MTF Evaluation according to change in posture and channel during CT examination for wrist Joint : X-axis and Z-axis changes around Isocenter

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ABSTRACT

This study aims to evaluate the Modulation Transfer Function (MTF) according to the change in the number of channels of the CT examination device by changing the posture of the patient to the X-axis and Y-axis in the wrist joint CT examination. Using a CT device and a wrist phantom, the test was performed by moving 0 (matched), 5, 10, and 15 cm in the X-axis around the isocenter, and the Z-axis was rotated by -20° and -40° . For the test, 16, -40 and 64 channels were used to check whether there was a difference for each number of channels. The examined images were compared by measuring the MTF values of the ulna and left and right sides of the radius. In the experiment where the isocenter was moved along the X-axis, the MTF value decreased with an increase in the moving distance, and the MTF value was found to be unaffected by the number of channels. In the experiment in which the wrist joint was rotated by -20° and -40° on the Z-axis, the degree of deviation and MTF were found to be irrelevant. It was not related to the number of channels either. In conclusion, the movement of the wrist along the X-axis should be restrained as much as possible for a wrist joint CT scan, whereas deviation around the Z-axis depending on the environment for the patient would not affect the MTF of the image.

Keywords: Wrist joint CT, Shifted X-axis, Rotated Z-axis, CT MTF, CT channel

Ⅰ. INTRODUCTION

Computed tomography (CT) apparatus has a fast inspection time and provides 2D and 3D images by reconstructing multiple images with a single inspection. In particular, with a Multi-Detector CT (MDCT), the test time is shortened to several seconds depending on the number of detector channels, enabling the imaging of the entire abdomen with just one breathing control.[1] In CT scan, the degree of transmission and absorption of X-rays, that is, the degree of appearance in the image varies according to the tissue density(Linear Attenuation Coefficient), and anatomical information such as bones, lungs and vessels can be observed in the image by applying various algorithms to the region of interest. In particular, bone is a material with high X-ray absorption rate; therefore, CT imaging is used to diagnose fracture or dislocation and even to plan a surgery. [2]The wrist joint itself is small and complex as it consists of eight carpals surrounded by five metacarpals, radius and ulnar, and the carpal tunnel at the base of the wrist has a very complex structure with the presence of the median nerve and several tendons. [3]Therefore, when examining the wrist,

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increasing the image quality is helpful for diagnosis. CT scan is usually performed by rotating the X-ray generator around the isocenter of the device. At this time, if the subject to be examined is out of the isocenter, it may increase the possibility of geometric distortion.[4] When scanning a wrist, the wrist is placed in the isocenter of the CT device, and this time, considering the amount of radiation exposure and the quality of the image, the examination is performed with the patient's hand raised above the head to avoid contact with other body organs. In order to keep the wrist in the isocenter while being raised above the head, the patient's body is tilted to one side. Most of the general patients can maintain the posture; however, it is difficult for patients who are unconscious or have great pain, such as patients with a comminuted fracture, to maintain the posture. Therefore, it is necessary to evaluate the image taken from a patient who is unable to keep the wrist in the isocenter while examining the wrist. Therefore, this study aims to evaluate the quality of wrist CT scan image by changing the central axis angle of the wrist and changing the number of channels of the device.

Ⅱ. MATERIALS AND METHODS

In this study, CT (Brilliance 64 slice, Philips, Holland) device and a wrist phantom (Hand/Wrist phantom RS-144T, Universal Medical, USA) were used. As shown in Table 1, conditions used for the test were kept constant in terms of the table height, window width/level, kV, mAs, SFOV, filter, etc. while changing the posture of the phantom.

In the experiment, the combination of MDCT detector array was changed to 16, -40 and 64 channels. For each number of channels, the phantom was moved from the isocenter to the left and right along the X-axis and rotated -20° and -40° around the Z-axis, which was the major axis direction of the wrist, while performing examination.

Table 1. Scan Parameter

Condition	Value
Height of Table	91 cm
Window Width/Level	1500/-200
kV	1-20 kV
mAs	150 mAs
Filter	Wrist/Hand_YC
Examined Body part	Extremity
Slice Thickness	1 mm
Pitch	0.7 mm
Channel	16, -40, 64 ch

1. Experiment on the change in the distance of the subject along the X-axis

In the experiment on the change in the location of the subject along the X-axis, the phantom was moved from the isocenter of the CT device (o cm) to the left by 5, 10 and 15 cm for the examination as shown in Figure 1. It was examined 1-20 times in total: 10 times each for isocenter (0 cm), 5 cm, 10 cm and 15 cm for each of the 16, 40 and 64 channel scans.

