International Journal of Psychosocial Rehabilitation, Vol. 24, Issue 06, 2020
ISSN: 1475-7192

Optimization of radiation dose for sacrum bone examination with AP, axial AP and axial PA projections

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ABSTRACT-- *Sacrum bone examination projection is Anteroposterior axial with CR 15º to the cephalad, the posterior-anterior axial with CR 15º caudal and lateral. Some practitioners take action to examine the sacrum bone with AP projections used the perpendicular beam. The radiation dose has a negative effect in the stochastic and deterministic. One factor in radiation dose is the distance between the source and the organ. The research aims to determine the projection that produces good information with minimal doses. This is an experimental study. Radiographs from AP, Axial AP and Axial PA projection assessed by the radiologist regarding the clarity of anatomic and the dosage was measured using TLD. Data analyzed by Friedman and Wilcoxon test with α = 5%.The results showed there were differences in anatomical information clarity radiographs on the AP, Axial AP and Axial PA projections with p-value = 0.001. The best information obtained on Axial PA projections. There are differences in radiation doses in the right ovary (p-value = 0.002), left ovary (p-value < 0.001) and Gonad (p-value < 0.001). The Axial PA projection produced the best information with a minimum dose.*

Keywords--*Sacrum Bone, AP, Axial AP, Axial PA Projection, Anatomical Information, Radiation Dose.*

I. INTRODUCTION

X-rays are the most widely used source of ionizing radiation for diagnostic testing in clinical applications [1]. Radiodiagnostic examination is one of the utilization of ionizing radiation to confirm the diagnosis results needed by patients in order to identify abnormalities of a patient, with minimal radiation exposure but provides good quality medical imaging [2]

In 2000 the number of routine radiological X-ray examinations diagnostics carried out around the world are reported to be around 1910 million, with collective dose effective and per capita doses of 2.3 million man-Sv and 0.4 mSv respectively. The number of examinations increased to 3100 million, with a collective effective dose being 4 million man-Sv and a per capita dose of 0.6 mSv. From the two data it can be seen that in the past eight years there has been an increase in the number of examinations of more than 60%, followed by an increase in the collective effective dose of 74% per capita dose by 50% [3]. Sacrum bone is one of the objects examined with conventional radiodiagnostic. Sacrum bone examination techniques, there are several positions, namely the Antero-posterior axial with the beam direction 15 degrees to the cephalad, the postero-anterior axial with the beam

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Received: 22 Sep 2019 | Revised: 13 Oct 2019 | Accepted: 15 Jan 2020

direction 15 degrees caudal and lateral with the beam direction perpendicular [4]. On examination of the sacrum bones there are several other critical organs such as the gonad and ovary that are sensitive to ionizing radiation [4] [5] [6].

Quality radiographs is influenced by geometric and non-geometric factor [1]. On radiological examination of the sacrum bones around there are sensitive organs to radiation, namely the ovary and gonads [3]. In addition to the quality of radiographic radiation protection must be a major concern in radiodiagnostic examination. [7] [8]. Radiation has a negative effect in the form of stochastic and non-stochastic effects (deterministic] [7] [8] [9]

In-hospital services, Sacrum bone examinations are often carried out with a projection of AP perpendicular rays. In the examination of the sacrum around objects there are reproductive organs and sensitive to radiation including the ovary and gonads so that it is necessary to pay attention to the dose received from each organ. Differences in the use of projections and the direction of light will affect the position and distance of the object to the Image Receptor as well as affect organs sensitive to radiation [1]

II. METHODOLOGY

The type of experimental research is the design of three group one shot post test only. The research sample is radiographic examination of the sacrum bone with 9 radiograph that of pelvic phantom using three AP, Axial AP and Axial PA projections with FFD 100 cm, kV = 70 and mAs = 20.

