Radiation dose reduction on cervical spine radiographic examination by using posteroanterior oblique projection

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Abstract. Cervical spine radiographic examination with 45° oblique projection can be performed using anteroposterior (AP) oblique or posteroanterior (PA) oblique. There are radiosensitive organs that are exposed to radiation during the examination. This study aims to determine the radiation dose (Entrance Surface Dose) received by thyroid, eye, and breast on radiographic examination in AP oblique and PA oblique projections. Radiographic phantom with equivalent structure to human body was positioned in AP oblique and PA oblique. A modified protractor was used to maintain the positioning precision. The optimum exposure factors (confirmed by Exposure Index) were used. Radiation dose on the thyroid, the eye, and the breast were measured 9 times using Termoluminisence Dosemeter for each positioning techniques. Data were analyzed by independent t-test. The average radiation dose received by the thyroid, the breast, and the eye between AP oblique and PA oblique projections were (0.915 and 0.174), (0.059 and 0.025), and (0.234 and 0.079), respectively. There were significant differences in the radiation dose received by the thyroid (p value <0.05), the breast (p value <0.05), and the eye (p value <0.05). The radiation dose were lower (81% on thyroid), (58% on breast), (66% on eye) by using PA oblique projection.

1. Introduction
Cervical radiographic examination is a common diagnostic imaging modality for spinal complaints evaluation and tumors, fractures, and degenerative pathologies identification [1,2]. There are several projections used in cervical radiographs i.e AP open mouth, AP axial, lateral, and oblique projection. The oblique projection is an additional view to demonstrate the patency of the intervertebral foramen [2,3]. Oblique projections were performed to support diagnosis of radiculopathy [2], trauma [4], and to guide epidural injection [5].

Oblique projection can be performed with AP oblique or PA oblique [6] [3]. In both projections, the body position is 45° to the image receptor. In AP oblique, X-ray passing through the anterior side of the body to the posterior side, and the beam is angulated 15° to 20° cephalad. In the PA oblique projection, X-ray passing through with opposite direction, and the beam is angulated 15° to 20° caudad. The optimal patient body tilt varies from 45° to 55° [2,3,6].

Radiation exposure from medical imaging induces the risk of causing cancer [7]. In the neck area, there are thyroid, eyes, and breasts that are sensitive to radiation exposure. Radiation exposure to these organs has the potential to cause cancer or malignancy [8,9]. Thyroid radiation exposure can cause thyroid cancer [10,11] and cataracts to the eye [12,13].
Radiographers play an important role in minimizing the risk due to radiation in medical imaging. The choice of projection on radiographic examination affects the amount of radiation dose received by radiosensitive organs. The closer the distance between the X-ray source and the organ, the greater the radiation exposure received.

Using the right projection can minimize the radiation dose received by the radiosensitive organ. Previous studies [14-16] have shown that using a PA projection can reduce the dose without significant reduction of diagnostic information. The use of PA projection on clavicle radiography can reduce the dose significantly compared to AP projections [14]. Using PA projection on lumbar examination can reduce the effective dose and absorption dose received in the lumbar organs compared to AP projection without decrease image quality [15]. In a recent literature review, it was stated that PA projection is more recommended than AP projection because the radiosensitive organs is located closest to the anterior surface of the body [16]. This study aims to determine the difference in radiation dose between the projection of the AP oblique and PA oblique on cervical radiography.

2. Material and methods
Radiographic phantom was exposed nine times using two radiographic positioning techniques: 45° facing towards the X-ray source (AP oblique) and 45° back to the X-ray source (PA oblique). Radiation dose (Entrance Skin Dose) to the radiosensitive organs were measured for each projection.

2.1. Radiographic imaging
Radiographic imaging was performed using a calibrated multipurpose X-ray unit (BMI-BRG 100 RF, Italy). The image receptor was and 24 cm x 30 cm imaging plate (Carestream™ CR System).

2.2. Positioning
Radiographic phantom (Kyoto Kagaku™ CTU-41) with equivalent structure to human body was positioned on two positioning techniques: right anteroposterior oblique and left posteroanterior oblique as shown in Figure 1. The obliquity of both projections were 45°. A modified protractor was used to maintain its precision. The beam was angulated 15° cranial for anteroposterior oblique projection and 15° caudal for posteroanterior projection. Collimation field (24 cm x 30 cm), Source to Image Distance (180 cm), and optimum exposure factors (confirmed by Exposure Index on Carestream™ CR System), 80 kV, 16 mAs, were controlled.

2.3. Dose measurement
Termoluminisence Dosemeter (TLD) chips (TLD-100™ LiF:Mg, Ti) were placed on the thyroid, the eye, and the breast as shown in Figure 2. Entrance Surface Dose (ESD) were measured 9 times for each positioning techniques. TLD chips chips for measurement were provided and calibrated by National Nuclear Energy Agency of Indonesia (PTKMR-BATAN).

![Figure 1. Object positioning for AP oblique projection (A) and PA oblique projection (B)](image-url)
2.4. Data analysis
Data were analyzed using independent t-test to determine differences in radiation dose received by radiosensitive organs. The confidence level was set 95%.

3. Result
AP oblique and PA oblique projection provide the same anatomical image informations as visualized in Figure 3. The brightness and contrast on both projection were relatively equal.

