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A Study on Radiation Dose and Image Quality using High-Pitch Mode when Examining the Lumbar Region with Dual-Energy Computed Tomography

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Abstract: *The purpose of this study was to investigate whether the high pitch protocol method of dual-energy computed tomography can be successfully applied to a lumbar vertebrae CT scan and reduce the effect of exposure dose; the main indicators were the image quality and reduced scan time. This study was conducted using MDCT 256 row dual source, Somatom Definition Flash (Siemens medical system: Germany), on 69 patients who had lumbar vertebrae CT scans from March 1, 2021, to June 30, 2021. First, to determine the applicability of the high pitch protocol method, the phantom images quality was compared with that of the existing lumbar vertebrae CT scan method and the examination method using the high pitch protocol method with the AAPM phantom, respectively. In the phantom image, CT noise, uniformity, and spatial resolution were not significantly different between the existing lumbar vertebrae CT scan method and the examination method using the high pitch protocol. In addition, in images examined from clinical patients, single-sample t-test results of the comparison of the mean value of CT noise, uniformity, and spatial resolution did not show statistically significant differences, 0.081, 0.078, and 0.387, respectively. The results of the qualitative evaluation showed that all were also higher than 3 points, which is fair, and the radiation dose was reduced by 9.76% in the high pitch protocol. When examining the lumbar region with dual-energy computed tomography, the examination method using high-pitch mode reduced the radiation dose and shortened the examination time, with the same image quality as that of the existing lumbar vertebrae CT scan.*

Keywords: Dual-Energy Computed Tomography; Lumbar Vertebrae; High Pitch Protocol; Radiation Dose

1. Introduction

In the field of diagnostic radiology, X-ray facilities and devices according to scientific progress have been developing at a fairly rapid rate, and their use is also increasing.[1] It is statistically reported that the number of radiographic examinations in the diagnostic region is more than once a year even in advanced countries, and in Korea, the number of X-ray examinations, such as health checkups, is on the rise as the public's interest in health promotion increases along with the improvement of the quality of life.

In particular, Computed Tomography(CT) examination has become highly diversified to the extent of considering it as a customized examination method due to the rapid advancement of technologies applied to the CT equipment, thereby offering a wide range of options [2]. There have been rapid technological advancements for CT equipment after having begun with single channel and progressing to 128 channel dual energy MDCT through the developments of 16, 64 and 128 channels [3].

A CT scan, commonly referred to as a CAT scan, is a type of X-ray that produces cross-sectional images of a specific part of the body[4]. CT scans are performed in a hospital's radiology department or at a clinic that specializes in diagnostic procedures. It may use to investigate problems with your whole body. This includes pain due to injuries, disease, or infection[5].

Medical radiation such as CT is commonly used as an essential diagnostic method in modern medicine because the benefit from its use is greater despite the risk factor of exposure. Especially, CT of the spine can be associated with high radiation doses and radiation protection has to be considered.[6]

According to previous our research, general anteroposterior radiography using the proposed incident angle improves image quality and the diagnostic information of the vertebral body.[7] And Research using Dual Energy CT ECG Gating High Pitch Chest Pain Protocol Mode was also conducted [8].

Based on our previous research, we were applied to the lumbar vertebrae CT scan when examining the lumbar region with dual-energy CT. This study was designed to reduce the patient's exposure dose and significantly shorten the examination time by applying the high pitch scan mode of Dual source MDCT to the lumbar vertebrae scan, while maintaining the image quality as it is[9].

2. Materials and Methods

2.1 Period and subject

We selected 69 patients who had normal radiological findings. The research subjects were 69 patients who underwent a lumbar CT scan among outpatients who visited Pusan National University Yangsan Hospital from March 1, 2021, to June 30, 2021. The subjects of this study were 69 patients, 24 males, and 45 females. The average age was 56 years old.

2.2 Materials and Equipment Used

The study was conducted by using the CT equipment, **MDCT 256 row dual source**: Somatom Definition Flash (Siemens medical system: Germany) AAPM(American Association of Physicists in Medicine) CT Performance Phantom 610 was used to compare the image quality of the existing lumbar vertebrae CT scan method and the lumbar vertebrae scan method applying high pitch.

