

Optimum Angle of Incidence for General Anteroposterior Radiographic Image According to Lordosis angle : For Obese People

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Abstract: The obesity leads to be the result of the weakening of anatomical structure as well as the gravity effect. And, the obesity interferes with normal sagittal balance and fails to maintain a straight posture with minimal energy. Therefore, the obesity can be an important factor in causing back pain by changing the lumbar lordosis. In this study, we will present an appropriate angle of incidence for obese people to reduce the image distortion of L4, L5 during a general anteroposterior radiography examination. To reduce image distortion according to the change of lordosis, the angle of incidence was applied 9 ° and 21 ° to L4 and L5 vertebra body when obesity and low back pain (LBP) perform the general anteroposterior radiography examination.

Keywords: Lumbar Vertebrae; Lordotic Angle; Intervertebral Angle; Obesity; Distortion Factor; Anteroposterior Radiography Image

1. Introduction

The spinal curvature in humans is optimized from the neck to the pelvis to evenly distribute body weight during walking or everyday life; particularly, the lumbar spine takes the form of a normal physiological curve called a lordosis. The normal curvature distributes the weight evenly to minimize the load on the vertebral body, increases the shock absorption of the vertebrae, and facilitates the stability and equilibrium at each joint [1-2]. Maintaining a normal spinal curvature is important for optimal shock absorption when exposed to sudden forces.

Lumbar lordosis angle (LLA) is a representative index for evaluating the degree of bending of the lumbar vertebrae. It can be used to evaluate the curvature of the lumbar vertebrae; it can be used to measure the structural stability of the lumbar spine and the stability of each segment of the vertebral body [3].

The incidence of spinal disorders is increasing due to aging, obesity, wrong lifestyle, and osteoporosis, and most of them are related to the lumbar vertebrae. Low back pain has become a major health problem affecting the adult population. Obese persons are more susceptible to musculoskeletal disorders of the lumbar spine due to abdominal obesity. The basic diagnostic methods for low back pain include physical and radiological examinations.

With the increasing incidence of spinal disorders, the demand for general radiographic examinations of the lumbar vertebrae is increasing. Consequently, digitized radiological equipment, which has become more common, is used for basic radiographic examination of patients [4]. General radiography examination of the lumbar vertebrae using radiation, for instance, is the most frequently used for basic examination and diagnosis of back pain. General radiography of the lumbar vertebrae is the most basic assessment for patients with various

forms of back pain and leg or pelvic sensation, inflammatory or degenerative diseases and deformities of other joints, tumors, and trauma [5].

The general anteroposterior radiography of the lumbar vertebrae is aimed at obtaining an image of the entire lumbar vertebrae. A vertical incision is performed uniformly, regardless of the structure of lumbar vertebrae forming the C-shaped curvature and patients' body shape. The lumbar vertebrae 4 (L4) and 5 (L5), which suffer most dislocations of the lumbar vertebrae, are more distorted than lumbar vertebrae 1, 2, and 3 (L1, L2, L3) [6].

It is useful to distinguish between trauma, tumor, and infection from other intervertebral disc disorders. However, it is difficult to distinguish posterior structures such as the pedicle, the vertebral arch, the articular process, and the intervertebral disc or posterior joint cartilage because they overlap [6]. It is also difficult to obtain the interarticular image adjacent to the image of the vertebral body with the correct anatomical structure. In addition, the Ferguson view, with the lumbosacral angle as the incident angle, depicts not only the desired sacroiliac joint well but also the joints between L5 and sacrum 1 (S1). Images of L5 appear to be less distorted than those of the normal frontal bone.

As a general rule, the general anteroposterior radiography of the lumbar vertebrae is performed while the knee joint is flexed to stretch the physiological curvature in the supine position. The lateral examination allows the slight bending of the hip and knee joints to stabilize the posture in the lateral recumbent position. Stagnara et al. reported that there was no difference between the lordosis angles of the standing and the lateral recumbent postures during general lateral radioscopic examination [7]. In contrast, Anderson et al. reported that there was a difference, which was caused by the contraction of knee muscles due to the flexion of the knee [8]. However, there is no standardized measurement method. In other words, various methods can be used depending on the research. For example, while Hansson et al. [9] measured the angle formed by L1 and the superior portion of S1, while Fernand and Fox [10] used the angle formed by the superior extension of S1 and the superior portion of L1.