Experimental design as follows:

$X_1 \longrightarrow O_1O_2$

$X_2 \longrightarrow O_3O_4$

$X_3 \longrightarrow O_5O_6$

X_1 = AP Projection AP

X_2 = Axaial AP Projection

X_3 = Axial PA Projection

O_1 = Anatomic Information on AP Projection

O_2 = Radiation doses of Sensitive Organs on AP Projection

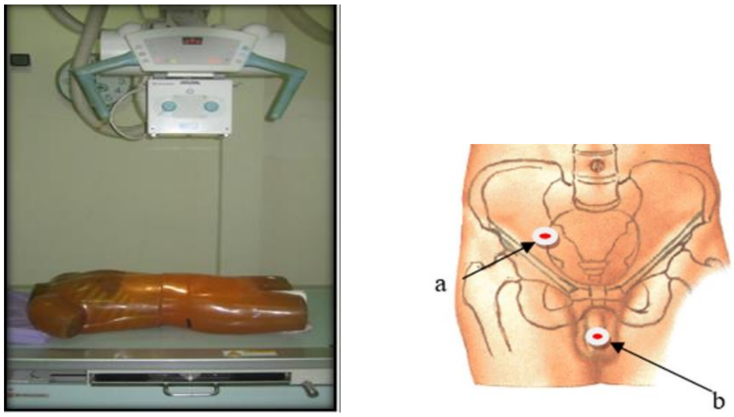
O_3 = Anatomical Information on Axial AP Projection

O_4 = Radiation doses of Sensitive Organs on Axial AP Projection

O_5 = Information Anatomy of Axial PA Projection

O_6 = Radiation dose of sensitive organs in Axial PA projection

International Journal of Psychosocial Rehabilitation, Vol. 24, Issue 06, 2020
ISSN: 1475-7192



(A) (B)

Figure. 1 : Phantom position on the manufacture of Sacrum (A) radiographs. Arrangement of location of TLD a in the position of female reproductive organs (ovary), b. male reproductive organs (testes) (B)

Radiographs assessed for clarity of sacrum anatomical information include clarity of L5-S1 Joint, Superior Articular Process of Sacrum, Sacral Foramina, Apex of Sacrum and Sacroiliac Joint. Radiographs were assessed by radiologist with criteria 1 = unclear, 2 = sufficiently clear, 3 = clear [10]. Radiation dose is measured by the TLD on the right ovary, left ovary and gonads. The radiation dose is the skin surface dose / ESE [11] [12]. Data analyzed by the Friedman test and Wilcoxon test with an error rate of 5%.

III. 3 Results and Discussion

3.1 Results

3.1.1. Univariate analysis

Results radiograph created by using a third Projection AP, Axial AP and Axial PA as shown in figure 1.

(a) (b) (c)

Figure 2: Radiographs of the sacrum bone (a) AP Projections, (b) Axial AP Projections, (c) Axia PA Projections

Radiologist assessment of the clarity of anatomic information as in tables 1, 2 and 3.

Received: 22 Sep 2019 | Revised: 13 Oct 2019 | Accepted: 15 Jan 2020

Table 1: Results of Asesessment of Clarity Information Anatomy Sacrum bone AP Projection

Anatomy	Unclear		Sufficiently clear		Clear		Amount	
	f	%	f	%	f	%	f	%
L5-S1 Joint	0	0	2	22,2	7	77,8	9	100
Sup-or articular process of sacrum	0	0	7	77,8	2	22,2	9	100
Sacral foramina	0	0	8	88,8	1	11,1	9	100
Apex of sacrum	0	0	9	100,0	0	0,00	9	100
Sacroiliac joint	0	0	6	66,7	3	33,3	9	100

Clarity of anatomy information on Sacrum Bone AP projections mostly considered quite clear on the anatomy of the Superior Articular process of Sacrum (77.8%), Sacral Foramina (88.8%) and Apex of Sacrum (100, 0%), whereas AP Projection is considered better for showing L5-S2 Joints (77.8%).

Table 2: Results of Assessment of Clarity information Anatomy Sacrum Axial AP Projection

Anatomy	Unclear		Sufficiently clear		Clear		Amount	
	f	%	f	%	f	%	F	%
L5-S1 Joint	0	0	1	11,1	8	88,9	9	100
Sup-or articular process of sacrum	0	0	3	33,3	6	66,7	9	100
Sacral foramina	0	0	3	33,3	6	66,7	9	100
Apex of sacrum	0	0	4	44,4	5	55,6	9	100
Sacroiliac joint	0	0	5	55,6	4	44,4	9	100

Clarity of Information anatomical sacrum bone in Axial AP projections stated that axial AP clearly shows a good anatomical picture in the L5-s1 joint (88.9%), Superior Articular Process of Sacrum (66.7%) Sacral Foramina (66, 7%) Apex of sacrum (55.6%) while the Sacroiliac Joint is mostly considered quite clear (66.7%).