2.3 Methods

2.3.1 Scan Methods

Table 1. Existing Lumbar Vertebrae CT Scan Parameters and High-pitch Lumbar scan parameters

Conditions	Existing Lumbar Vertebrae CT Scan Parameters	High pitch Lumbar Scan parameters
Effective (mAs)	100 mAs	100 mAs
kVp	100 kVp	100 kVp
Slice thickness (mm)	3mm (128×0.6 collimation)	1 mm (128×0.6 collimation)
Reconstruction increment (mm)	3.0 mm	0.5 mm
Rotation time (sec)	1.0 sec	0.28 sec
Pitch	0.8	0.7

Table 1 shows Existing Lumbar Vertebrae CT Scan Parameters and High-pitch Lumbar scan parameters, which are CT scan conditions commonly used in medical institutions. 100 mAs of tube current, 100 kVp of tube voltage is the same. The remaining four values were different. In the case of existing Lumbar Vertebrae CT Scan Parameters, slice thickness is 3mm (128×0.6 collimation), reconincrement is 3mm, rotation time is 1.0sec and pitch is0.8 pitch. But the high pitch mode to be investigated in this study is slice thickness 1mm (12800.6 collimation) and reconincrement 0.5mm, the pitch 0.7 and rotation time 0.28sec. CT Images were implemented by applying the protocol lumbar vertebrae from each condition. The scan range may vary slightly

depending on the patient but is basically from the 11th thoracic vertebrae to the 1st sacrum, and the scan range was the same when each examination method was applied to patients. The AAPM Phantom was scanned with with the existing protocol lumbar vertebrae CT scan with the Table 1 parameter values. The scan range was made to include the entire phantom.

2.3.2 Quality measurement region and comparison method

As shown in Fig. 1 and Fig. 2, to determine the applicability of the examination method using High pitch protocol, the phantom images were compared for noise, uniformity, and spatial resolution after scanning with the existing lumbar vertebrae CT scan method using the AAPM Phantom and the CT scan method using the high pitch. The mean values were compared by setting the region of interest (ROI) of 0.5 square (cm) from images obtained by the existing lumbar vertebrae CT scan methods and images obtained by high pitch mode examination methods, respectively.

The comparison region of the ROI measured in this study is shown in Figures 1 and 2. First, the spinal cord between lumbar vertebra 1 and 2 was measured, second, the center of the intervertebral disc between lumbar vertebra 3 and 4 was measured, third, the center of the intervertebral disc between lumbar vertebra 4 and 5 was measured as the region of interest.

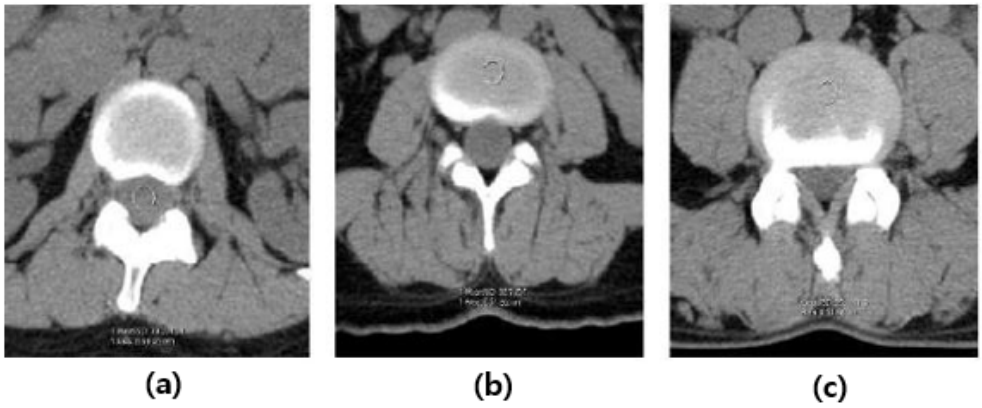

Figure 1. ROI location on lumbar spine protocol images. (a) Lumbar spinal cord between the L1 and L2 vertebral level, (b) Lumbar disc between the L3 and L4 vertebral level and (c) Lumbar disc between the L4 and L5 vertebral level