In our previous study, we measured the LLA and the intervertebral disc angle (IDA) using the lateral image of the lumbar vertebrae in the recumbent posture without weight. We suggest an optimum angle of incidence for general anteroposterior radiography of the lumbar vertebrae. We present an optimal incident angle for reducing image distortion through the analysis of LLA and IDA [20].

This study demonstrate that general anteroposterior radiography using the proposed incident angle improves image quality and the diagnostic information of the vertebral body. Especially, it is expected that our study is the first research to suggest an optimum angle of incidence for general anteroposterior radiography for obese people.

2. Research Subjects and Methods

2.1 Research subjects

As a result of applying the moderate effect size 0.25, the power of 90%, and the significance level of 0.05 for one - way ANOVA using G * power 3.1 analysis, the number of samples satisfying normal distribution was 170, respectively. We selected 170 patients who have the reading result of 'Negative' from medical specialist of radiology among the patients who underwent anteroposterior and lateral examination for lumbar vertebrae from January 1 to December 31, 2018.

2.2 Research method

2.2.1 Lumbar Lordosis Angle (LLA) and Intervertebral Disc Angle (IDA)

There is no measurement method that everyone is accredited regarding LLA measurement. In order words, various methods can be used depending on the research. In this study, LLA and IDA were measured in the lateral recumbent position. The lateral X-ray examination is performed to bend hip joint and knee joint lightly to stabilize the posture in the lateral recumbent position. In order to observe the lordosis curve for the lumbar vertebrae, as shown Fig 1, the crossing angle between the upper surface of L1 and the upper surface of S1 was measured [11].

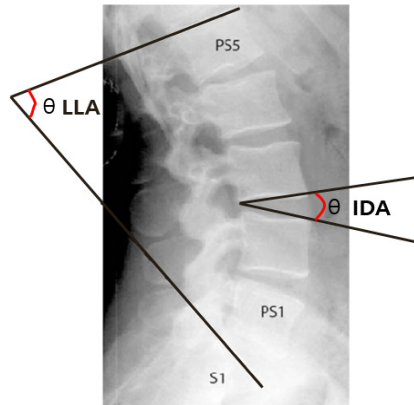


Figure 1. Measurement of lumbar lordosis angle and intervertebral disc angle

And the angle of intersection line of the upper surface and the lower surface at disc of the lumbar vertebrae was measured [12]. All measurements were averaged three times in order to reduce the error in the measurement.

2.2.2 Measure distortion and Distorted area ratio comparison

We performed the image distortion measurement of lumbar vertebrae by using the ATOM® phantom (702model, CIRS). The distorted area ratio was evaluated by images before and after applying the angle of incidence for L4 and L5 presented by this study.

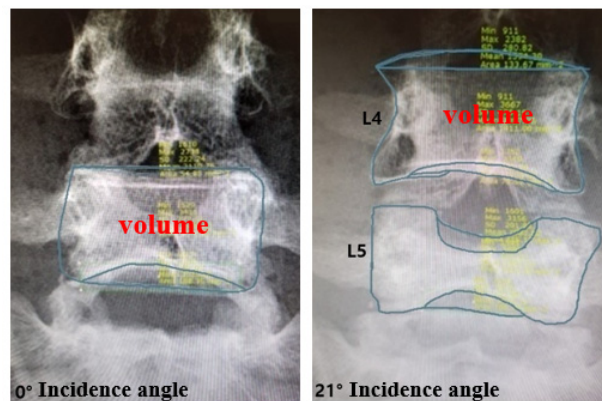


Figure 2. Distortion area measurement using PACS program (marosis, marotech)

Figure 2 show the process of measuring a distorted area to anteroposterior lumbar vertebrae images. The distortion area was measured using a volume measurement program (ROI free draw tool) of PACS program (marosis, marotech). The area of distortion was obtained by measuring area of the vertebral body, the area of distortion of the upper endplate and the area of distortion of the lower endplate by using the following equation used by Kim et al. [13]. The distortion factor can be expressed as percentage of distortion area (%) = distortion area of vertebral body contour and lower contour / total vertebral body area × 100.