The average radiation dose received by the thyroid, the breast, and the eye between anteroposterior oblique and posteroanterior oblique projections were (0.915 mGy and 0.174 mGy), (0.059 mGy and 0.025 mGy), and (0.234 mGy and 0.079 mGy), respectively as shown in Figure 4 and Table 1.
Table 1. ESD received by radiosensitive organs on AP and PA projection of cervical radiography

| No | Thyroid | Breast | Eye |
|----|---------|--------|-----|
|    | AP<sup>a</sup> | PA<sup>b</sup> | AP<sup>a</sup> | PA<sup>b</sup> | AP<sup>a</sup> | PA<sup>b</sup> |
| 1  | 0.977   | 0.201  | 0.012 | 0.020 | 0.210 | 0.070 |
| 2  | 0.897   | 0.144  | 0.088 | 0.050 | 0.270 | 0.080 |
| 3  | 0.928   | 0.156  | 0.067 | 0.030 | 0.253 | 0.101 |
| 4  | 1.016   | 0.192  | 0.012 | 0.030 | 0.217 | 0.092 |
| 5  | 0.933   | 0.150  | 0.091 | 0.011 | 0.279 | 0.033 |
| 6  | 0.915   | 0.163  | 0.070 | 0.021 | 0.261 | 0.083 |
| 7  | 1.027   | 0.224  | 0.023 | 0.021 | 0.223 | 0.074 |
| 8  | 0.940   | 0.156  | 0.095 | 0.011 | 0.287 | 0.085 |
| 9  | 0.874   | 0.179  | 0.073 | 0.032 | 0.269 | 0.090 |
| Min | 0.874  | 0.144 | 0.012 | 0.011 | 0.210 | 0.033 |
| Max | 1.027  | 0.224 | 0.095 | 0.050 | 0.287 | 0.101 |
| Avr | 0.945  | 0.174 | 0.059 | 0.025 | 0.252 | 0.079 |
| SD  | 5%     | 3%    | 3%   | 1%   | 3%   | 2%   |

<sup>a</sup>AP oblique
<sup>b</sup>PA oblique

Independent t-test showed that there is significant difference on radiation dose received by the thyroid (p-value < 0.05), the breast (p-value < 0.05) and the eye (p-value < 0.05) between AP oblique and PA oblique. The average radiation dose received by the thyroid, the breast, and the eye on PA oblique is lower than on AP oblique. Dose reductions were 81% on thyroid, 58% on the breast, and 66% on the eye.

4. Discussion
Radiation dose measurement in this study used entrance skin dose measurement to represent the radiation dose received by radiosensitive organs on cervical radiographic examination that are located on superficial body. The thyroid, the breast, the eye are located on the anterior side.
The radiation dose received by radiosensitive organs are lower on PA oblique projection. It is due to the greater distance of the organ to the radiation source in the PA oblique projection than in the AP oblique projection. In the PA oblique projection the X-ray penetrates the posterior side to the anterior while in the AP projection the X-ray penetrates the anterior to the posterior side. The radiation dose received by the eye, the thyroid, and the breast in the PA oblique projection is lower because the radiosensitive organs are located on the anterior side of the body so that the distance of these organs to the X-ray source is relatively far compared to the oblique AP projection.

The radiation dose received by the radiosensitive organs in both projections is relatively small if compared to the threshold level. However, even the smallest dose of radiation has to be concerned. In contrast to the non-stochastic radiation effects that associated with a threshold level, the stochastic effect has no threshold dose. Even the smallest radiation exposure received can cause side effects, so efforts must be made to ensure that the patient receives as low as possible radiation dose.

Among other radiosensitive organs, the radiation dose received by the thyroid is the highest. This is because the thyroid is located in the center of the collimation field, while the eyes and breasts are located in the outside. Although located outside of the collimation, the eyes and breasts receive scatter radiation due to its location that close to the collimation area. Therefore, collimation field must be strictly adjusted so that the radiation dose received by the eye and breast can be minimized.

PA oblique projection is a recommended projection for cervical radiographic examination because it can reduce the radiation dose to sensitive organs. The choice of projection will determine the radiation dose received by the radiosensitive organs. Previous research shows that PA projection on radiographic examination of clavicle [14] and lumbar spine [15] can reduce radiation dose without a significant decrease in image quality.

PA oblique and AP oblique projections provide comparable image information. Both of these projections can visualize the intervertebral foramen because the obliquity of the objects in these two projections is the same (45°) according to the anatomical location of the intervertebral foramen. The literature suggests that the obliquity of the oblique projection is 45° [6]. However, other studies have shown that the optimal obliquity is 46,3° to visualize intervertebral foramen of C2-C3 and 56,1° to intervertebral foramen of C7-T1 [2]. Visualization of the intervertebral foramen is very important in the diagnosis of cases associated with the cervical syndrome. The intervertebral disc space is visible in both projections because the beam angulation match to the intervertebral disc space angle. In the oblique AP projection, the beam is angled 15° cephalad and in the PA oblique, the beam is angled 15° caudad. With proper positioning, visualization of the other anatomical structures in the two projections is relatively equal.

Positioning of the PA oblique is relatively easy to do because the examination is performed with the erect patient position. Adjusting the body tilt on erect position is much more easily than in a recumbent position. Source to Image Distance (SID) needs to be considered in the examination process because of the long Object to Image Distance [6]. The SID needs to be increased to compensate the large Object to Image Distance.

5. Conclusion
There is significant different on radiation dose received by the thyroid (p-value <0.05), the breast (p-value <0.05), and the eye (p-value <0.05) in cervical spine radiographic examination between AP and PA oblique projection.

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