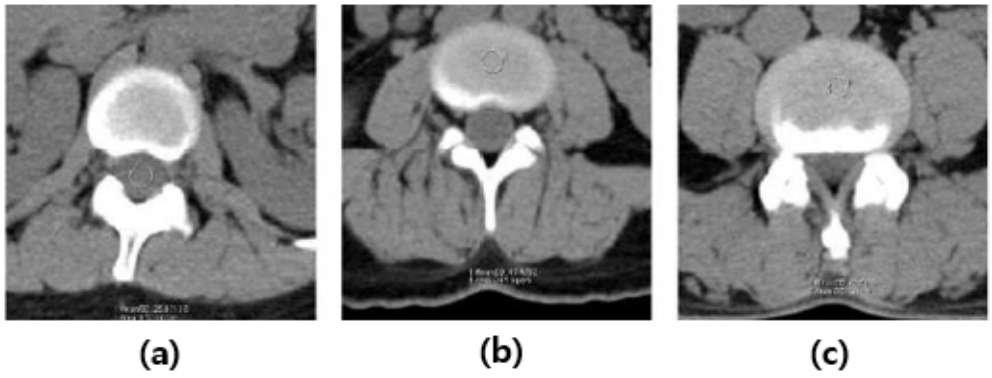

Figure 2. ROI location on high pitch protocol images. (a) Lumbar spinal cord between the L1 and L2 vertebral level, (b) Lumbar disc between the L3 and L4 vertebral level and (c) Lumbar disc between the L4 and L5 vertebral level

2.3.3 Dose comparison method

After examining the patient with the existing lumbar vertebrae CT scan method and the high pitch CT scan method, the dose length product (DLP) and the effective dose provided by the CT equipment used in the study

were compared with the patient's exposure dose, and the effective dose was calculated by multiplying the DLP value by 0.015 of the effective dose of EUR16262 (European Guide) [10].

2.3.4 Image evaluation method

Table 2. Quality Score of the Image

Quality of image	Excellent	Good	Fair	Poor	Unsatisfaction
Score	5	4	3	2	1

Table 2 shows the images tested by two musculoskeletal system specialists and two CT radiologists using the existing lumbar vertebrae CT scan method using the image quality score on a 5-point scale from 1 point (unsatisfactory) to 5 points (excellent), and based on 3 points the images, qualitative evaluation was performed by comparing the images obtained with the high pitch CT scan to evaluate whether fractures, Disc HNP, and disc stenosis, which are the main objectives of the lumbar vertebrae CT scan, could be evaluated.

2.3.5 Statistical method

Statistical analysis was performed using the statistical package program of SPSS version 26.0 for window, and the statistical technique is a single-sample t-test test method, and it was determined to have statistical significance at the 95% confidence level, that is, the significance level p-value was 0.05 or less.

3. Results

3.1 Results of image quality comparison of lumbar spine protocol and high pitch protocol

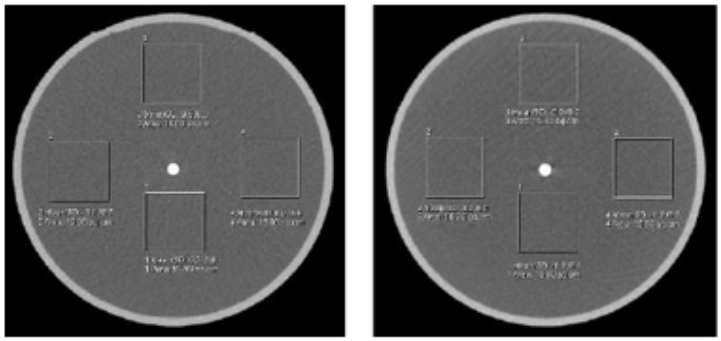

Figure 3. Location for noise and uniformity measurement on AAPM phantom. (a) The phantom of image in lumbar spine protocol and (b) The phantom of image in high pitch protocol

3.1.1 CT noise comparison result of lumbar spine protocol and high pitch protocol

Table 3. CT noise value in lumbar spine protocol and high pitch protocol

protocol	lumbar spine protocol	high pitch protocol
Noise (HU)	6.8	6.1

Table 3 shows CT noise value in lumbar spine protocol and high pitch protocol. **Noise in computed tomography** is an unwanted change in pixel values in an otherwise homogeneous image. Often noise is defined loosely as the grainy appearance on cross-sectional imaging; more often than not, this is quantum mottle. Noise

