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ORIGINAL ARTICLE

Quality of Temporal Bone CT Images: A Comparison of Flat Panel Cone Beam CT and Multi-slice CT

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Objective: Multi-slice computed tomography (MSCT) blurs fine, minute bony structures. From a safety standpoint, the radiation dose to the cornea cannot be ignored. To reduce these shortcomings of MSCT, a high-resolution cone beam CT (CBCT) scanner has been developed. This paper compares the image quality of MSCT and CBCT and shows representative images of the temporal bone to demonstrate the superior image quality of CBCT.

Materials and Methods: Forty original volume data sets of the temporal bone, including 20 CBCT and 20 MSCT data sets, were selected independently. Forty images each of the axial and coronal sections, incus, stapes, and horizontal portion of the facial canal were prepared in a uniform format. Each image was rated independently as fair, good, or excellent.

Results: As the inter- and intra-judge agreement of the two judges was highly significant or almost perfect, the average value of the ratings given to each image is called the "image quality score." The image quality scores for all of the CBCT images were significantly higher than those for all of the MSCT images ($p < 0.0001$).

Conclusion: CBCT can provide higher-quality images of the temporal bone than MSCT without a radiation hazard to the eyes.

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Introduction

Computed tomography (CT) of the temporal bone is used routinely in otology clinics. The development of multi-slice helical CT (MSCT) has improved the quality of images of the temporal bone and enhanced diagnostic competence significantly [1-5]. However, MSCT images of minute bony structures in the temporal bone are not always clear enough to allow an accurate diagnosis and images of metal implants are affected by inevitable noise contamination. From a safety standpoint, radiation to the cornea must not be ignored[6].

Recently, high-resolution cone beam computed tomography (CBCT) has been developed to reduce these shortcomings of MSCT[7-11]. The CBCT technology described here gives a high-resolution three-dimensional view of the temporal bone from any desired direction with very little radiation hazard to the eye. Given these advantages, we thought it important to clarify how superior the quality of the CBCT images of the temporal bone are to MSCT images, to promote the future clinical use of CBCT.

For this purpose, we used a forced choice rating, a method of psychometric measurement, to compare the image quality between CBCT and MSCT because MSCT with 0.5-mm collimation is reliable for detecting small bone structures[1-5]. This paper reports the results of the comparison and shows representative images to demonstrate the superior quality of temporal bone images obtained with CBCT.

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Materials and Methods

Selection of original CT volume data

Two otologists, one with 17 years of experience and the other with 11 years of experience, each independently chose 30 original CT volume data sets of the normal temporal bones of patients with organic disease on the opposite side or with a normal ear in which organic disease needed to be excluded. One selected 30 64-detector MSCT (Aquilion 64®, Toshiba Co., Tokyo, Japan) images from the 2008 database. The other selected 30 CBCT flat panel detector (3D Accuitomo 170®, J. Morita Manufacturing Co., Kyoto, Japan) images from the 2008 database. The otologists were asked to choose images with as high a quality as possible, based on their clinical experience.

From the 30 images, 20 original CT volume data, 10 males and 10 females, were then selected so as to match the patient ages. The average age was 52.0±16.6 years (24–74 years) in the CBCT group and 49.4±15.9 years (20–80 years) in the MSCT group, with no significant age difference between the groups (p=0.61).

Preparation of images

The MSCT and CBCT imaging parameters are summarized in Table 1. The scanning and reconstructive parameters were established to obtain high-quality images for general clinical use. The field of view (FOV) for MSCT was reduced to match to that of CBCT, which has a limited FOV.

Table 1. Imaging parameters of each CT

	CBCT	MSCT
Exposure condition (kV)	90	120
Exposure condition (mA)	8	300
Exposure time (seconds)	17.5	6
Collimation (mm)	0.125	0.33
Size of one frame (pixels)	750×750	512×512
Section thickness (mm)	1	1
CTDI volume (mGy)	8.8	103.1
field of view (FOV)	6-cm diameter 6-cm height	Round with 6-cm diameter
Position of the subject	Sitting	Recumbent

CBCT; cone beam computed tomography
MSCT; Multi-slice computed tomography
CTDI; computed tomography dose index

From the 40 original volume datasets, the axial and coronal views of the temporal bone was sliced at the central level of the lateral semicircular canal at low magnification (total, 80 images). Views of the incus, stapes, and horizontal portion of the facial canal, which are fine and important structures for ear surgery, were sliced at the central level of each structure at high magnification (total, 120 images). CBCT sagittal images were excluded, as in previous MSCT studies [1-5].