2.3 Data analysis

The statistical analysis was performed using SPSS-PC 21.0 (Statistical Package for the Social Science, SPSS). LLA, BMI and obesity were used as independent variables and IDA for the lumbar vertebrae 3 to 4, the lumbar vertebrae 4 to 5 and the lumbar vertebrae 5 to sacrum 1 were used as dependent variables, Independent T-test, one-way ANOVA, and Pearson correlation analysis were performed according to results of the analysis. All data were considered to be statistically significant if the p-value was less than 0.05.

3. Results

3.1 Influence of LLA and IDA by obesity

We investigated the relationships among LLA, IDA, and BMI measured in 170 patients. Table 1 shows the results of the analysis of the correlation among the BMI, LLA, and IDA of the lumbar vertebrae.

Table 1. Correlation among BMI, LLA and IDA

n=170	BMI	LLA	L3~L4	L4~L5	L5~S1
BMI	1	0.244**	0.015	0.119	0.147
LLA	0.244**	1	0.083	0.308**	0.469**
L3~L4	0.015	0.083	1	0.763**	0.485**
L4~L5	0.119	0.308**	0.763**	1	0.725**
L5~S1	0.147	0.469**	0.485**	0.725**	1

*p<0.05, **p<0.01

There was a weak correlation between LLA and BMI ($r = 0.244$, $p < 0.01$). There were also weak positive correlations between BMI and IDA for L3-L4 ($r = 0.015$, $p > 0.05$), IDA for L4-L5 ($r = 0.119$, $p > 0.05$), and IDA for L5- S1 ($r = 0.147$, $p > 0.05$); however, they were not statistically significant. Unlike the correlation between BMI and IDA, the correlation between LLA and IDA for the lumbar vertebrae showed a statistically significant positive correlation; particularly, the correlation between LLA and IDA for L5-S1 was strong ($r = 0.469$, $p < 0.01$).

Table 2. Correlation among Obesity, LLA and IDA

N=56	Obesity	LLA	L3~L4	L4~L5	L5~S1
Obesity	1	0.444**	0.051	0.194	0.029
LLA	0.444**	1	0.264*	0.417**	0.318*
L3~L4	0.051	0.264*	1	0.637**	0.448**
L4~L5	0.194	0.417**	0.637**	1	0.750**
L5~S1	0.029	0.318**	0.448**	0.750**	1

*p<0.05, **p<0.01

To assess the effect of obesity, we investigated the correlation between LLA and obesity in 56 patients. Table 2 shows the correlation between obesity and LLA and IDA for the lumbar vertebrae. As shown in Table 1, there was a weak positive correlation between BMI and LLA ($r = 0.244$, $p < 0.01$). However, there was a strong positive correlation between obesity and LLA ($r = 0.444$, $p < 0.01$), as shown in Table 2. On the other hand, there was a positive correlation between obesity and IDA for L3-L4 ($r = 0.051$, $p > 0.05$), IDA for L4-L5 ($r = 0.194$, $p > 0.05$), and IDA for L5-S1 ($r = 0.029$, $p > 0.05$); they were also not statistically significant.

Overall, there was a statistically significant strong positive correlation between LLA and IDA for the lumbar vertebrae. This shows that LLA and IDA are considerably related as shown in Tables 1 and 2. For cases of obesity, the correlation between LLA and IDA for L4-L5 was the strongest ($r = 0.417$, $p < 0.01$). The results suggest that obesity can affect the stability of L4-L5 more than L4-S1.

Table 3. Comparison of IDA according to BMI

N=170		L3~L4			L4~L5			L5~S1		
		Mean	SD	p-value	Mean	SD	p-value	Mean	SD	p-value
BMI	Normal (n=76)	5.66	3.57		13.23	4.90		29.13	5.50	
	Overweight (n=38)	5.98	3.18	0.441	14.66	4.48	0.000	34.46	4.04	0.000
	Obesity (n=56)	6.42	3.18		16.83	4.65		36.22	4.78	
LLA	Below 30°	5.58	3.62	0.154	13.10	4.98	0.000	29.40	5.49	0.000
	Over 30°	6.32	3.11		16.09	4.53		35.36	4.81	

Mean of IDA : $5.98 \pm 3.36^\circ$ for L3 ~ L4, $14.73 \pm 4.96^\circ$ for L4 ~ L5 and $32.66 \pm 5.91^\circ$ for L5 ~ S1

Average of LLA: $30.53 + 3.99$

To confirm the effect of obesity on IDA, we measured IDAs and stratified them by BMI. Table 3 shows the comparison of IDAs stratified by BMI. We stratified BMIs as follows: normal, 18.5-22.9; overweight, 23-24.9; obesity > 25. Based on the average LLA, we divided LLA into two parts at the value of 30.