in CT is measured via the signal to noise ratio (SNR); comparing the level of desired signal (photons) to the level of background noise (pixels deviating from normal). The higher the ratio, the less noise is present in the image. Noise in a cross-sectional image will equal a decrease in the picture quality and inadvertently will hinder the contrast resolution. A well-understood relationship exists with image noise and dose, expressed as [11]

$$\text{noise} \propto \frac{1}{\sqrt{exposure}} \tag{E1}$$

in which noise at a given exposure level (E1) is defined as the SD, σ(E1), of the CT numbers (HU) from a uniform ROI. The noise at a second exposure level (E2) can be predicted from a known exposure level E1 by the following relationship: [11]

$$\frac{\sigma(\text{E2})}{\sigma(\text{E1})} = \frac{\sqrt{E1}}{\sqrt{E2}} \tag{E2}$$

According to the above formula as shown in Table 4, the CT noise value was 6.8 HU in the lumbar spine protocol, 6.1 HU in the high pitch protocol, with approximately 0.7 being higher in the lumbar spine protocol.

3.1.2 Comparison result of uniformity of lumbar spine protocol and high pitch protocol

Table 4. Uniformity value in lumbar spine protocol and high pitch protocol

Direction	6 o'clock (A)	9 o'clock (B)	12 o'clock (C)	3 o'clock (D)
lumbar spine protocol	0.7	-0.1	0.5	0.6
high pitch protocol	-1.2	0.2	-0.9	-1.2

The uniformity describes how uniform the image of a homogenous material appears. The uniformity measurements are important to ensure that cupping and beam hardening artifacts are avoided. CT images are generated by measurement of attenuation of x-rays through the tissue of interest. As shown in Table 4, the difference between the center (A) and the periphery (B, C, D) was 0.8(A-B), 0.2(A-C), 0.1(A-D) in the phantom image scanned by the lumbar vertebrae scan method, and 1.4(A-B), 0.3(A-C), and 0(A-D) in the phantom image scanned by the high pitch test method.

3.1.3 Comparison of spatial resolution of lumbar spine protocol and high pitch protocol

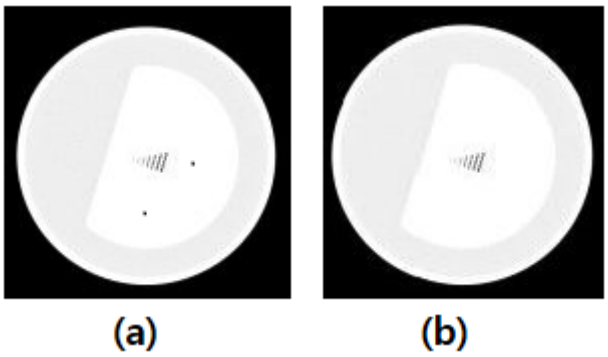

Figure 4. Spatial resolution image on AAPM phantom. (a) The phantom of image in lumbar spine protocol and (b) The phantom of image in high pitch protocol

Current CT scanners have a spatial resolution of 0.5–0.625 mm in the z-axis, and approximately 0.5 mm in the x- to y-axes. A basic requirement for adequate multi planar reconstruction is that the resolution is isotropic; eg, the resolution is approximately equal in all directions Spatial resolution is measured in line pairs per

centimeter (lp/cm) and is a measure of the uncertainty that derives by imaging formation errors of medical systems. As shown in Figure 4, the solid acrylic block contains a total of 8 sets, with 5 groups of air holes of different sizes. The distance between each group of air holes is 5 mm, and the respective diameters are 1.75, 1.5, 1.25, 1.0, 0.75, 0.6, 0.5, 0.4 mm, and the distance between the holes is equal to the diameter of each hole. In this cross-sectional image, both the lumbar vertebrae CT scan method and the high pitch CT scan method image can discriminate up to 0.75 mm. There was no difference in spatial resolution in the phantom test.

3.2 Image comparison results with patients in lumbar spine protocol and high pitch protocol

Table 5. Comparison of Mean values between lumbar spine protocol and high pitch protocol

Protocol	lumbar spine protocol			high pitch protocol		
L-spine location	L1-L2	L3-L4	L4-L5	L1-L2	L3-L4	L4-L5
Mean	12.475	10.187	12.200	11.700	8.912	11.025

As shown in Table 5, the average mean value obtained by the High pitch CT scan method was measured to be 0.775 lower in the spinal cord between lumbar vertebra 1 and 2, 1.275 lower in the intervertebral disc center between lumbar vertebra 3 and 4, and 1.175 lower in the intervertebral disc center between lumbar vertebra 4 and 5 than that obtained by the existing lumbar vertebrae CT scan method.

