research article

Comparison of anteroposterior and posteroanterior projection in lumbar spine radiography

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Background. The aim of the study was to compare patient radiation dose and image quality in planar lumbar spine radiography using the PA and AP projection in a large variety of patients of both sexes and different sizes.

Patients and methods. In the first phase data of image field size, DAP, effective dose and image quality were gathered for AP and PA projection in lumbar spine imaging of anthropomorphic phantom. In the second phase, data of BMI, image field size, diameter of the patient's abdomen, DAP, effective dose and image quality were gathered for 100 patients of both sexes who were referred to lumbar spine radiography. The patients were divided into two groups of 50 patients, one of which was imaged using the AP projection while the other the PA projection.

Results. The study on the phantom showed no statistically significant difference in image field size, DAP and image quality. However, the calculated effective dose in the PA projection was 25% lower compared to AP projection ($p = 0.008$). Measurements on the patients showed no statistically significant difference between the BMI and the image field size. In the PA projection, the thickness of abdomen was 10% ($p < 10^{-3}$) lower, DAP 27% lower ($p = 0.009$) and the effective dose 53% ($p < 10^{-3}$) lower than in AP projection. There was no statistically significant difference in image quality between the AP and the PA projection.

Conclusions. The study results support the use of the PA projection as the preferred method of choice in planar lumbar spine radiography.

Key words: lumbar spine radiography; PA projection; dose reduction; image quality

Introduction

In general radiography lumbar spine imaging is one of procedures with the highest patient radiation dose.[1-3] In order to reduce patient dose, one of the methods is the replacement of the conventional anteroposterior (AP) projection with the posterioanterior (PA) projection.[4-11] Even though the reviewed professional literature[12-14] still quotes AP projection as the method of choice for most of the procedures in plane radiography, the dose reduction with the use of PA projection was shown in several articles for a number of procedures, such as imaging of the clavicle[4], sacroiliac joint[5], abdomen[6], knee joint[15] and lumbar spine.[7,8,16]

Mc Entee and Kinsella (2010) noted that the use of PA projection of the clavicle can result in dose decrease of 28% to the eyes, 56% to the breast and 78% to the thyroid. Although the image quality was better in the AP projection by 6.3%, the images performed in the PA projection were diagnostically acceptable. Mekis *et al.*[5] investigated how dose reduction to the patient can be achieved with the use of PA projection in the sacroiliac joint imaging. The results show the reduction of DAP value by 12.6% and the reduction of entrance skin dose (ESD) by

21% when the PA projection is used. The reduction of dose to the patient was also shown in the article by Nic an Ghearr and Brennan[6] when they used PA projection for the imaging of the abdomen. They concluded that a 31% of ESD decrease and 56% decrease in effective dose can be observed when using PA projection with no statistically significant difference in the image quality.

Patient dose reduction in the lumbar spine radiography has already been explored by several authors. Brennan and Madigan[8] investigated the dose reduction to female patients when using PA instead of the conventional AP projection in lumbar spine radiography. They concluded that tissue displacement caused dose reduction with the use of PA projection. In their study the EDS was reduced by 38.6% without statistically significant difference in image quality.

Davey and England[7] reported that with the use of PA projection of lumbar spine, the effective dose can be decreased by 19.8%. The research was performed on the anthropomorphic phantom. They observed a loss of image quality in the PA projection but without statistically significant difference.

Based on the literature the dose reduction in the PA projection is the result of various factors, such as tissue compression (smaller diameter)[8], bone position as the protection of the internal organs and longer distance from the primary source.[7]

The PA imaging process is simple to perform, does not require any additional equipment nor increases the costs, which is often a limiting factor in many diagnostic procedures.[7] However, the PA projection has its limitations and cannot be used in emergency patients with lumbar spine injuries.[12-14]

The previous research regarding comparison between the AP and PA projections of the lumbar spine radiography were conducted on anthropomorphic phantom and on women within the weight range 70 ± 5 kg and 155 to 175 cm height range. No extensive research has yet been conducted on a larger population, including both genders and larger weight range. Therefore, the aim of the study was to determine the impact of PA projection in lumbar spine radiography to patient dose, tissue displacement and influence on image quality in a large variety of patients of both sexes and different sizes.