The digital data for all 200 sliced views were transferred to a personal computer as TIFF files to make images for assessments using graphics software (Adobe Photoshop, Adobe System Inc., CA, USA) (Figures 1 and 2). All of the slices were adjusted to give round images 4 cm in diameter and printed on glossy paper with an ink jet printer. Throughout this process, care was taken to maintain the quality of the slice view at the original high standard. In this way 200 slice view images were prepared for image quality assessment.

Assessing image quality

Another otologist with 7 years of clinical experience and one radiologist with 9 years of clinical experience were engaged to assess the image quality. They were blinded to the purpose of the task, the CT scanners used, and other parameters used to prepare the images. Each image was presented randomly to a judge for about 10 s, who rated it as 1; fair, 2; good, or 3; excellent according to their impression after considering clarity, sharpness, brightness, and noise contamination of the image as previous reports [12-14].

This rating task was carried out on different occasions so that each judge could not see the results of the other.

Statistical analysis

Inter- and intra-judge agreement were quantified using weighted kappa (κ) statistics [15]. Student's t-test was used to estimate the significance of differences between the ratings allotted to the CBCT and MSCT images.

The study protocol was approved by the ethics committee of Takanoko Hospital, and informed consent was obtained from all subjects before taking CT images.

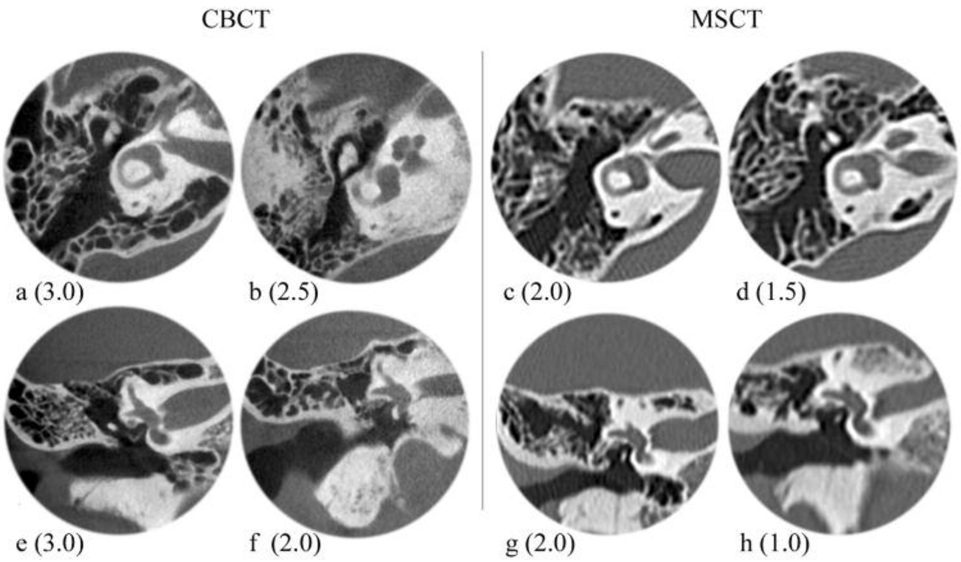

Figure 1. Images of low magnification with their image quality scores. The image quality score indicates difference of image quality distinctively. a,b,c,d: axial section; e,f,g,h: coronal section. ( ): scores of image quality.

Results

Inter- and intra-judge agreement

The rate of agreement in their judgments was 62.5, 72.5, 62.5, 67.3, and 77.5% for the images of axial sections, coronal sections, and the incus, stapes, and horizontal portion of the facial canal, respectively. The κ values for the quantitative analysis of the respective images were 0.74, 0.81, 0.83, 0.81, and 0.88. The result indicated that the inter- and intra-judge agreement was very high or almost perfect. Thus, we can say that the average value rating given to each image reasonably represented the quality of that image. The average value is called the "image quality score" in the following sections.

Difference in image quality between CBCT and MSCT

Table 2 summarizes the image quality scores of the low- and high-magnification image sets. The CBCT scores for both set were higher than those for the MSCT images. Student's t-test indicated that the differences were statistically significant ($p<0.0001$).

Figure 1 shows representative low-magnification images with the image quality scores to demonstrate the difference in image quality between CBCT and MSCT. It can be seen that the image quality score was suitable for indicating differences in image quality.

Table 2. Image quality score

	CBCT	MSCT
Low magnification		
Axial section	3.0±0.1 (2.5-3.0)*	1.7±0.2 (1.5-2.0)
Coronal section	2.8±0.3 (2.0-3.0)*	1.5±0.4 (1.0-2.0)
High magnification		
Incus	2.8±0.3 (2.5-3.0)*	1.3±0.3 (1.0-2.0)
Stapes	2.6±0.4 (2.0-3.0)*	1.2±0.2 (1.0-1.5)
Facial canal	2.9±0.2 (2.5-3.0)*	1.5±0.5 (1.0-2.0)

*Mean ± SD (Range). *: p<0.0001, Student t-test*

Figure 2 shows representative high-magnification images. As seen here, the CBCT images show that the border between bone and air or soft tissue is more distinct and sharper than the MSCT images and tiny bone structures were more readily identifiable on the CBCT images than on the MSCT images. The superior quality of the CBCT images is attributable mainly to the excellent spatial resolution of the CBCT scanner.

