High Resolution Computed Tomography in Stapedial Otosclerosis

S. R. Priya · P. P. Singh · Lalendra Upreti ·
Lakshmi Vaid

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Abstract The value of high-resolution CT scanning in diagnosing stapedial otosclerosis and in influencing surgical planning was studied. 40 cases, consisting of patients of both genders, above the age of 14 years, with a clinical diagnosis of otosclerosis underwent HRCT of the temporal bones. Images were acquired in axial plane, with a bone algorithm, keeping slice thickness at 0.5 mm and intervals of 0.5 mm. Reconstruction of the volume data set was done to obtain overlapping slices in various planes, so as to obtain the best possible images of the footplate of stapes. The thickness of the footplate was measured and the site of lesion was noted in these images. On exploratory tympanotomy, the footplate was assessed and graded according to a visual scale. HRCT was able to diagnose stapedial otosclerosis in 85% ears. It was able to identify the presence of a thickened footplate correctly with a sensitivity of 85.3% (P value 0.16). It was able to correctly localize the site of otosclerotic focus in 85% cases (P value <0.01). Thus, an estimate of the thickness of the footplate likely to be encountered and thus the amount of drilling likely to be required to create a fenestra; and the likely site of maximum thickness could be made pre-operatively. This study also established the value of multislice CT on the acquisition of such data. This method

obviates the requirement of difficult patient positioning, reduces scanning time; while greatly improving the sensitivity of the scanning.

Keywords Otosclerosis · Stapedotomy · Radiology temporal bone · HRCT conductive deafness

Introduction

Otosclerosis is a common cause of deafness in the Indian subcontinent [1], affecting about one percent of the population. India is among those nations counted as having a high prevalence of the condition.

Although otosclerosis had been recognized 300 years ago [2], its histopathology been described nearly a 100 years ago and surgery for the condition has been optimized, its diagnosis is still made largely clinically.

Radiological investigation for temporal bone lesions assumed importance only after the advent of Computed Tomography in 1972, and especially after introduction of high resolution and multislice CT in 1978[3].

As the resolution and ease of manipulation of the CT is improving, along with the expertise in interpretation, the accuracy of High Resolution Computed Tomography (HRCT) in diagnosing otosclerosis is being established. Several studies have been done in the last 15 years to identify the tomographic features of otosclerosis, to correlate the same with clinical and histopathological features, and to assess its sensitivity as a reliable diagnostic tool.

The present study aimed to provide a definite comparison between the images of the footplate and the observations during surgery, thus providing a qualitative and quantitative assay of the utility of HRCT in stapedial otosclerosis.

S. R. Priya (✉) · P. P. Singh · L. Vaid
Department of ENT, Guru Teg Bahadur Hospital,
Dilshad Garden, Delhi 110092, India
e-mail: essarpriya@yahoo.com

L. Upreti
Department of Radiology, Govind Ballabh Pant Hospital,
Delhi, India

Materials and Methods

Patients were selected from the out patient department of the Department of Otorhinolaryngology and Head and Neck Surgery, Guru Teg Bahadur Hospital, Delhi, India. The diagnostic criteria were—history of gradually progressive unilateral or bilateral deafness, with otoscopy showing an intact tympanic membrane and tuning fork tests suggesting conductive deafness. Informed consent was obtained. Patients were of both sexes above the age of 14 years. Patients with features suggestive of possibility of other ossicular defects and cases of revision surgery were excluded from the study. This study was carried out between January 2006 and December 2007. A detailed history was taken to rule out other causes of deafness and to identify a positive family history. After applying the exclusion criteria, a total of 40 ears (in 40 patients) were included in the study. Pre-operative air and bone conduction thresholds for the frequencies of 500, 1000 and 2000 Hz were recorded and the air-bone gap (pre-operative) was calculated, confirming presence of only a conductive type of deafness. Tympanogram and stapedial reflex testing was also carried out. Relevant laboratory tests were done.

Subsequently, HRCT of the temporal bones was obtained in the Department of Radiodiagnosis in the same hospital. Scanning was done on a Somatom Plus 4 Volume Zoom Multislice Scanner. Volume data set was obtained in axial plane with a slice thickness of 0.5 mm at intervals of 0.5 mm, at the rate of four sections per second. Images were produced with a high-resolution bone algorithm with a window width kept at 4000 Hounsfield Units. Reconstruction of the volume data set was done keeping section thickness at 0.5 mm and interval of 0.3 mm to obtain overlapping slices. The volume data set was then manipulated in various imaging planes to obtain the best possible images of the footplate. The thickness of the footplate was measured on these images. During the evaluation of the scans, additional information about the site of the

otosclerotic lesion was also noted. All scans were read at the workstation console.