Patients and methods

Cross-sectional study with the experimental research method was performed in this study. The study was conducted in two phases. In the first phase, the measurements were performed on an anthropomorphic phantom, and in the second phase, on 100 patients that were referred to lumbar spine radiography and were randomly divided into two groups of equal size. One group was imaged using the AP projection while the second group using the PA projection.

In both phases, the measurements were performed at the Radiology Department of the Community Health Centre Ljubljana on the Siemens Axiom Aristos FX Plus system. The grid ratio used in the study was 15:1, with 80 line/cm, the focus-detector distance was 115 cm. Prior to and during the study, the quality assurance test was performed on all parts of the x-ray machine.

Beam positioning in AP and PA projections was performed according to the literature.[12-14,17] The longitudinal line of the central ray was positioned in the centre of the body line and at the transverse line at the lowest point of the rib cage.

For each patient, the image size area was measured to enable the comparison of the image field size between AP and PA projection and to ensure that the image size would not affect the DAP and influence the calculation of dose received by the phantom and the patients.

Dosimetry

The dose area product (DAP) was measured using a built-in DAP which calibration was tested prior to the study.

Phantom measurements

Prior to the patient study, the measurements were carried out on the anthropomorphic phantom PBU60 (Kyotogagaku Co., Ltd, Japan) that has the same attenuation factor as a patient with weight of 50 kg and a height of 165 cm (Figure 1). Measurements on the phantom were performed using the same protocol as in the lumbar spine imaging in the department where the study was conducted. In both projections, the tube voltage was 79 kV and was not changed during the measurements. The central chamber of automatic exposure control (AEC) was used in both projections. The additional copper filtration of 0.1 mm was used in all the exposures. The phantom was imaged 10 times, 5 times in the AP and then 5 times in the PA projection. The phantom and the x-ray system were moved and reset for each exposure, so that the error of the positioning was included in the measurements.

FIGURE 1. Image of the anthropomorphic phantom used in the study.

Patient measurements

The second part of the study was performed on 100 patients who were referred to the lumbar spine radiography. The patients were randomly divided into two groups of 50. All of the patients were measured and weighted and their BMI was calculated. The exposure parameters were the same as in the phantom measurements and did not differ in the AP and PA projection. Before each exposure, the thickness of the patient's abdomen at the part of the transverse beam position (lowest point of the rib cage) was measured to determine whether the PA projection showed flattening of the excess abdomen.

The approval of the National Medical Ethics Committee was obtained prior to the study. All the participants were informed about the purpose of the study and gave a written consent to participate in the study. None of the patients declined the participation in the study.

Image quality

The images were assessed by three experienced radiology specialists working in the Health Community Center Ljubljana, with more than 5 years of experience. A blind randomized study was used, and all images were assessed on the same diagnostic monitor. All 110 radiographs were assessed on a 5-point scale, in the same way as in study conducted by Davey and England[7], where a 5-point Likert score rating was used. The ratings on the scale were as follows: score 1 - insufficient; score 2 - sufficient; score 3 - well; score 4 - very good and the score 5 - excellent.

The images were assessed according to the following criteria, which are listed in the guidelines[18]:

1. Complete visualisation of the lumbar spine and sacrum.
2. Visually sharp imaging, as a single line, of the upper and lower-plate surfaces in the centred beam area.
3. Visualisation of the intervertebral spaces in the centred beam area.
4. Visually sharp imaging of the pedicels, transverse processes, spinous processes and intervertebral joints.
5. Visualisation of the sacroiliac joints
6. Visually sharp imaging of the cortical and trabecular structures

For each criterion, a minimum possible score was 1 and a maximum possible score was 5. Scores were achieved in a way that each image could receive a minimum 6 and a maximum 30 score. Next, the average score of all three evaluators was calculated for each image.

During the assessment, it was not possible to change the contrast of the image or use a magnification or take measurements on the pictures which could indicate a PA projection.