Discussion

For accurate imaging diagnosis, a good-quality radiologic picture is always desirable. The quality of CT images is affected by multiple, complex visual

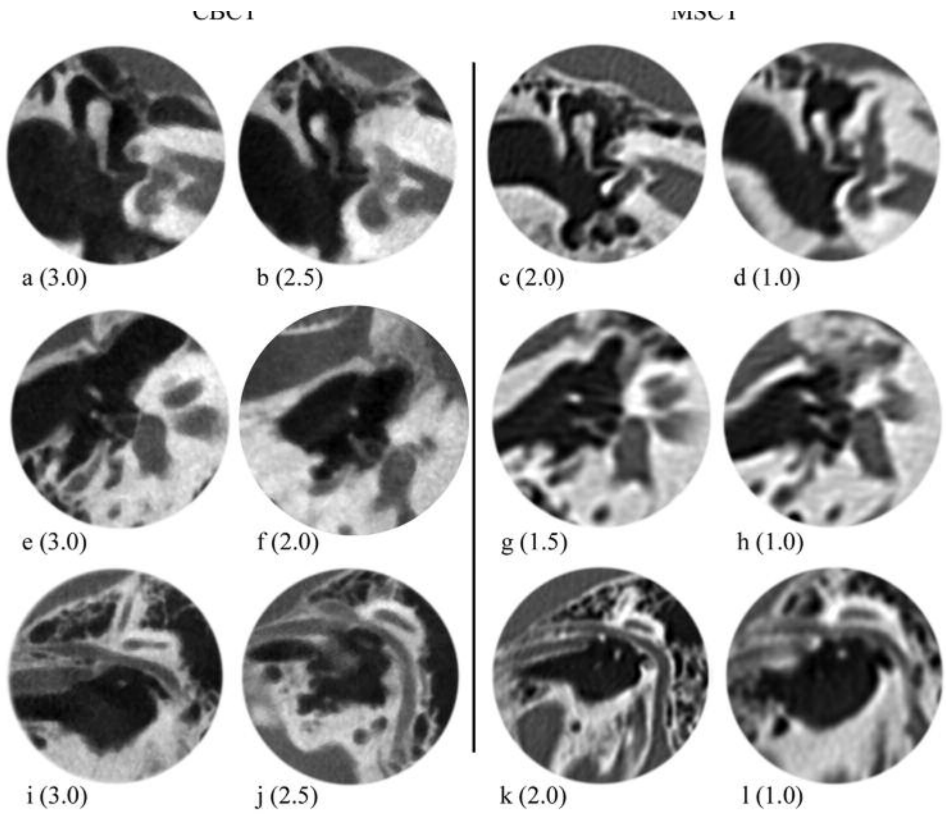

Figure 2. High magnification images with image quality score. Image quality score clearly reflects superior spatial resolution of the CBCT. a,b,c,d : incus; e,f,g,h : stapes; i,j,k,l : horizontal portion of facial canal. ( ): scores of image quality.

factors, such as noise, sharpness, and contrast, and is ultimately assessed by the subjective impression of the diagnostician. Thus, the psychometric rating we used is a reasonable method for evaluating image quality. Using a forced choice rating, we demonstrated that the image quality of CBCT with a flat panel detector was significantly better than that of 64-detector MSCT.

Using a similar method, Liang et al.[12][14] assessed five commercial CBCT scanners, including the first-generation model of the one we used with an image intensifier (the first-generation 3D Accuitomo®), and one 16-detector MSCT scanner for image quality and the depiction of anatomical structures in a dry human mandible. Of the six scanners, the first-generation 3D Accuitomo®), CBCT provided the best result, although the MSCT scanner (resolution 0.28 mm) was superior to all of the CBCT scanners in terms of image quality. Recently, a flat-panel has been incorporated in the CBCT (third generation) to improve the resolution of the CT image, with less metal and blooming artifacts[16-18]. However, it was not clear whether the CBCT with a flat panel actually provided CT images of better quality than a 64-detector MSCT scanner. Here, we demonstrated that the CBCT with a flat-panel detector provided better-quality images of the temporal bone than a 64-detector MSCT. This indicates that the diagnostic value of CBCT in otologic practice is very high.