Normative values were according to literature on the measurements done on stapes footplate [4, 5] (Fig. 1a, b). The thickness of the footplate was considered abnormal if it was found to be greater than 0.6 mm [4]. A footplate that was grey instead of the normal white was considered otospongiotic. A non-linear hypodensity in the area anterior to the oval window was taken as evidence of an otosclerotic lesion [4]. A widened oval window, a thickened footplate with minimal involvement of the oval window margins or an oval window that is completely obliterated by a thick bony plate [5] were all different variations of otosclerotic lesions that were looked out for and recognized. Keeping these criteria in mind, the thickness of the footplate in millimeters, the position of the otosclerotic locus (polar) and the type of focus (annulus—only focus vs. entire footplate focus) was recorded and comparisons with surgical observations were done on these lines.

All selected patients underwent exploratory tympanotomy, performed by the same surgeon (PPS) in a single-blinded setting. The surgery was done under local anaesthesia except in cases where the patient was apprehensive or had additional medical illnesses such as hypertension.

On table, the existence of footplate fixation was confirmed by gentle palpation and the location of the otosclerotic focus was determined visually. An assessment of the degree of footplate thickness was made according to the ease of perforation while creating the fenestra. A visual scale was devised to grade the thickness of the footplate as follows:

- Grade 1 Blue reflex present over the footplate with an annular fixation
- Grade 2 Blue reflex not seen, thin obliterative focus present over the footplate

Fig. 1 Radiological appearance of normal oval window region. **a** axial view. **b** oblique coronal view. *M* malleus, *I* incus, *SS* suprastructure, *VSBLE* vestibule, *FP* footplate

Grade 3 Thick obliterative focus

Subsequently a Teflon or titanium piston was placed entering the fenestra and encircling the long process of incus. The rest of the procedure was completed as usual.

The sensitivity and specificity of HRCT as a diagnostic tool for stapedial otosclerosis was assessed. The sensitivity and specificity of HRCT to detect quantitative thickening of footplate of stapes in patients of otosclerosis was determined. The sensitivity of HRCT in detecting the site of otosclerotic focus was calculated. Pearson Chi-square test and Fischer's exact test were used for testing the above, using SPSS.

Results

Patient Profile

Of the 40 patients included, 21 (52.5%) were females and 19 (47.5%) were males, with a female:male ratio of 1.1:1. The mean age independent of sex was 33.475 years with a range of 14–60 years. The average duration of deafness ranged from 6 months to 15 years, with an average of 3.154 years overall. The average air-bone gap was found to be 39.375 dB.

HRCT as a Diagnostic Indicator

All the 40 patients who were operated upon were confirmed to have stapedial otosclerosis as confirmed by palpation of footplate. Out of these, HRCT had been able to provide a diagnostic indicator in 34 cases (85%). The indicator was either a thickened footplate, with or without an anterior oval window focus; or an anterior oval window focus alone.

The CT scans identified an increased thickness of the stapedial footplate (above 0.6 mm) in 31 out of 40 ears. During surgery, this was confirmed in 29 ears, while 2 ears were found to have a normal/borderline (Grade I) thickening of stapes.

CT scans predicted a normal thickness (0.3 to ≤ 0.6 mm) in 9 cases. Of these, 5 ears were found to have a thick footplate (>0.6 mm) per-operatively. However, the surgical findings of a thin footplate corresponded to the radiological finding in four cases. Thus the CT was able to identify 29 cases out of a total of 34 ears with a thickened footplate (85%).

As seen in Table 1, the sensitivity of CT scan in detecting a truly thick footplate is 85.3%.

The predictive value for a thickened footplate is 85% while the predictive value for a normal thickness footplate is 66%. On application of Pearson's Chi square test and

Table 1 Comparison between Ct and surgical assessment

	Thin footplate (peroperative)	Thick footplate (peroperative)	Total
Thin footplate (CT scan)	4	5	9
Thick footplate (CT scan)	2	29	31
Total	6	34	40

Fig. 2 Graph showing the distribution of patients according to grades of thickness of footplate (surgical) in both sexes

Fisher's exact test, the *P* value of the test is 0.16, which is significant.