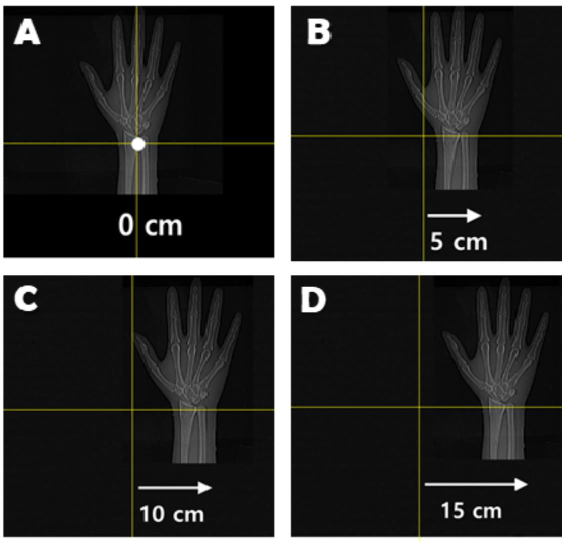
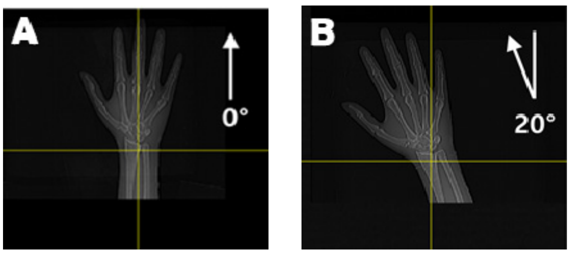


Fig. 1. Experiment on the change in the distance of the subject along the X-axis in which the point where the X-axis meets the radio-ulna joint is moved to the left by 0 cm (A), 5 cm (B), 10 cm (C) and 15 cm (D)

2. Experiment on the change in the angle of the subject around the Z-axis

The wrist is anatomically connected to the elbow and shoulder, and the shoulder extends outward around the patient's body. Looking at the direction where the center line of the isocenter and the major axis of the wrist coincide with the Z-axis, if the patient's body cannot move outside the gantry of the CT device, the wrist usually rotates around the Z-axis. Therefore, an experiment was conducted to rotate the wrist phantom around the Z-axis. At this time, the clockwise deviation was not considered as it was almost improbable in terms of the actual anatomical structure. Therefore, as shown in Figure 2, the experiment was performed on the case where it was located on the Z-axis and rotated by -20° and -40° . It was examined 60 times in total: 10 times each for the -20° and -40° deviations from the isocenter (0°) for each of the 16, -40 and 64 channel scans. After the scan, the data was re-arranged to 0° in the deviation state, and the image was reconsctructed.



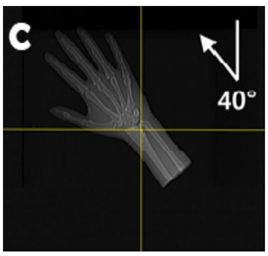


Fig. 2. Experiment on the change in the angle of the subject around the Z-axis in which examination was performed while rotating the major axis of the wrist around the Z-axis by 0° (A), -20° (B) and -40° (C)

3. Image Analysis

For image analysis, the Modulation Transfer Function (MTF) was calculated using image J and Originpro. MTF refers to the ability to distinguish two adjacent objects, which can be used for evaluating spatial resolution. MTF is the normalized magnitude of the Fourier transform of the line-spread function (LSF). In this study, For LDF, the edge-spread function (ESF) was obtained through differentiation after setting the Region of Interest (ROI) in radius and ulna. At this time, the MTF evaluation method used the slanted-edge method[5,6]. For statistics on the MTF value according to the distance along the X-axis for each number of channels, the average MTF value was analyzed through Kruskal Wallis test. The MTF calue according to angle of deviation around the Z-axis for each number of channels was subjected to an Mann-Whitney u-test. At this time, when the p value was less than 0.05, it was judged to be statistically significant.