Table 3: Results of Assessment of Clarity Information Anatomy Sacrum Bone Axial PA Projection

Anatomy	Unclear		Sufficiently clear		Clear		Amount	
	f	%	f	%	f	%	f	%
L5-S1 Joint	0	0	1	0	8	100	9	100

Sup-or articular process of sacrum	0	0	2	22,2	7	77,8	9	100
Sacral foramina	0	0	2	22,2	7	77,8	9	100
Apex of sacrum	0	0	0	0,0	9	100,0	9	100
Sacroiliac joint	0	0	1	11,1	8	88,9	9	100

Radiologist assessment of bone anatomy information clarity sacrum on Axial PA Projection All revealed clarity in the five anatomies assessed included the L5-s1 Joint (100.0%), Superior Articular Process of Sacrum (77.8) Sacral Foramina (77.8) %) Apex of sacrum (100.0%) and Sacroiliac Joint (88.9%).

Radiation dose received by sensitive organs around the Sacrum bone consisting of right ovary, left ovary and Gonads as in table 4.

Table 4: Radiation Doses received by sensitive Organs around the bones of the Sacrum

Organs	Dose (mSv)		
	AP Mean ± SD	Axial AP Mean ± SD	Axial PA Mean ± SD
Right Ovary	1.653 ± 0.067	1.611 ± 0.011	1.584 ± 0.009
Left Ovary	1.659 ± 0.018	1.587 ± 0.050	1.549 ± 0.031
Gonad	1.341 ± 0.014	1.220 ± 0.007	1.086 ± 0.004

Radiation dose received by the organ sensitive to sacrum bone examination showed that on Axial PA Projection organs Sensitive received the smallest .

3.1.2. Bivariate analysis

The results of the different test anatomical information clarity in the three projection of sacrum bone examination are shown in Table 5.

Table 5: Results of different test Anatomical Information of Sacrum Bone information between the AP, Axial AP and Axial PA Projections.

Variable	Mean Rank	p-value*	Variable	p-value**
AP Projection	1.11		AP vs Axial AP	0.017
Axial AP Projection	2.06	0.001	AP vs Axial PA	0.011
Axial PA Projection	2.83		Axial AP vs Axial PA	0.068

* Friedman Test

** Wilcoxon Test

Test for different clarity of anatomical information sacrum bone show a significant difference with p-value = 0.001. Axial PA Projection can show the clearest anatomic information with a mean Rank of 2.83. Further difference test with Wilcoxon to see the difference in clarity of sacrum bone between projections shows the difference between AP with Axial AP Projection (p-value = 0.017) and between AP with Axial PA Projection (p-value = 0.011), but there is no difference between Axial AP with Axial PA Projection (p-value = 0.068).

The results of different tests to see the difference in clarity of information on each anatomy in the Sacrum Bone examination are shown in tables 6.

Table 6: Results of different test Anatomical Information clarity anatomical sacral bone between AP projections, Axial AP and Axial PA

Variable	Anatomy	p-value
	Joint L5 -S1	0.779
AP Projection	Superior Articular Process of Sacrum	0.072
Axial AP Projection	Sacral Foramina	0.032
Axial PA Projection	Apex of Sacrum	0.001
	Sacro iliac joint	0.015

In the AP, Axial AP and Axial PA projections showed no significant difference in the clarity of L5 joint information - S1 (p-value = 0.779) and anatomy superior articular process of sacrum (p-value = 0.072). The results for different test anatomical clarity Sacral Foramina shows a difference with p-value = 0.032, Apex of sacrum (p-value = 0.001) and the sacroiliac joint (p-value = 0.015).