Table 6. One sample T-test analysis of SNR mean value.

	Test value = 12.475					
	t	df	Sig.(2-tailed)	Mean difference	95% Confidence interval of the difference	
					Lower	Upper
L1-L2	-2.038	7	0.081	-0.7750	-1.674	0.123
	Test value = 10.187					
	t	df	Sig.(2-tailed)	Mean difference	95% Confidence interval of the difference	
					Lower	Upper
L3-L4	-2.060	7	0.078	-1.275	-2.737	0.188
	Test value = 12.200					
	t	df	Sig.(2-tailed)	Mean difference	95% Confidence interval of the difference	
					Lower	Upper
L4-L5	-0.922	7	0.387	-1.175	-4.189	1.839

As shown in Table 6, the single-sample t-test results show that at the significance level of 0.05 (confidence interval of 95%), the significance probability was 0.081 in the spinal cord between the lumbar vertebrae 1 and 2, 0.078 at the center of the intervertebral disc between the lumbar vertebrae 3 and 4, 0.387 on the center of the intervertebral disc between the lumbar vertebrae 4 and 5, which shows that all of these are not significantly different from the average value of the existing lumbar vertebrae CT scan method.

Table 7. Comparison of DLP and Effective dose between lumbar spine and high pitch protocol

Protocol	lumbar spine protocol	high pitch protocol	Dose reduction (%)
DLP (mGy*cm)	549.25 mGy*cm	497.25 mGy*cm	9.467
Effective dose (mSv)	8.239 mSv	7.459 mSv	

As shown in Table 7. as a result of comparing the DLP (Dose Length Product) provided by the CT equipment after examining patients with the existing lumbar vertebrae CT scan method and the high pitch CT scan method, the average DLP value in the existing lumbar vertebrae CT scan method is 25 mGy*cm and 497.25 mGy*cm in the high pitch CT scan method. By applying high pitch, it is reduced by 9.467% compared to the existing dose.