III. RESULT

This study conducted two types of experiments: the first experiment was conducted to examine the MTF changes according to the number of channels of the CT device and the X-axis distance, and the second experiment was on the MTF changes according to the deviation of the subject around the Z-axis.

1. MTF according to change in the distance of the subject along the X-axis

As a result of analyzing the MTF while moving the subject along the X-axis, in the 16-channel scan, the MTF was the highest at the point 0 cm away along the X-axis with 0.62±0.03, and the lowest at the point 15 cm away with 0.53±0.03($p<0.05$). In the -40-channel scan, it was higher at the point 0 cm away with 0.59±0.02 than 0.49±0.03 at the point 15 cm away($p<0.05$). In the 64-channel scan, it was the highest at the point 0 cm away along the X-axis with 0.59±0.01, and the lowest the lowest at the point 15 cm away with 0.51±0.02($p<0.05$). In the results from the right side of the radius, the MTF values at the point 0 cm away were always higher than the values measures at the point 15 cm away regardless of the number of channels. In the right radius and ulna, the MTF values decreased with an increase in the distance regardless of the number of channels [Table 1].

Table. 1. MTF value according to the distance along the X-axis for each number of channels

site	distance	16 channel	40 channel	64 channel	p1
Left radius	0 cm	0.62±0.03	0.59±0.02	0.59±0.01	.094
	5 cm	0.58±0.03	0.58±0.02	0.58±0.01	.293
	10 cm	0.56±0.01	0.55±0.01	0.56±0.03	.095
	15 cm	0.53±0.03	0.49±0.03	0.51±0.02	.772
p2		.000	.000	.000	
Right radius	0 cm	0.61±0.01	0.60±0.03	0.62±0.00	.229
	5 cm	0.59±0.04	0.56±0.01	0.61±0.09	.864
	10 cm	0.56±0.02	0.53±0.02	0.55±0.02	.468
	15 cm	0.52±0.02	0.52±0.02	0.53±0.02	.029
p2		.000	.000	.000	
Ulna	0 cm	0.59±0.02	0.59±0.02	0.59±0.01	.813
	5 cm	0.56±0.03	0.58±0.05	0.54±0.01	.115
	10 cm	0.52±0.01	0.54±0.01	0.53±0.01	.016
	15 cm	0.51±0.01	0.51±0.01	0.52±0.02	.072
p2		.000	.000	.000	

2. MTF according to change in the angle of the subject around the Z-axis

As a result of analyzing the MTF while changing the angle of the subject around the Z-axis, the MTF was 0.59±0.03 when it was rotated -20° in the left radius; it was 0.67±0.02 when rotated -40°($p<0.05$). In the 40-channel and 64-channel scans, the MTF values were higher when rotated -40° around the Z-axis than -20°. However, in the 16-channel scan performed on the right radius was higher after -20° deviation with 0.58±0.02 than 0.56±0.02 after -40° deviation($p>0.05$). In the -40-channel and 64-channel scans, the MTF values were high after rotating -20° than -40°. For ulna, the MTF was the same at 0.60±0.01 after rotating -20° and -40° in the 16-channel scan($p>0.05$), and the result was the same in the -40-channel scan($p>0.05$). However, in the 64-channel scan, the MTF values were 0.59±0.01 at -20° and 0.64±0.04 at -40°, showing a higher value after rotating -40°($p<0.05$) [Table 2].

Table. 2. MTF value according to angle of deviation around the Z-axis for each number of channels

site	angle	16 channel	40 channel	64 channel	p1
Left radius	-20°	0.59±0.03	0.59±0.02	0.67±0.04	.083
	-40°	0.67±0.02	0.67±0.03	0.69±0.03	.283
p2		.043	.684	.043	
Right radius	-20°	0.58±0.02	0.56±0.02	0.57±0.03	.001
	-40°	0.56±0.02	0.55±0.01	0.54±0.02	.371
p2		.000	.000	.529	
Ulna	-20°	0.60±0.01	0.59±0.01	0.59±0.01	.010
	-40°	0.60±0.03	0.59±0.02	0.64±0.04	.002
p2		.796	.529	.000	