Polly [11] reported the following IDAs: 9.3° for L3-L4, 11° for L4-L5, and 12° for L5-S1. Lee [9] reported 11° for L3-L4, 13° for L4-L5, and 15° for L5-S1. In this study, the mean IDAs for normal, overweight, and obese individuals were $5.66^\circ \pm 3.57^\circ$, $5.98^\circ \pm 3.18^\circ$, and $6.42^\circ \pm 3.18^\circ$ for L3-L4, respectively, $13.23^\circ \pm 4.90^\circ$, $14.66^\circ \pm 4.48^\circ$, and $16.83^\circ \pm 4.65^\circ$ for L4-L5, respectively, and $29.13^\circ \pm 5.50^\circ$, $34.46^\circ \pm 4.04^\circ$, and $36.22^\circ \pm 4.78^\circ$ for L5-S1, respectively. The previous research reported severe posterior spinal arthropathy syndrome if IDA was more than 15° for L4-L5 [3, 15]. According to our research, the IDA of obese people was 16.83° for L4-L5. Thus, we expected that obesity may cause lumbar instability-related disorders such as lumbar degenerative disease, lumbar spinal stenosis, and spondylolisthesis.

We expected that obesity would affect IDA; compared with a previous study, there was a large difference between L5 and S1. Several factors may influence the findings from general anteroposterior radiography; measurement accuracy may be affected by the lateral recumbent position, the degree of knee flexion, the effect of time, and other latent effects [16].

3.2 Decision of incident angle by lumbar vertebra body according to LLA

Generally, anteroposterior radiography of the lumbar vertebrae is performed while the knee joint is flexed to stretch the physiological curvature in the supine position. Since the image is taken in the supine position, it is impossible to measure the angle of incidence. We used the lateral radiograph image for applying the angle of incidence, as shown in Fig 1. As shown in Table 3, in this study, we determined the incident angles of the L4 vertebral body as the average value of IDAs for L3-L4 (5.58°) and L4-L5 (13.10°) and the average value of IDAs for L4-L5 (13.10°) and L5-S1 (29.40°) below 30° of LLA. We determined the incident angles of the L5 vertebral body as the average value of IDAs for L3-L4 (6.32°) and L4-L5 (16.09°) and the average value of IDAs for L4-L5 (16.09°) and L5-S1 (35.36°) above 30° of LLA.

Table 4. Incident angle of lumbar vertebra body L4, L5 according to LLA

L-spine region	LLA below 30° (n=77)		LLA over 30° (n=93)	
	Mean	SD	Mean	SD
L4	9.14	5.30	11.21	4.82
L5	21.05	4.24	26.13	5.67

Average of LLA: 30.53 + 3.99

The vertebral bodies of L4 and L5 had more degenerative changes than those of L1, L2, and L3, and they were more unstable. For this reason, the L4 and L5 vertebral bodies were only considered. Table 4 shows the optimum angle of incidence for L4 and L5. Unlike our previous results [20], the incident angle of the L4 body was 9.14° below 30° of LLA and 11.21° over 30° of LLA while that of the L5 body was 21.05° below 30° of LLA and 26.13° over 30° of LLA in this study.

Table 4 shows that the LLA over 30° is greater than the LLA below 30°. Besides, we confirmed that the distribution was similar to that of the normal and other groups at 30° of LLA, as shown in Table 3, 4. From these results, it would be necessary to apply an angle of incidence over 30° of LLA except in normal people.

3.3 Distortion factor measurement

In this study, we used a phantom with no change of LLA to evaluate the distortion factor because each patient has a different lordosis angle. In general, when performing anteroposterior radiography, most of the images are taken without providing an incident angle, and they frequently get distorted. We investigated image distortion during general anteroposterior radiography after providing an incident angle. First, we determined the optimal incident angle from the results of Table 4. The distortion area was measured using the method in Fig 2.