Accuracy of Determination of Degree of Footplate Thickening

As seen in the graph in Fig. 2, 14 out of 40 (35%) ears had footplates of CT thickness of 0.5 to 0.6 mm. These were observed during surgery to correspond to a Grade I thickness and were perforated easily (Fig. 3a, b). Those ears with footplate thickness of 0.7 mm radiologically had Grade II footplates, which could be perforated with minimal drilling (Fig. 4a, b). These were found in 15 of the 40 ears operated upon (37.5%). A thick obliterative focus over the footplate that required significant drilling in order to create a fenestra was seen in 11 out of 40 ears (27.5%). These had been shown by CT to have a thickness of 0.8–0.9 mm (Fig. 5a, b). Thus the CT observations are a good indicator of the likely degree of thickening of the footplate. (The graph in Fig. 2 also shows that female patients predominantly have a grade I focus—ten females as compared to four males.

Determination of Accuracy in Predicting Site of Otosclerotic Focus

HRCT predicted a predominant anterior oval window focus (Fig. 6a, b) in 11 ears (out of which there was a sole

Fig. 3 Footplate (*arrow*) of grade I thickness (0.5–0.6 mm).
a Axial view on CT scan.
b Surgical confirmation of a grade I footplate in same case

Fig. 4 Footplate (*arrow*) of grade II (~0.7 mm) thickness.
a Axial view on CT scan.
b Surgical confirmation of grade III footplate in same case

Fig. 5 Footplate (*arrow*) of grade III (≥ 0.8 mm) thickness.
a Axial view on CT scan.
b Surgical confirmation of a grade III footplate in same case

anterior focus in three cases). Intraoperatively, this figure was 15. The number of ears where an obliterative/entire oval window focus (Fig. 7a, b) was predicted radiologically was 23, while this figure surgically was 25. Sensitivity of HRCT in localizing the position of the otosclerotic focus on the footplate is 85%. On application of Pearson's Chi square test and Fisher's exact test, the P value of the test is <0.01 , which is highly significant.

Discussion

Otosclerosis is an important and common cause of conductive deafness. Presently most patients with acquired conductive deafness are managed with a presumptive diagnosis based on clinical features—this diagnosis may be otosclerosis or tympanosclerosis or ossicular erosion. The surgeon generally plans for all possibilities and proceeds

Fig. 6 Anterior oval window otosclerotic focus (*arrow*). **a** Axial view on CT scan. **b** Surgical finding of same case

Fig. 7 Obliterative otosclerotic focus (*arrow*). **a** Axial view on CT. **b** Surgical finding of same case

with exploratory tympanotomy. In the last decade, the role of HRCT in ruling out other causes of conductive deafness has been better delineated. Development of spiral CT, techniques for multiplanar multislice CT, computed reconstruction of images have led to recognition of the most probable aetiology, though tympanotomy is still the golden standard. Lately, however, radiodiagnostic studies have approached 90 percent or higher sensitivities in diagnosing otosclerosis.

The bases for diagnosing otosclerosis in literature are—an increase or decrease in width of oval window and sclerotic or hypodense foci on or around footplate [5–7], thickened, irregular or hypodense footplate or presence of demineralized areas in temporal bone [4, 8] and change in gray scale [9]. We have included the quantitative measurement of the thickness of footplate of stapes as additional decisive diagnostic indicator. The results have been similar to other contemporary studies, however it is certain that with better precision software for measurement of such submillimetre thickness, this factor will gain more importance as the decisive diagnostic indicator.

Swartz et al. [6] studied the utility of CT scanning in the assessment of fenestral otosclerosis in 1984. On examining images in both axial and coronal views without reconstruction, they found that 26 patients out of a total of 35 patients had a positive finding of a bony excrescence at or adjacent to the oval window. In 2001, Fraysse et al. [10] described a sensitivity of 91.3% in finding otosclerosis on CT. Naumann et al. [8] found a sensitivity of 85% in localizing an otosclerotic focus in 30 patients suspected to have otosclerosis in 2005, in which study they have commented upon the utility of planar reconstruction and 0.5 mm slices in increasing diagnostic yield. In the present study, multiplanar reconstruction allowed us to study the focus in the best possible plane and made detection easy and accurate.

