Localization of active otosclerotic foci by tympano-cochlear scintigraphy (TCS) using correlative imaging

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Localization of active otosclerotic foci by tympano-cochlear scintigraphy (TCS) using correlative imaging

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Abstract

High-resolution, tympano-cochlear scintigraphy (TCS) is a useful tool for visualizing changes in labyrinthine bone metabolism in active otosclerosis *in vivo*. But until now, the activity patterns have mostly been rather imprecisely ascribed to the labyrinthine structures; more exactly by means of high-resolution CT (HR-CT). Experimental studies on TCS using a human temporal bone model revealed that correlative imaging of X-ray photographs and the scintigrams or superimposition with masks of the temporal bone drawn from the X-rays can facilitate the localization of small foci of about 0.5–1 mm.

Clinical applications of the visualization technique, combining functional with structural images, confirmed the benefit of this method, improving the accuracy in detection and localization of focal activity enrichment of the petrous bone in cases of active otosclerosis by means of TCS.

Key words: Otosclerosis; Temporal bone; Labyrinth; Radionuclide imaging

Introduction

In addition to high-resolution CT (HR-CT) for detection of morphological alterations in the bony labyrinth, high-resolution tympano-cochlear scintigraphy (TCS) has become a useful technique for visualizing changes in labyrinthine bone metabolism. This method originally described by Bornemann *et al.* (1981) is based on the fact, that osseous foci of high metabolic activity, including those of the bony labyrinth, are able to accumulate bone-seeking isotopes. This was previously demonstrated *extra corporem* by Linthicum *et al.* (1973) on otosclerotic bone specimens by means of pre-operative labelling with strontium (^{85}Sr). Nowadays using shortlife radiopharmaceuticals like the ^{99m}Tc-linked diphosphonates, tympanocochlear scintigraphy (TCS) enables the detection of alterations in labyrinthine bone metabolism *in vivo*. By means of TCS, an increased bone metabolism of the labyrinth comparable to active otosclerosis has also been shown in cases of osteogenesis imperfecta (Ross *et al.*, 1993).

These alterations of the petrous bone in otospongiosis (Siebenmann, 1900) showing an increased bone metabolism are principally detectable by TCS, but, until now, they could not be subtly differentiated regarding localization and extent without performing HR-CT. Although the critical detection limit at HR-CT is reputed to be about 1 mm in diameter (Valvassori, 1993), the accuracy of this method alone in detecting small otospongiotic foci, which are commonly located at the oval window, is often reduced due to partial volume effects.

For further improvement of the topographical assignment of the activity patterns and the interpretation of clinical findings by TCS we performed experimental and clinical studies to specify the diagnostic value of TCS regarding detection and localization limit.

Materials and methods

Figure 1 shows the diagram of the experimental procedure. Ten human temporal bones had a radical mastoidectomy procedure performed and were incubated for 15–20 hours in an aqueous solution of ^{99m}Tc-labelled diphosphonates (methylene-diphosphonate (MDP) or dicarboxypropane-diphosphonate (DPD)) of 150–200 MBq to achieve a basic activity corresponding to that two hours after administration of the radioisotope *in vivo*. Particles of 0.5–1 mm in diameter and an activity of 0.05–0.06 MBq served as markers for the surface of the petrous pyramid and the fine structures of the labyrinth (round and oval windows, semicircular canals). In the clinical study with TCS in patients with clinically and audiometrically suspected otosclerosis scintigraphic imaging was performed two hours after intravenous DPD-administration of 740–800 MBq.

In both the experimental and the clinical studies a high-resolution scintigraphic system equipped with a special mounting device for the pinhole collimator of