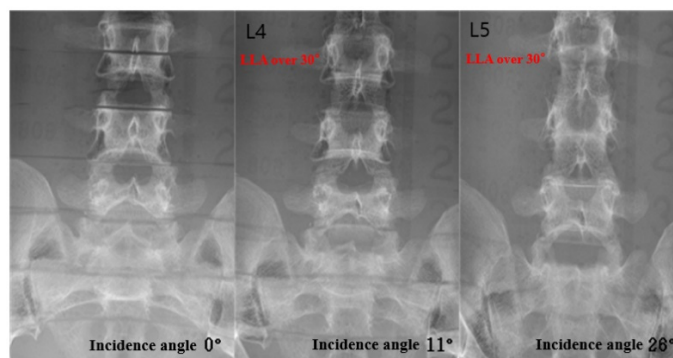


Figure 3. L4 and L5 body AnteroPosterior radiography image applied to incident angle by using the phantom over 30° of LLA

Figure 3 shows the magnitude of distortion of the images of the lumbar vertebral bodies after applying the angle of incidence over 30° of LLA to phantom. The angles of incidence of 11° and 26° over 30° of LLA were determined for L4 and L5 by rounding off to the nearest whole number from Table 4. When the optimum angle of incidence was applied, the image distortion reduced, as shown in Fig 3.

Table 5. Comparison of distortion area and distortion factor according to incident angle on L4, L5

	Incident angle (N=170)	Vertebra body area(mm ²)	Upper endplate distortion area(mm ²)	Lower endplate distortion area(mm ²)	Distortion area ratio(%)
L4	0°	1400.02	143.67	77.56	14.83
	11°	1465.13	148.22	25.38	12.01
L5	0°	1435.23	117.27	116.59	15.35
	26°	1774.38	52.75	186.82	13.43

We calculated the distorted area ratio for L4 and L5 vertebra bodies when the incident angle was applied to 0°, 11°, and 26°. According to Table 5, the ratio for the L4 vertebral body decreased from 14.83% to 12.08% and that of the L5 vertebral body decreased from 15.35% to 13.43% after applying the angle of incidence.

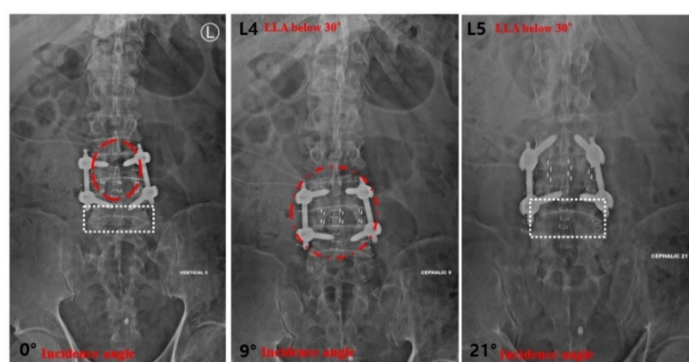


Figure 4. L4, L5 body Antero-Posterior X-ray image applied to incident angle below 30° of LLA

Figure 4 shows the radiographs of the pain-prone area of lumbar vertebral disease. The incident angle was applied to L4 (9°) and L5 (21°) below 30° of LLA by rounding off to the nearest whole number from Table 4. We could confirm that radiographs of a patient with union surgery had improvements in distortion in parts such as the vertebral body, the intervertebral disc angle, and implant after applying the angle of incidence compared with when it was 0°. Figure 4 shows that the overlapping parts in the intervertebral view are absent after using an optimum angle of incidence based on LLA.

4. Discussion

For 170 patients, the correlations between LLA, IDA and BMI were analyzed; LLA and BMI showed a weak positive correlation ($r = 0.244$, $p < 0.01$). Particularly, our data show the correlation between obesity and the angle of lordosis for lumbar vertebrae was found to be a strong positive correlation. In 56 patients, obesity and LLA showed a strong positive correlation ($r = 0.444$, $p < 0.01$). We can expect that obesity does affect lumbar lordosis based on this result.

LLA is a representative index for evaluating the degree of curvature of the lumbar spine. It can evaluate the structural stability of lumbar region. IDA is a measure of the stability of each vertebrae body of the spine. Particularly, the changed body shape due to obesity can affect mechanical structure as well as various musculo-skeletal disorders. And the obesity increases your chances of causing lumbar instability.

