ss-115-web/pub996_web-1a.pdf
3. National Radiological Protection Board. Patient dose reduction in diagnostic radiology [monograph on the Internet]. London: Health Protection Agency; 1990. Documents of the NRPB, Vol 1, No 3 [cited 2010 Feb 10]. Available from: http://www.hpa.org.uk/Publications/Radiation/NPRBArchive/Documents of the NRPB/Absd0103/
4. Osibote OA, de Azevedo AC. Estimation of adult doses for common diagnostic X-ray examination in Rio de Janeiro. Phys Med 2008; 24: 21 - 8.
5. Ng KH, Rassiah P, Wang HB, et al. Dose to patients in routine X-ray examinations in Malaysia. Br J Radiol 1998; 71: 654 - 60.
6. Shahbazi-Gahrouei D. Entrance surface dose measurements for routine X-ray examinations in

Chaharmahal and Bakhtiari hospitals. J Radiat Res 2006; 4: 29 - 33.

7. National Council on Radiation Protection and Measurements. Quality assurance for diagnostic imaging equipment. NCRP Report No. 99. Maryland: The Council; 1998.
8. International Commission for Radiation Units and Measurements (ICRU). Patient dosimetry for x-ray used in medical imaging. ICRU 2005; 5: 4 - 6.
9. Petoussi Henss N, Zankl M, Drexler G, et al. Calculation of backscatter factors for diagnostic radiology using Monte Carlo methods. Phy Med Biol 1998; 43: 2237 - 50.
10. Warren-Forward HM, Miller JS. Optimization of radiographic technique for chest radiography. Br J Radiol 1995; 68: 1221 - 9.
11. Contento G, Malisan MR, Padovani R, et al. A comparison of diagnostic practice and patient exposures in Britain, France and Italy. Br J Radiol 1988; 61: 143 - 52.
12. Martin CJ, Darragh CL, McKenzie GA, et al. Implementation of a programme for reduction of radiographic dose and results achieved through increases in tube potential. Br J Radiol 1993; 66: 228 - 33.