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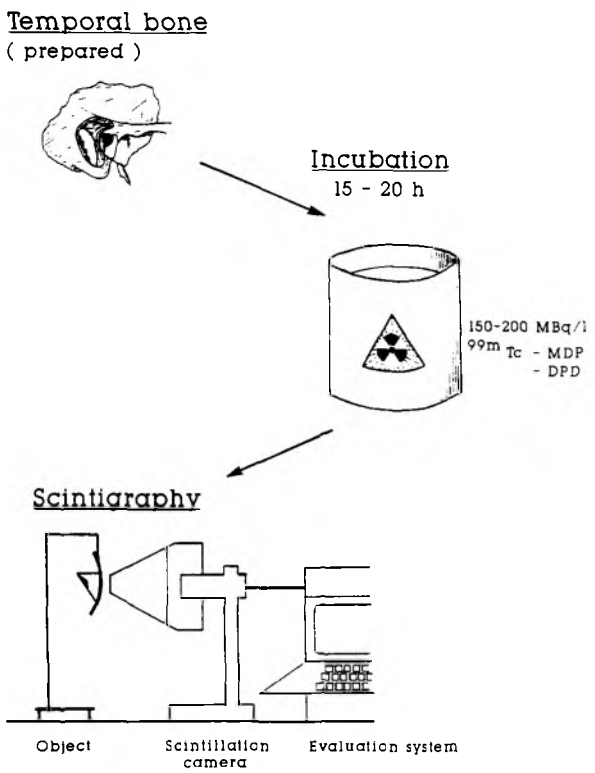


FIG. 1
Diagram of the experimental procedure.

the scintillation camera (Picker, Dyna 4/15) with an aperture size of 2 mm was used (Figure 2). Static imaging was performed over 10 minutes in the manner of modified Mayer's projection (Figures 3a, b).

The topographical assignment of the activity patterns is based on coventional X-ray imaging of the temporal bone models (Figure 4) of a human skull. Additionally, corresponding masks (Figure 4) drawn from the X-ray photographs were used to illustrate the important landmarks and the fine structures of the labyrinth to facilitate the assessment of the activity patterns in the clinical situation.

Results

Experimental findings

After 15–20 hours of incubation of the temporal bones in a solution of ^{99m}Tc-MDP or -DPD coarse structures like the zygomatic process and the clivus

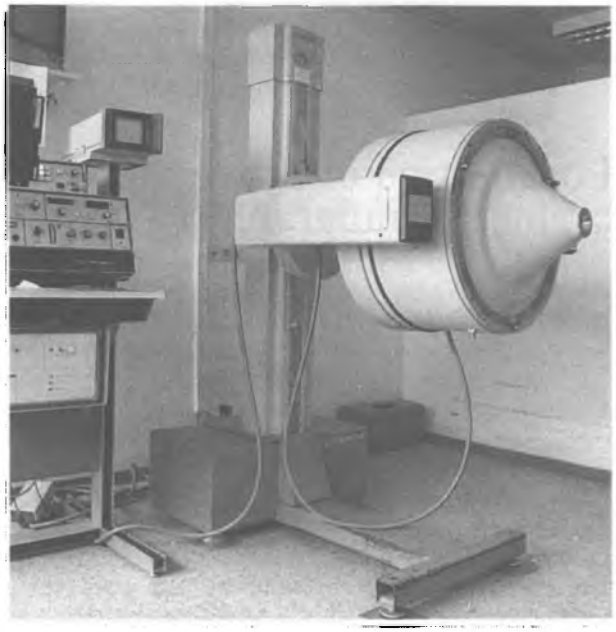
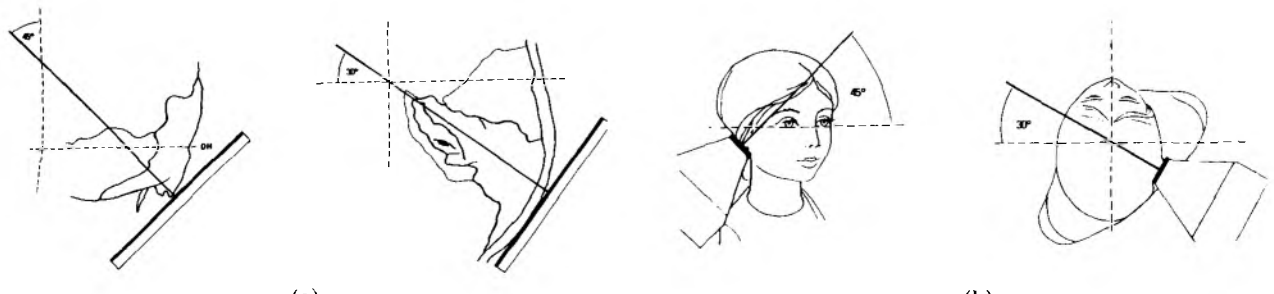


