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Research article

Flat-panel CT versus 128-slice CT in temporal bone imaging: Assessment of image quality and radiation dose

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A R T I C L E I N F O

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A B S T R A C T

Objective: We compared the image quality and radiation dose of flat-panel CT (FPCT) and multi-slice CT (MSCT) performed respectively with an angiographic unit and a 128-slice CT scanner. We investigated whether the higher spatial resolution of FPCT translated into higher image quality and we sought to eliminate inter-subject variability by scanning temporal bone specimens with both techniques.
Materials and methods: Fifteen temporal bone specimens were imaged with FPCT and MSCT. Two neuroradiologists experienced in otoradiology evaluated 30 anatomical structures with a 0–2 score; 18 structures important from a clinical perspective were assigned a twofold value in calculation of the overall score. The radiation dose was calculated through the use of an anthropomorphic phantom.
Results: The image quality was significantly higher for FPCT than MSCT for 10 of the 30 anatomical structures; the overall score was also significantly higher for FPCT ($p = 0.001$).

The equivalent dose of the two techniques was very similar, but with different effective doses to the organs.
Conclusion: FPCT performed on an angiographic unit provides higher image quality in temporal bone assessment compared to MSCT performed on a 128-slice CT scanner thanks to its higher spatial resolution, with comparable equivalent doses but different effective doses to the organs.

1. Introduction

Temporal bone imaging can be challenging due to the minute and complex anatomical structures of the middle and inner ear. Despite their diminutive dimensions, pathological changes to these structures may have profound consequences on hearing and balance, often requiring exploratory and reconstructive surgery [1]. Thin slices multislice CT (MSCT) represents the traditional technique of choice for imaging of the temporal bone, with a spatial definition up to 0,4 × 0,4 mm in-plane and 0,5 mm in slice thickness and the possibility of multiplanar reconstructions [2].

Flat Panel CT (FPCT) is a technique with very high isotropic spatial resolution (up to 110 × 110 × 110 μm^3) which can be conceived as a CT scanner in which the detector rows have been replaced by an area detector with smaller detector element size, resulting in very high intrinsic spatial resolution and wide z-axis coverage [3]. FPCT was recently employed in the assessment of cochlear implants and metallic prostheses after reconstructive surgery of the middle ear, as it is less susceptible by metallic artifacts [4–6], but dedicated FPCT scanners are still not widely available [7]. Interestingly though, FPCT can also be performed with angiographic C-arm units equipped with a flat panel detector, available in many neuroradiology departments. The image quality and the radiation dose in imaging of the temporal bone has recently been assessed comparing FPCT and 64-slice MSCT [8].

Despite the higher spatial resolution of FPCT, the well-known disadvantages of decreased soft-tissue contrast resolution and an increase in the scattering artifacts, prompted a comparison between FPCT and a modern 128-slice CT scanner to assess the image quality and the

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radiation dose.

The purpose of the present study is to investigate the image quality, weighted for clinically relevant anatomical structures, and the radiation dose of FPCT compared to a 128-slice MSCT scanner.

2. Materials and methods

2.1. Temporal bone specimens

Sixteen temporal bone specimens of normal hearing patients, who died from causes unrelated to skull base or ear conditions, were imaged with both FPCT and MSCT. According to the Categories of Human Biological Materials [9], the temporal bone specimens were anonymous specimens donated to the Institute of Audiology of the University of Milan more than 25 years ago for scientific use and fulfilled all requirements regarding the good practice and ethical use of human materials by the International Federation of Associations of Anatomists [10]. Each specimen was conserved in a refrigerator at 4 °C inside a glass jar with about 300 ml of formalin. They were used for education purposes, research and training of residents and surgeons in the Otorhinolaryngology Department of our Hospital. Two specimens, during an educational course on dissection, underwent a mastoidectomy and, as no relevant structures (middle ear structures in particular) were affected by this intervention, they were judged suitable for evaluation. One temporal bone specimen was excluded because the middle ear structures had been surgically removed during an educational course on the specimens. Thus, were considered for the analysis 15 temporal bones specimens, with no pathologic findings detected on MSCT or FPCT.

2.2. MSCT and FPCT acquisition

MSCT examinations were performed with a 128-slice CT scanner (Somatom Definition Flash; Siemens). The MSCT scan had the following scan parameters: current, 130 mA; voltage, 120 kV; pitch, 0.85:1; rotation time, 1 s; section collimation, 0.5 mm; acquisition FOV, 50 cm^2; matrix, 512 × 512; scan length, 70 mm. The scan time was 21 s. The CT dose index volume was 33.8 mGy, and the dose-length product was 238 mGy cm. The images were reconstructed from the raw data with a 512 × 512 matrix and a 10-cm FOV, leading to a 0.195 x 0.195 mm pixel size in the plane of acquisition. Images were reconstructed by using a standard filtered back-projection algorithm with a high-resolution kernel (U70), with a slice thickness of 0.5 mm. The acquisition parameters for MSCT were suggested by the vendor and were adopted after a literature review [11,2,12], being considered the best compromise between image quality and radiation dose. The reconstruction parameters were obtained after an optimization process in the last 4 years of clinical practice, in order to achieve the best compromise between image quality and spatial resolution.