Ⅳ. DISCUSSION

CT scan is a useful method that has excellent diagnostic value and provides anatomical information in a relatively short time through an image implemented as a tomography. However, since X-rays are rotated and irradiated around a single axis, image quality changes according to the positions of the X, Y and Z-axes. For examining a wrist with a particularly complex anatomical structure, it is advantageous in terms of X-ray exposure and image quality to perform the examination while the patient is in a prone or supine position with the hand raised above the head. The wrist is connected to the elbow and shoulder joints; therefore, the patient's body should be moved to position the major axis of the wrist in the isocenter of the CT device. When examining the wrist of the patients who are unable to take such a posture, movements and deviations may occur along the X and Z-axes. Several previous studies have reported that failure to match the X and Y-axes in the isocenter of the CT device degrades the image quality in the imaging examination[7-9]. However, there are not enough studies conducted on the wrist, and there is no evaluation of the image quality caused by the deviation of the major axis of the wrist in the Z-axis. Therefore, in this study, the image quality was evaluated using a wrist-only phantom assuming the cases in which the subject was moved from the CT isocenter to the left along the X-axis and the major axis of the wrist was rotated around the Z-axis. For each variable, the changes according to the number of channels of the CT device were observed as well. As a result of the study, in the wrist examination with the subject moving along the X-axis, sharpness decreased as the distance from the isocenter increased, and there was no significant difference depending on the number of channels. Hara et. al[10] reported that MTF tended to decrease as the distance from isocenter increased in a comparative study of MTF between isocenter and peripheral area in multi-detector CT (MDCT). In addition, Utrup and Brown[11] reported that there was no significant difference in the X-axis and Y-axis according to the number of channels in their study on the comparison of MTF of the 16, 64 and 128-channel scans Comprehensively, the MTF decreases as the distance from the isocenter along the X-axis increases, which means that it cannot be compensated by increasing the number of channels of the CT device.

When the subject was rotated by -20° or -40° around the Z-axis, there was no apparent pattern for the MTF value for each number of channels according to the measurement position. According to Kwan et. al.[12], the z-axis is hardly affected by the MTF in axial images since the spatial resolution of the Z-axis is close to the physical resolution of the longitudinal direction. The reason that a certain pattern could not be confirmed in this study can be explained by the z-axis in the axial image that is hardly affected by the spatial resolution. Therefore, in a wrist CT examination, rotating the major axis direction of the wrist around Z-axis would not have a significant effect on MTF.

Ⅴ. CONCLUSION

In conclusion, the movement of the patient's wrist from the isocenter along the X-axis should be restrained as much as possible for a wrist joint CT scan. However, the deviation of the patient's wrist around the Z-axis can be allowed depending on the condition of the patient without affecting the spatial resolution too much. Since this study did not evaluate SNR, additional SNR evaluation studies may be required. Therefore, this study is expected to provide basic data for the SNR evaluation studies in the future.

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손목관절 CT 검사 시 자세 변화와 채널 변경에 따른 MTF 평가 : Isocenter를 중심으로 X-축, Z-축 변화

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요 약

본 연구의 목적은 손목관절 CT 검사에서 환자 자세를 X-축, Y-축으로 변화시키고 CT 검사장치의 channe l 변화에 따른 MTF 평가를 하는 것이다. CT 장치와 손목 팬텀을 이용하여 isocenter를 중심으로 X-축으로 0(일치), 5, 10, 15 cm 이동시켜 검사하고, Z-축은 반시계 방향으로 -20°, -40° 회전하여 검사하였다. 검사는 16, -40, 64 channel을 이용하여 channel 별 차이가 있는지도 확인하고자 하였다. 검사한 영상은 자뼈와 좌우측 노뼈의 MTF 값을 측정하여 비교하였다. isocenter를 중심으로 X-축으로 이동시킨 실험에서 이동 거리가 커질수록 MTF 값은 감소하였고, 이때 MTF 값은 channel과는 무관한 것으로 확인되었다. Z-축에서 반시계 방향으로 -20°, -40° 손목관절을 회전시킨 실험에서 회전정도와 MTF는 무관한 것으로 확인되었다. 또한 ch annel과도 무관하였다. 결론적으로 손목관절 CT 검사에서 손목은 X-축 방향으로 이동을 최대한 억제시키고, Z-축으로의 회전은 검사 대상자의 환경에 따라 변화하여도 영상의 MTF에는 큰 영향을 주지 않을 것이라 사료된다.

중심단어: 손목관절 CT, X-축 이동, Z-축 회전, CT MTF, CT channel

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