Effective dose calculations

The effective dose was calculated using the Monte Carlo simulation program PCXMC 2.0 (STUK, Radiation and Nuclear Safety Authority in Finland). The image field size, weight and height were inserted into the program for each patient individually. The effective dose calculations were then performed for each patient according to the Monte Carlo simulation and the measured DAP value.

Statistical analysis

All the measurements were processed with the IBM SPSS STATISTICS version 23. Shapiro-Wilk test was used to check the normal distribution of the sample. For the phantom measurements, a non-parametric Mann-Whitney U test was used. For the patient study, the T-test for independent samples and Mann-Whitney U test were performed. Cohen's coefficient Kappa was used to check the level of matching of the assessors. The significance of $p < 0.05$ was used for all the tests. The results DAP and effective dose are presented with relative difference and standard mean error (relative difference ± standard mean error).

TABLE 1. Basic statistical characteristics of the phantom study

Variable	Projection	Mean	Standard deviation	Median	Minimum	Maximum
Imaging field size (cm²)	AP	725.5	120.0	690.1	587.4	913.5
	PA	788.1	66.2	770.3	723.6	874.5
Dose-area product (µGy m²)	AP	26.7	3.6	25.9	22.4	32.1
	PA	28.6	2.0	28.0	26.7	31.0
Effective dose (µSv)	AP	117	18	114	95	144
	PA	85	5	83	80	91
Average image estimation	AP	27.5	1.3	27.0	26.3	29.7
	PA	27.3	1.1	27.7	25.3	28.0

TABLE 2. Results of patient study

Variable	Projection	Mean	Standard deviation	Median	Minimum	Maximum
Body mass index	AP	26.6	3.2	26.3	19.7	35.2
	PA	26.6	4.0	26.6	20.0	35.7
Imaging field size (cm²)	AP	822.8	62.2	832.5	653.4	992.0
	PA	830.8	65.4	848.4	630.9	941.1
Patient's abdominal diameter (cm)	AP	23.6	4.0	24.0	16.0	30.0
	PA	21.2	2.8	22.0	15.5	28.0
Dose-area product (µGy m²)	AP	61.0	30.9	55.4	21.6	137.6
	PA	44.7	19.8	41.4	15.3	94.5
Effective dose (µSv)	AP	169	72	159	55	346
	PA	79	24	77	45	136
Average image estimation	AP	27.4	1.5	27.9	23.3	29.7
	PA	27.5	1.4	28	24.7	29.7

Results

Phantom study

In the phantom study, 10 measurements of DAP and 30 image quality assessments were obtained. The basic statistical characteristics of the measurement (imaging field size, DAP, effective dose and image quality assessment) performed on the phantom are shown in the Table 1. There was no statistically significant difference between imaging filed size ($p = 0.310$), DAP ($p = 0.310$) and image quality assessment ($p = 0.690$). The effective dose calculations showed a 25 ± 5% lower value ($p = 0.008$) when the phantom was imaged in the PA projection.

Patient study

In the second part of the study, a total of 100 BMI, image field size, abdominal diameter, DAP, effective dose and 300 image quality assessments were collected. The results of all the listed values are summarized in the Table 2.

First, an analysis of the imaging filed size and the BMI was performed. The PA and AP group were compared with respect to BMI distribution using the independent samples T test and no statistically significant difference was found between the groups ($p = 0.949$). The image field size analysis using Mann Whitney U test showed the same result, confirming there was no statistically significant difference ($p = 0.391$). According to the obtained results, comparison of all the other values was performed.

The use of a PA projection instead of the standard AP resulted in a decrease of the patient abdominal diameter by 10% (2.4 cm). The results were analysed using independent samples T test that showed a statistically significant difference ($p < 10^{-3}$) between the abdominal thickness of AP and

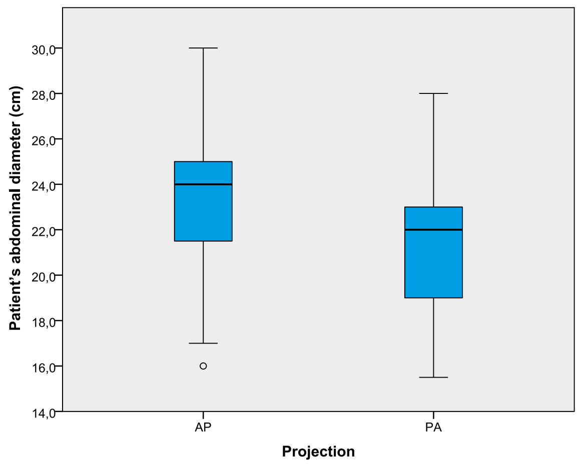

FIGURE 2. The comparison of the patient's abdominal diameter in AP and PA projection.