In this investigation, axial and coronal images of the entire temporal bone and images of three minute structures in the middle ear were chosen to assess image quality because we thought them suitable for this purpose. However, with our extensive use of CBCT with a flat panel over the last 5 years, we have learned that ear CBCT images are useful not only for clinical purposes, but also for research and education. Thus, we think that it is worthwhile to show examples of other parts of the temporal bone here to strengthen the results of this study (Figure 3).

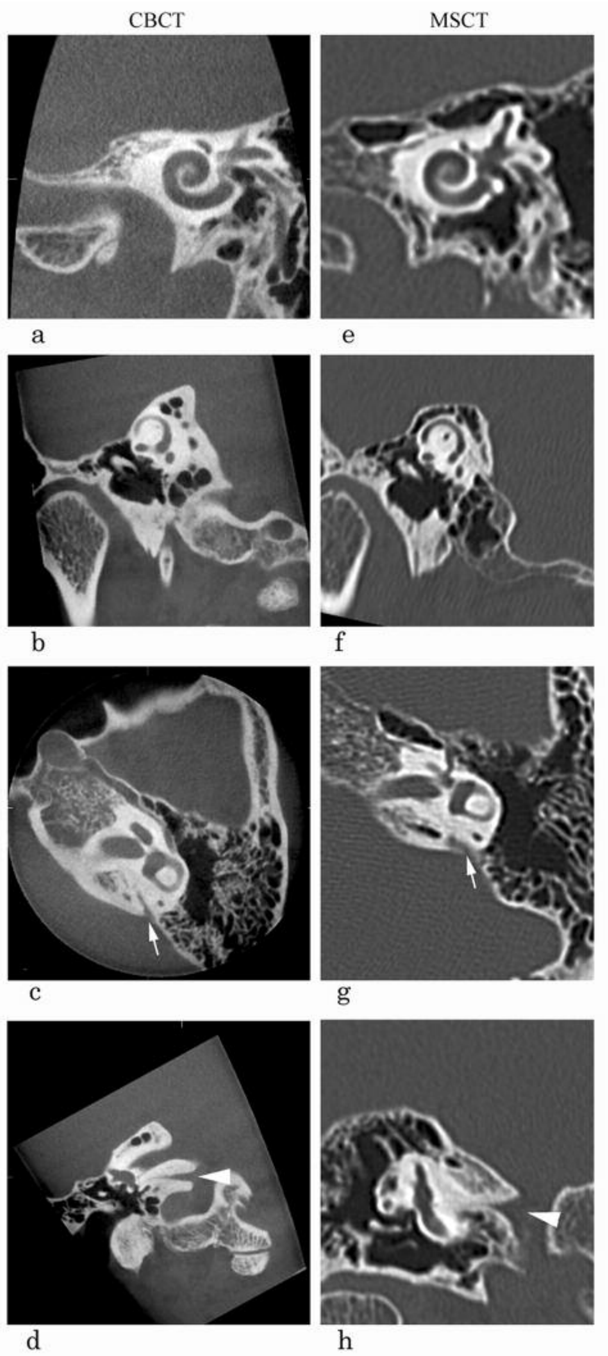

Figure 3. CBCT and MSCT images showing details of the inner ear. Both the CTs showed same bony structures but quality of the images of the CBCT is apparently superior to those of the MSCT due mainly to higher resolution of the CBCT. The border between bone structure and soft tissue by the CBCT seems clearer and sharper than that by the MSCT. a,e: cochlea; b,f: semicircular canal; c,g: vestibular aqueduct; d,h: cochlear aqueduct.

To store volume data in the mother computer of the CBCT, the subject sits on a chair with his/her head fixed for 17.5 s. Given this long exposure, the use of CBCT in children is quite limited. This limitation is a disadvantage that is difficult to overcome. The CBCT has a high spatial resolution and is good at depicting minute bony structures, but is not as good at depicting soft tissues compared with a MSCT scanner. Because the FOV of the CBCT is smaller than that of a MSCT scanner, CBCT cannot observe wide areas of the skull or other parts of the body. There are other disadvantages of CBCT, mainly due to the limited radiation dose. Although the use of CBCT is restricted to temporal bone imaging and imaging diagnosis of ear disease, these disadvantages are within the permissible scope, considering the safety of this CT method.

The level of radiation exposure to the eye is a major concern in temporal bone CT[6]. The CT dose index (CTDI) volumes of CBCT are calculated as 8.8 mGy/ear and 17.6 mGy for both ears. The index of the 64-detector MSCT scanner in routine use is estimated as 103.1 mGy/head. Although direct comparison of these figures is not meaningful, we can reasonably say that the radiation hazard to the eye with CBCT is much less than that with MSCT.

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