Different test is carried out to determine the difference in radiation dose received by sensitive organs (right ovary, left ovary and gonad). The dose was measured using ESE (Entrance Skin Exposure). Test results of different radiation dose received by right ovary as in table 7.

Table 7: Results of different test radiation dose in right ovary on AP, Axial AP and Axial PA projections.

Variable	Mean Rank	p-value*	Variable	p-value**
AP Projection	2.89		AP vs Axial AP	0.011
Axial AP Projection	1.89	0.002	AP vs Axial PA	0.011
Axial PA Projection	1.22		Axial AP vs Axial PA	0.021

* Friedman Test

** Wilcoxon test

Test results indicate that there is a difference in radiation dose received between the three projections with p-value = 0.002. There is a difference in right ovary radiation dose between AP Projection – Axial AP Projection (p-value = 0.011), AP – Axial PA Projection (p-value = 0.008) and Axia AP – Axial PA projection (p-value = 0.021).

AP projections produce highest right ovary doses, and AP Axial Projection produce gives a higher radiation dose to the right ovary than the Axial PA projection.

Doses received by the left ovary in the three Sacrum bone examination projections are as in table 8.

Table 8: Results of different radiation dose received in the Left Ovary between the AP, Axial AP and Axial PA Projections.

Variable	Mean Rank	p-value*	Variable	p-value**
AP Projection	2.89		AP vs Axial AP	0.011
Axial AP Projection	2.00	0.001	AP vs Axial PA	0.011
Axial PA Projection	1.11		Axial AP vs Axial PA	0.032

* Friedman Test

** Wilcoxon test

The test results show the difference in radiation dose received by the left ovary between three projections with p-value = 0.001. The highest dose in the left ovary is the AP projection.

The results of the different radiation dose tests received by the left ovary showed a significant difference between the AP and AP Axial projections (p-value = 0.011), between the AP projections with the Axial PA projections (p-value = 0.018) and between the Axial AP with PA axial projection (p-value = 0.032). The different dosage tests received by the gonads pass through three sacral bone projections as in table 9.

Table 9: Results of different Tests of the radiation dose received ini the Gonad between the AP, Axial AP and Axial PA Projections.

Variable	Mean Rank	p-value*	Variable	p-value**
AP Projection	3.00		AP vs Axial AP	0.008
Axial AP Projection	2.00	< 0.001	AP vs Axial PA	0.008
Axial PA Projection	1.00		Axial AP vs Axial PA	0.007

* Friedman Test

** Wilcoxon test

The test result showed there were differences in radiation doses received by Gonad on examination of the sacral bone between AP, Axial AP and Axial PA projections with a p-value <0.001. Gonad received the lowest dose in the Axial PA Projection, while the highest dose was received by Gonad in the AP projection. The radiation dose received by the gonad shows that there are differences between the projections used. Between AP with Axial AP Projection (p-value = 0.008), AP with Axial PA (p-value = 0.008) and between Axial AP and Axial PA Projection (p-value = 0.007)

3.1.3 Dosage Optimization and Anatomical Clarity Information on Sacrum Bone Examination

To determine the minimum radiation dose and, the best anatomical information is determined based on the Mean Rank and the smallest radiation dose. The radiation dosen in right ovary, left ovary dose and the smallest gonadal dose are accepted on PA axial projections. While the highest overall Sacrum bone anatomic information is also shown in axial PA projections, although statistically the axial AP and axial PA projections do not show significant differences in anatomic information. Axial PA Projection is the ideal projection to display images of Sacrum bone with a minimum dose value.

IV. DISCUSSION

3.1.1 Anatomical Information Differences The AP, Axial Ap and PA Axial Projection

Results of the study showedd that there are differences in anatomical clarity between the AP, Axial AP and Axial PA projections. Axial PA Projection can show the overall anatomy of the sacrum bone more clearly than the AP and Axial AP projections. The ability of axial PA projection shows a better anatomical picture than the other two projections, especially in describing the anatomy of the sacrum foramen, sacrum bone apex and sacroiliac joint. Axial PA projection has the same ability to describe anatomical clarity with AP axial projection in showing the L5-S1 Joint and Superior Articular Process of Sacrum.