3.3 Qualitative image evaluation result of high pitch protocol

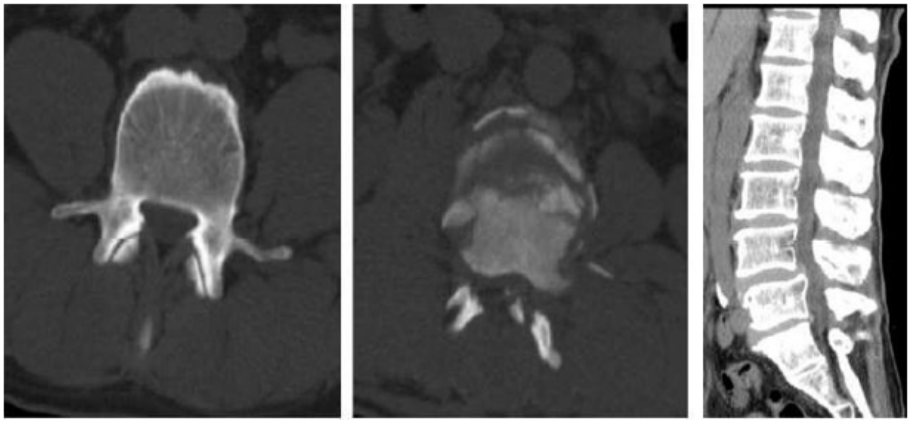

Figure 5. Image of lumbar spine protocol

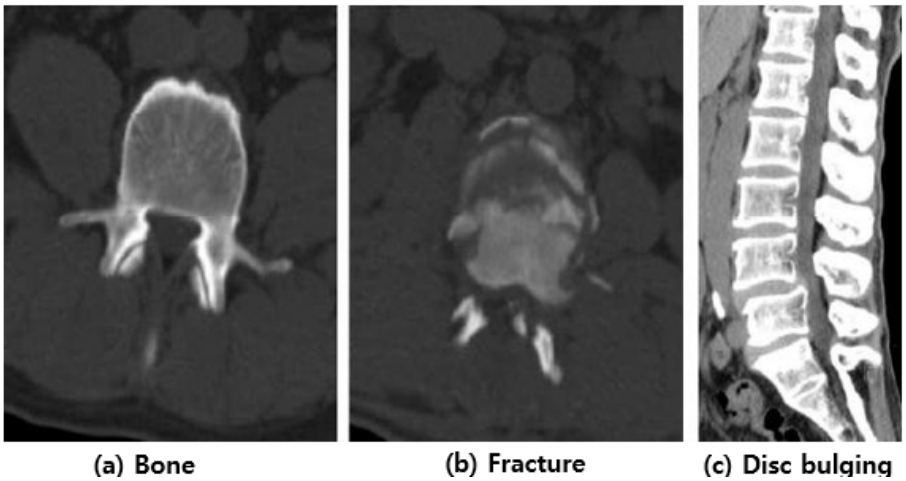

Figure 6. Image of high pitch protocol

Table 8. Evaluation of high pitch protocol image

Variable	Lumbar fracture	Lumbar herniated nucleus pulpous	Lumbar Stenosis
Radiologist 1	3.12	3.47	3.15
Radiologist 1	3.63	3.72	3.65
Radiologic technologist 1	3.14	3.67	3.47
Radiologic technologist 1	2.81	3.11	3.23
Mean	3.19	3.49	3.37

As shown in Table 8, as a result of the qualitative evaluation by two musculoskeletal radiologists and two CT radiologists, the average was 3.19 points for fractures, 3.49 points for intervertebral disc stenosis, and 3.37 points for stenosis, higher than the average of 3 points.

4. Discussion

In the case of high-pitch Dual-source CT, it is widely used to reduce motion artifact [8, 12]. Especially, in the cardiac examination, motion artifact is the key factor that degrades the image quality. High-pitch dual-source spiral CT is highly effective at not only reducing both cardiac and respiratory motion artifacts in free-breathing children, but also at achieving low radiation dose. Furthermore, it is an important artifact factor that affects all the neighboring organs. There have been rapid technological advancements for CT equipment after having begun with single channel and progressing to 128 channel dual energy MDCT through the developments of 16, 64 and 128 channels

The principle of high pitch scan of Dual source MDCT is that the A-X ray tube is followed by the B-X ray tube investigating and supplementing the regions that the A-X ray tube failed to investigate[13]. Therefore, there is no loss in information acquisition even if PITCH 1 or higher is set. However, this shows limitations in test capacity as the irradiation dose, test range, and pitch are interlinked.

When the high pitch examination method is used for cardiac examination, the exposure dose is reduced by 60% compared to the retrospective ECG gating method (min-dose application) [14], and the prospective ECG gating method has the effect of reducing by 86%, and the dose is reduced by 50% even when applied to the dissection examination, but when applied to lumbar vertebrae scan, the reduction rate of exposure dose is about 9.5%[15]. The pitch in the cardiac examination was about 3.2, so it was very easy to do so, but the decrease in pitch due to increased dose and a wider range of tests did not result in an expected dose reduction in this study, but the test time could be reduced from an average of 11 secs to 1.6 secs. This would be useful for examining patients with claustrophobia or those who complain of pain and have difficulty maintaining posture during the examination[16].

As a result of comparing the existing lumbar vertebrae CT scan method with the high pitch CT scan method, it was confirmed that the image quality was not significantly different between the phantom image and the clinical area image. In this study, phantom images were compared to determine whether the high pitch scan mode of dual-source MDCT can be applied to other examination regions. It was confirmed that there was no significant difference in noise, uniformity, and spatial resolution. In other words, the high pitch scan mode of the Dual source MDCT may apply not only to lumbar vertebrae but also to other regions, reducing patient exposure dose and reducing test time, which may further enhance patient satisfaction.

This study was conducted to investigate the applicability and the reduction of the patient exposure dose due to the image evaluation and reduction of irradiation time. In other words, this is method to reduce the patient's radiation dose to the lumbar vertebrae of the spine[17] based on expedient diagnosis through the use of the high-pitch mode technique of dual source CT equipment.

5. Conclusions

Through this study, it was found that high-pitch mode can be applied when examining the lumbar region with dual energy computed tomography and has the effect of reducing the exposure dose by about 9.5%. This scan method is considered to be a useful examination method that can further increase the patient's test satisfaction by reducing the patient's exposure dose and shortening the test time.

Conflicts of Interest: The authors declare no conflict of interest.

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