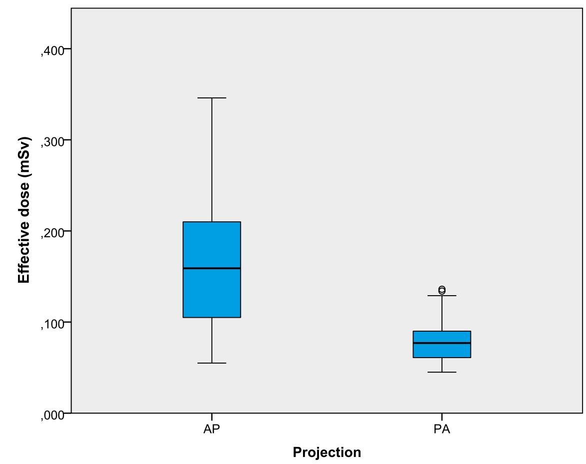

FIGURE 4. The comparison of the effective dose in both projections.

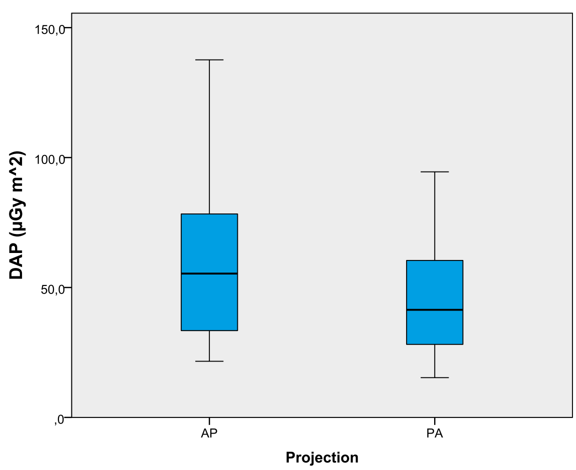

FIGURE 3. The comparison of DAP between the AP and PA projection.

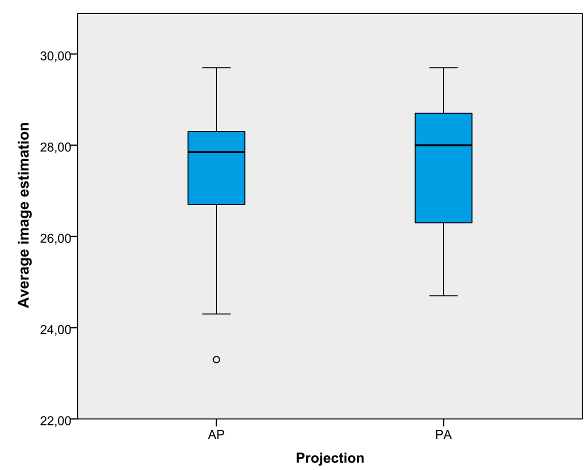

FIGURE 5. Graphical comparison of the average image estimation between the AP and PA projection.

PA projection of lumbar spine (Figure 2). The average DAP value was 16.3 µGym² (27 ± 7%) lower in the PA projection. Nonparametric Mann-Whitney U test, showed a statistically significant differences ($p = 0.009$) between the DAP in the AP and PA projections (Figure 3). The average effective dose was 90 µSv (53 ± 3%) lower in PA projection. The Mann Whitney U test shows statistically significant difference of $p < 10^{-3}$ (Figure 4). There was no statistically significant difference between the image quality ($p = 0.690$) in the AP and PA projection (Figure 5).