False negative results (2 out of 21 patients) have been described by Mafee [7] as those where there is an annular fibrous fixation or when the lesion was too small to be detected, which was said to be 2 mm at the time of their study. Naumann et al. [8] have explained the presence of two false negatives in their study of 44 CT scans, to be due

to the fact that the inactive form of the lesion has the same density as the surrounding bone and therefore remains undetected, whereas lesions from the active otospongiotic form are more visible because they are hypodense as compared to the bone of the otic capsule. Fraysse et al. [10] commented upon these ‘infra-radiological’ cases as being due to a beginning focus, it being present in 8.7% of the cases in their study. In our study, those cases of otosclerosis that were not picked up by HRCT (6 out of 40 cases or 15%) were later identified, upon tympanotomy, to be those due to an annular type of fixation. This finding is supported by a histological study by Cherukapally et al. [11] where it was established that ankylosis or fibrous changes of the annular ligament can cause significant conductive deafness.

Fraysse [10] found that in 11.3% of cases a radiological focus did not translate into conductive deafness. This was also the case with two of our patients (5%) with unilateral symptoms, whose other ear had a normal air-bone gap on audiometry, but presence of a significantly thick footplate on CT. Of these, one patient on follow-up has complaints suggestive of beginning otosclerosis in the previously asymptomatic ear. However three other patients in our study who had unilateral otosclerosis did have a radiologically confirmed absence of any significant focus in the asymptomatic ear.

Site of Focus

Veillon et al. [4] classified fenestral otosclerotic lesions according to the site of focus as Type 1A to 3 according to whether the fissula or anterior oval window or footplate was involved. Naumann et al. [8] have illustrated the presence of isolated anterior oval window focus and have mentioned absence of positive radiological findings in two patients with such a locus. Vicente et al. [12] describe the cases in their study to have a predominance of anterior oval window focus. We found that 12 out of 40 cases had predominant anterior focus, while 3 had a sole anterior focus.

Patient Positioning

Mafee et al. [7] advocated the use of 20-degree coronal oblique views (obtained after hyperextension) to get good images of the footplate as well as to reduce partial volume averaging. They used sections of 1 or 0.5 mm with overlapping and no reconstruction. Naumann et al. [8] studied the oval window by free rotation of the image at the time of reading, at the workstation. In the present study all scans were acquired in the axial plane and multiplanar reconstruction was done. All scans were studied at the console. We found this method accurate, with no indication for acquisition of direct coronal oblique views, thus eliminating patient discomfort and reducing scanning time.

Nature of Focus

During our study, though we were able to identify the presence of spongiotic versus sclerotic foci, we noted that the thickness of the footplate was significantly and similarly increased in both types of lesions and both gave rise to a similar degree of deafness.

Correlation Between Thickness of Footplate and Deafness

Naumann et al. [8] and Shin et al. [13] found a positive correlation between the audiometric finding and the presence of the otosclerotic focus on HRCT. However in our study we have not observed the same. As shown in the graph in Fig. 8, a higher (surgical) grading of the stapes footplate thickness did not translate into a more severe hearing loss. An equal number of patients of both sexes with grade I and II foci had an air-bone gap of between 31 and 40 dB, while fewer patients with a grade III focus had severe (>40 dB) deafness as compared to patients with a grade I focus.

Obliterative Focus

Raman R et al. [14], in Vellore, India, found truly oblitative foci in 33.9% patients (139 out of 420 ears). In our study thick oblitative foci (corresponding to our Grade III), was found in 11 out of 40 cases i.e., 27.5%. In the above workers’ study, the male:female ratio in oblitative otosclerosis was 1.48:1. In our study, we found a similar preponderance of male patients in the higher grades of lesions, and the male:female ratio observed in oblitative otosclerosis in our study was 1.2:1.

Conclusions

- (1) HRCT scanning in the given protocol enables diagnosis of stapedia otosclerosis in 85% of cases.

Fig. 8 Graph showing the grades of footplate thickness (surgical) versus air-bone gap in both sexes

- (2) HRCT allows localization of the otosclerotic focus in the oval window area in 85% cases.
- (3) The sensitivity of CT scan in detecting a truly thick footplate is 85.3%. Thus HRCT is a good tool to quantify otosclerotic thickening of footplate of stapes.
- (4) The determination of the site and size of the fenestral focus has significant influence on surgical planning.
- (5) Multislice CT scanning has obviated the need for direct oblique coronal scanning, thus decreasing scanning time and increasing patient compliance.

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