FPCT was performed with a C-arm angiographic system (Allura Xper FD20; Philips Healthcare, Best, the Netherlands), including a digital flat panel detector 30 x 40 cm, with a source-to-image-receptor distance of 120 cm. The FPCT scanning parameters were pre-set on the angiographic unit for the acquisition mode called “XperCt”, designed for the assessment of intracranial stents. The high image quality and low dose in temporal bone assessment with this protocol has recently been described [8]; the only parameter that was possible to modify from the XperCt protocol was the length of the FOV in the z direction, which was optimized during the last year of clinical practice in order to acquire only the temporal bone, reducing the dose and the scattering artifacts. The scan had the following parameters: current, 260 mA; voltage, 80 kV; FOV, 20 × 15 cm^2 ; scan height, 55 mm. By rotating 240° (from 60° to 300°) passing through the posterior part of the head and avoiding the anterior part, the pivoting C-arm of the angiography unit acquired a volume dataset of up to 622 projections, with a scan time of 25 s. The dose-area product was 4700 mGy cm^2, and the air kerma was 133 mGy. The temporal bone specimen was reprocessed separately into a FOV of 67% of the volume acquired, with a voxel size of 0.14 × 0.14 × 0.14 mm^3. Postprocessing of this volume dataset was performed with a reconstruction software (Allura 3D-RA 6.3.0/XperCt 3.1.0; Philips Healthcare), allowing all the possibilities of standard 3D-postprocessing such as multiplanar reformations, curved reformations, volume-rendering technique, shaded surface display technique, and MIP. Images were reconstructed with a slice thickness of 0.14 mm. The average reconstruction time was approximately 10 min.

The temporal bone specimens were placed on the head holder of the scanners, surrounded by two 0,5 liters plastic bags full of water in order to reduce the difference in attenuation between air and bone and increase the homogeneity of the volume.

2.3. Image quality assessment

Two neuroradiologists with 3 years (ES) and 8 years (GC) of experience in otoradiology independently evaluated FPCT and MSCT of the 15 specimens in a randomized order, which was generated separately for the 30 acquisitions (15 FPCT and 15 MSCT) in order to avoid evaluation of the same specimen consecutively. The two different randomized lists for the two readers were generated with the use of SPSS v.24 statistical software (IBM, Armonk, New York). The readers were permitted to scroll through the image sections, change the CT window level and width and perform multiplanar reconstructions and MIP of the volume data.

Thirty anatomical structures of the external, middle and inner ear were evaluated with a 0–2 score: 0 = the structure could not be visualized, 1 = the structure could be identified but not well-delineated from the surrounding tissues, or some parts of the structures were poorly identified and 2 = the structure was well visualized and delineated from the surroundings in all of its parts [1,7,8].

The 30 anatomical structures to be assessed were the tympanic membrane, the handle of malleus, the head of malleus, the bone marrow of malleus, the incudo-malleolar joint, the body of incus, the bone marrow of incus, the long process of incus, the short process of incus, the lenticular process of incus, the incudo-stapedial joint, the head of stapes, the anterior crus of the stapes, the posterior crus of the stapes, the footplate of the stapes, the tendon of tensor tympani muscle, the stapedius muscle, the anterior ligament of the malleus, the superior ligament of the malleus, the lateral ligament of the malleus, the posterior ligament of the incus, the bony labirinth of the cochlea, the interscalar septum, the modiulus, the vestibular acqueduct, the cochlear acqueduct, the geniculate ganglion, the bony canal of the facial nerve, the corda tympani and the greater petrosal nerve.

For statistical analysis the mean score of the two readers for each structure was considered. The overall score was calculated for each specimen for MSCT and FPCT by adding the scores of the two readers and by assigning a twofold value to 18 structures considered the most significant from a clinical standpoint (highlighted in bold in Table 1), with a maximum overall score of [(2 points x 12 structure x 2 readers) + (4 points x 18 structures x 2 readers)] = 192.

The two readers in consensus placed a circular region of interest (ROI) (approximately 50 mm^2) in the inner portion of the internal acoustic canal, avoiding surrounding bony structure. The signal was defined as the mean CT attenuation value within the ROI, and the noise as the standard deviation of the CT attenuation values within the ROI. The signal-to-noise ratio (SNR) was calculated. Finally, the two readers also evaluated in consensus the amount of artifacts for each of the 30 acquisitions, with the following scoring: 0 = numerous artifacts, 1 = moderate amount of artifacts, 2 = few artifacts, 3 = no artifacts, as shown in the online supplemental Figs. 1–4. A paired Wilcoxon test was used to compare quantitative and ordinal qualitative variables between FPCT and MSCT. The Bonferroni correction for multiple testing was applied to compare the image quality scores of each structure and the overall score: as 30 different structures were tested, the p-values of the