Obese people can change the biomechanical structure of the lumbar vertebral bodies by the load of gravity and weaken muscles around the lumbar vertebrae such as the psoas muscle. For example, the intervertebral disc may be elongated or the space between discs may become wider or narrower, and this can easily affect lumbar lordosis. If the vertebral body cannot support the strength by physiological force, it will be gradually bent. Our result shows that LLA and IDA are affected by obesity (Tables 1, 2, and 3). For this reason, we expected that obese person would have a large angle of LLA.

The contributions of the anatomical structures to the stability of the vertebrae were 39% in the spinal articulation, 29% in the intervertebral disc and the annulus fibrosus, and 19% in the supraspinal ligament, the interspinal ligament, and 13% in the ligamenta flava [12]. Nolan and Sherk [17] report that the semispinalis cervicis and capitis muscles and the interspinous and supraspinous ligaments, which constitute the cervical spinous process, ligament, and muscle complex, are important for maintaining the cervical and sagittal dynamic and static balance. Lee et al. [18] reported that the cervical spine curvature is maintained by the cervical spinous process, ligament, and muscle complex formed to maintain the biomechanical load.

Obese people can weaken the muscles and ligaments around them. Obese people also interferes with normal sagittal balance and prevent the maintenance of a straight posture with minimal energy; it prevents the effective distribution and absorption of the load on the spine, making it impossible for the spinal muscle to use energy efficiently. Therefore, obesity may be an important cause of back pain by changing lumbar lordosis.

However, due to the lack of understanding of the complex biomechanical mechanisms of the lumbar vertebrae, the exact pathophysiology of spinal diseases caused by obesity has not yet been established. There also inadequate studies on spinal diseases, especially the mechanical, structural, and musculoskeletal disorders, caused by obesity. We would need more research on these.

Next, we investigated the distortion of images obtained by general anteroposterior radiography using an incident angle. To determine the appropriate angle of incidence, we used the results from Table 4. The average incident angles were $9.14^\circ \pm 5.30^\circ$ below 30° of LLA and $11.21^\circ \pm 4.82^\circ$ over 30° of LLA for the L4 body and $21.05^\circ \pm 4.24^\circ$ below 30° of LLA and $26.13^\circ \pm 5.67^\circ$ over 30° of LLA for the L5 body.

We compared the distorted area ratios when the incident angle was 0° , 11° , and 26° using the ATOM® phantom. It was confirmed that the distorted area ratio of the lumbar vertebrae was reduced and the area of vertebra body was increased except the upper and lower distorted area. In addition, the image evaluation was more clearly identifiable for the interval between the vertebrae [19]. Figure 4 shows that the overlapping parts of the intervertebral view were absent after applying 9° and 21° angles of incidence below 30° of LLA. The radiograph of a patient with union surgery had improvements in the distortion of images of parts such as vertebra body, intervertebral disc angle, and implant.

We looked forward to obtaining the exact anteroposterior image for L4 and L5 in obese persons if the appropriate angle of incidence was applied. The diagnostic value of the image was improved by a radiographic examination of the lumbar vertebrae. However, L1, L2, and L3 were distorted in the normal anteroposterior images obtained after applying the angle of incidence.

Finally, on general radiographic examination, the amount of radiation may vary depending on the angle of incidence. Therefore, an evaluation of the radiation should be performed when we use the incident angle for general anteroposterior radiography. It is necessary to examine only the target site to reduce unnecessary exposure of the patient.

In the end, obesity increase the risk of lumbar disc disease because of excessive pressure and belly fat. To prevent degenerative diseases of the spine, it is important to lower the BMI. Further studies are needed to generalize our results, and we expect to provide standard values for the means of LLA and IDA in healthy normal Koreans in the standing and lateral recumbent postures through future research.

5. Conclusions

Our data showed a strong statistically significant correlation between obesity and the angle of lordosis of the lumbar vertebrae. We presented the optimum angle of incidence for L4 and L5 based on LLA. As a result of the incident angle, the distortion ratio area decreased from 14.83% to 12.08% at L4 and 15.35% to 13.43% at L5. The radiograph image of a patient with union surgery had improvements in distortions in parts such as the vertebral body, intervertebral disc angle, and implant. By reducing the distortion in the general anteroposterior image of the lumbar vertebrae, it was possible to obtain an accurate anteroposterior vertebral body and improve the image quality and diagnostic information of the desired region. Especially, for obese people, it is expected to improve the image quality if you give a large incident angle of incidence than normal people.

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