Cohens Kappa coefficient showed no matching between the assessors, so we also tested the difference between AP and PA projection for each assessor separately and found that there were no statistically significant differences between AP and PA projection in individual assessors ($p = 0.091$; $p = 0.416$; $p = 0.411$).

Discussion

The aim of the study was to compare patient radiation dose and image quality in lumbar spine plane radiography using the PA and AP projection in a large variety of patients of both sexes and different sizes.

We found that the use of PA projection leads to a reduction of DAP and effective dose by 27% and 53% respectively with no statistically significant impact on image quality. The main parameters that influence the dose reduction were BMI[19,20], size of imaging field[21] and the diameter of the patient.[8] As the difference in the BMI can influence the patient dose, the differences in BMI between the AP and PA projection were explored. In this study, the BMI and the size of imaging field had no statistically significant difference, therefore we can conclude that the dose reduction was due to the use of PA projection.

The differences in the diameter of the abdomen between the patients in AP and PA projection was 10% which is in agreement with the study conducted by Brennan and Madigan[8], where the difference between AP and PA projection was 9.6%.

In the phantom study there was no statistically significant difference between DAP in AP and PA projection. Such results were expected because the phantom is made of a rigid material that cannot be dispersed and consequently the diameter of the phantom does not change. The results of the current and previous studies[8] confirm that the diameter of the patient has a large influence on the patient dose. In the patient study, a statistically significant difference was established between DAP in both projections, with the average DAP value being 27% lower in PA projection. Similar results in DAP reduction were obtained in the research conducted by Mekis *et al*.[5] where an average of 12.6% reduction in sacroiliac joint imaging was reported, and in the study by Nic an Ghearr and Brennan (1998)[6] where an average DAP reduction in imaging of the abdomen by 31% was evidenced.

Statistically significant difference in effective dose between the AP and PA projections were found in both parts of the study. In the phantom study, there was a decrease of effective dose by an average of approximately 27%, while in the patient study, an average 53% decrease was observed. The difference in results obtained in the phantom and the patient is due to tissue redistribution in the patients, leading to reduced thickness of the imaged area. The findings of the current study are consistent with those of previous research.[4,6-8] Nic an Ghearr and Brennan[6] documented that with the use of PA projection the effective dose in abdomen imaging in plane radiography can be reduced by an average of 56%. The results obtained in a phantom study by Davey and England[7] indicate that the effective dose in lumbar spine radiography can be reduced by an average of 19.8%. The difference between the dose to internal organs in both projections was not investigated, as was the case in the study by Davey and England[7], and by which we could confirm additional advantages of the PA projection regarding the patient dose.

No statistically significant difference was found in the comparison of the image quality of radiographs gained with AP and PA projection in both parts of the study. Most of the studies investigating the difference between the AP and PA projection do not identify any difference in the image quality between the projections. Only in the study conducted by Mc Entee and Kinsella[4], an improvement of image quality by 6.3% was reported in the AP projection. The authors, however, claim that despite reduced quality, the images performed in the PA projection were still diagnostically acceptable. Tsuno and Shu[22] argue that the PA projection of the lumbar spine is preferred because of the anatomy of the body part and the curve of the lumbar spine that is imaged better in the PA than in the AP projection.

The decrease of the patient comfort for patients with acute injuries, stomach pains, and respiratory distress are the restrictions for the PA projection of the lumbar spine radiography, which are described by Davey and England[7] and Chaparian *et al.*[11] In certain pathologies, the AP projection cannot be replaced by the PA projection, however, most of the patients can be imaged in the PA projection.

The PA projection is a technique that does not require any additional equipment and therefore brings no additional costs. It can be managed quickly without discomfort to the patient and loss of diagnostically important information with a significant decrease of the dose received by the patient.

Conclusions

The DAP reduction of approximately 27% and effective dose reduction of approximately 53% is achievable by using the PA instead of a standard AP projection in lumbar spine radiography. The change of the projection has no influence on the image quality ($p = 0.690$). The results of the study support the use of the PA projection as the preferred method of choice given that the lumbar spine imaging is one of the procedures in the plane radiography with the highest patient radiation dose.

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