The ability of a radiograph to display a clear anatomical picture of an object being photographed is determined by the contrast and quality of the radiograph. Contrast is Radiograph influenced by the object being photographed including thickness, density, atomic number and quality of the X-ray (kV). In addition to the object factors that are photographed Image recorder (Screen film system) and scatter and fog play a role in producing radiograph a good. [1]. The second factor that determines the clarity of image information (image) is quality Radiograph. Quality is Radiograph determined by several factors, namely radiographic mottle, sharpness (sharpness), detail (resolution) and distortion [1] [14].

Geometric factors are one of the factors that determine the quality of the radiograph. Geometric factors include the distance between the source of the beam with the Image Reorder / *Focus Film Distance* (FFD), the distance between the object with the film /*object film distance* (OFD) and the size of the focal spot. In examination radiograph the third sacrum bone the projection used by AP, Axial AP and Axial PA is set with the same FFD which is 100 cm and is carried out with the same plane so that the focal spot size is also the same. What distinguishes between the three is the distance between the object and the image recorder (IR), the location of the object to the central beam, the use of angled rays and the position of the object against the Image Receptor (IR). In AP projection, the distance of the sacrum bone to the film is closest compared to Axial AP and Axial PA projections. OFD affects the size of the object being photographed [10]. Sacrum AP projections have relatively no enlargement (Distortion in Size) compared to the other two projections. However, when viewed from the position of sacrum bone objects in the AP position forming an angle to the Image recorder, this results in the resulting shadow will experience a change in shape (distortion in shape) that is experiencing a shortening (*Foreshortening*) [1] [10]. The presence of distortion in this form causes the anatomy of the sacrum to be less visible than the other two projections (Axial AP and Axial PA). This closest distance also causes organs sensitive around the sacrum (ovary and gonads) to get a greater dose than the other two projections [1] [14].

In Axial AP Projection, the Beam is set at 15 degrees Cephalad with a point at 2.5 inches above the symphysis pubis. By adjusting the angle of the beam toward the cephalad, the center of the beam will be perpendicular to the sacrum bone object which anatomically has a curved shape, this will reduce the *distortion in shape*, so that the sacrum bone is seen in a wider size. On the Axial AP projection the foramen sacrum is more clearly visible than the AP projection. On the AP projection some of the sacrum bone apex is still overlapping with the symphysis pubis bone, the sacroiliac joint is less visible open [10].

In Axial PA Projection, the picture of sacrum bones also does not experience distortion in the form / shortening (*foreshortening*). Axial PA Projection can describe the sacrum bone wider than the AP projection. The advantage of Axial PA projection is that it can show the picture of the sacrum foramen, sacroiliac joint and sacrum bone apex more clearly than AP and Axial AP projections. Judging from the position of the Axial PA projection object, it is relatively uncomfortable compared to the AP and Axial AP projections. The difference in anatomical clarity is due to the direction of the center of the beam (CR), the position of the object towards the center of the beam and the position of the object towards the Image recorder [1] [10].

3.1.2 Differences in Receiving Doses by Sensitive Organs

The results showed there were differences in the value of radiation doses received by sensitive organs around the sacrum organs including the right ovary, left ovary and gonads. The difference in dose received by the organ is determined by the distance of the organ to the source of radiation in this case the X-ray tube. In this study all three projections inset with 100 cm FFD. In AP projection the distance of the light source to the reproductive organs is closest compared to the Axial AP and Axial PA projections. This results in the dose received by the ovary and gonad organs getting the highest surface dose compared to Axial AP and Axia PA projections. Whereas in the Axial PA projection the distance of the organ is the sensitive most to the source of light, thus making the dose received by the ovary and gonad the smallest dose.

The deterministic effect on male reproductive organs (gonads) is sterility [16]. Exposure to radiation in the testes will disrupt the process of sperm cell formation which will ultimately affect the number of sperm cells to be produced. The radiation dose of 0.15 Gy (0.15 Sv) is a temporary sterility threshold dose, because it has resulted in a decrease in sperm cell counts for several weeks. While the threshold dose for permanent sterility is 3.5 - 6 Gy (3.5-6 Sv) [7] [8]

The effect of radiation on the ovum is very dependent on age. The older the age, the more sensitive it is to radiation. In addition to sterility, radiation can cause early menopause as a result of hormonal disorders of the reproductive system. The sterility threshold dose according to ICRP 60 is 2.5 - 6 Gy. At a younger age (around 20 years), permanent sterility occurs at higher doses, reaching 12-15 Gy. [7] [15].

Received: 22 Sep 2019 | Revised: 13 Oct 2019 | Accepted: 15 Jan 2020

In addition to deterministic effects that are limited by threshold doses, radiation has a stochastic effect where the effect size is not determined by the dose size. Stochastic effects that may arise due to radiation exposure are cancer, leukemia and genetic effects [7] [[8] [16]

3.1.3 Projections that produce clear anatomic information with the smallest dose of radiation

AP, Axial AP and Axial PA projections provide different anatomical information among the three, however, between Axial AP and Axial PA projections there is no difference in revealing anatomic information. The three AP Projections, Axial AP and Axial PA give different doses to sensitive organs around the sacrum bone including the right ovary, left ovary and gonads. Axial PA projection is a projection that can show the clearest picture of the sacrum with a minimum dose received by the ovary and gonads.

The clarity of anatomic information is determined by geometric factors, in this case the distance between the organ and the radiation source. And the position of the object against the Image Recorder. [1]. Axial AP and Axial PA projections produce images that are able to show the whole sacrum bone with minimal distortion because the central beam is perpendicular to the sacrum bone. [1] [3].

Axial PA Projection gives the smallest dose in the ovary or gonad among other examination projections. The smaller the dose, the effect of radiation on cause smaller. As far as possible in every examination the dose received by the patient is as small as possible in accordance with the philosophy of radiation safety, namely As Low As Reasonable Achievable (ALARA) [17]. Even the smallest dose of radiation received will have a stochastic effect. [7] [9] [17]

V. CONCLUSIAN ANDA SUGESTIONS

4.1. Conclusions

1. There is a difference in the anatomical information on Sacrum bone examination between AP, Axial AP and Axial PA Projection (p-value = 0.001). There are differences in sacrum bone anatomy information between AP and Axial AP Projection (p-value = 0.017), between AP Axial and Axial PA Projection (p-value = 0.011). There is no difference anatomical information between Axial AP and Axial PA Projections (p-value = 0.068)
2. There is a difference in the dose received by the right ovary of the Sacrum bone examination between AP, Axial AP and Axial PA Projections (p-value = 0.002). There is a difference in right ovary dose between AP and AP Axial Projection (p-value = 0.011), between AP with Axial PA projection with p-value = 0.008 and between Axial AP and Axial PA Projection (p-value = 0.021).
3. There is a difference in the dose received by the left ovary of the Sacrum bone examination between the AP, Axial AP and Axial PA projections (p-value <0.001). There is a difference in left ovary dose between AP and Axial AP Projection (p-value = 0.011), between AP projection with Axial PA Projection (p-value = 0.008) and between Axial AP and Axial PA Projection (p-value = 0.032).
4. There is difference in dosen received by gonad the Sacrum bone examination between AP, Axial AP and Axial PA Projections (p-value <0.001). There is a difference in gonad dose between AP and Axial AP Projection

(p-value = 0.008), between the AP with PA Axial projection (p-value = 0.008) and between Axial AP and Axial PA Projection (p-value = 0.007).

5. Projections that produce Sacrum bone anatomy information clearly and the dose received by the organ sensitive smallest is the PA Axial projection.

4.2 Suggestions

On examination of the sacrum bone radiation protection must be done as much as possible to reduce the dose received by sensitive organs.

1. On examination of the sacrum bone it should be sought to choose examination techniques that can produce anatomic information clearly and pay attention to the dose received by the patient.

VI. ACKNOWLEDGEMENTS

Thank you researchers to the Director of the Semarang Health Polytechnic for the facilities provided so that the research can be carried out. Thanks also to the research conveyed to the Head of the National Atomic Energy Agency (BATAN) for the cooperation so that this research could run smoothly

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