FIG. 2
Pinhole collimator for the scintillation camera (Picker, Dyna 4/15) equipped with a special mounting device used in both the experimental and the clinical studies.

region are the first recognizable in the scintigrams. The latter serves as an important landmark for the fine structures of the petrous bone in the *in vivo* situation as well. In the scintigram, the bony labyrinth can be found following the mid-orthogonal line from the clivus plane in dorso-cranial direction (Figure 5). Using the collimator system described above at a distance of 3 cm to the object fine structures of the labyrinth like the cochlea, labyrinthine windows, semicircular canals can be visualized corresponding to a spatial resolution of about 3–4 mm (Figure 5). The tracers applied for marking had an activity of 0.05–0.06 MBq and measured 0.5–1 mm in diameter. The pixel size of the computer matrix of 64 × 64 corresponded to 2 mm.

Clinical findings

In the clinical study with TCS correlative imaging also proved to be useful. Figure 6 represents a normal scintigraphic finding such as occur in healthy persons or in cases of inactive otosclerosis where the



(a) (b)

FIG. 3
Projection of the X-ray imaging of the temporal bone model (a) corresponding to the adjustment of the collimator during scintigraphy in the clinical situation (b).

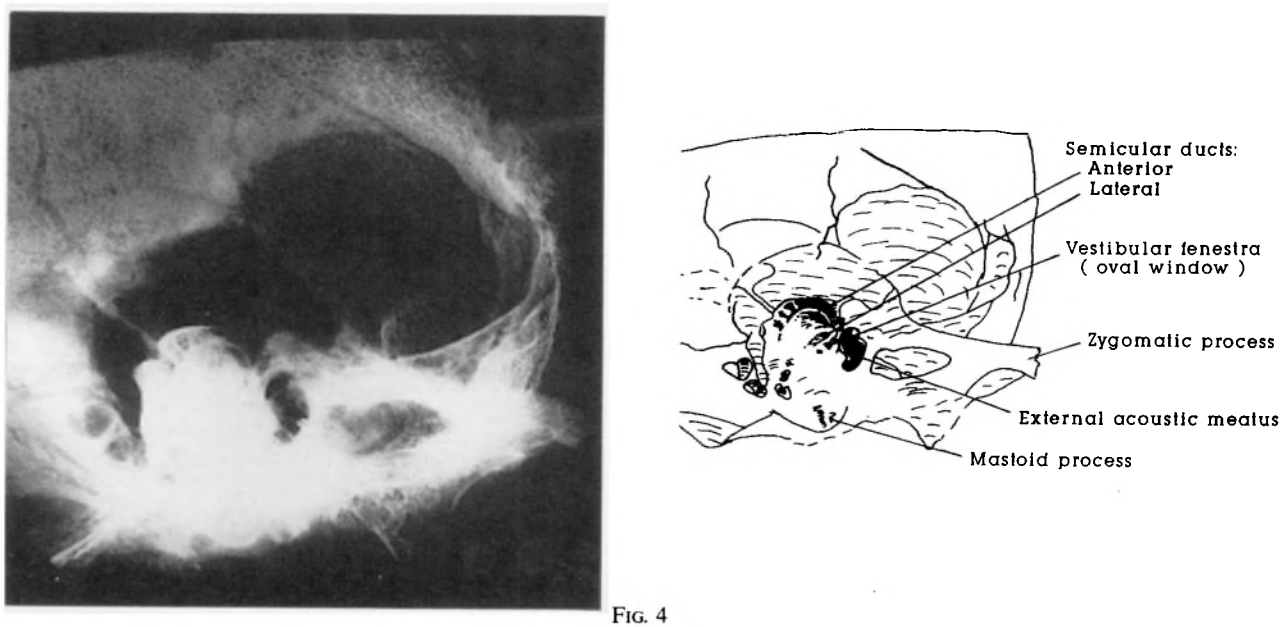


FIG. 4

Conventional X-ray photograph of a human temporal bone model in a modified Mayer's projection (left) and its mask (right).

region of the petrous bone is hardly visible compared to the clivus region or the cervical spine, which have a higher metabolic activity.

The TCS findings are quite different in active otosclerosis which is exemplarily demonstrated in Figures 7 and 8 showing the scintigrams of two patients with histologically confirmed active otosclerosis of different extent.

The TCS images shown in Figure 7a of a patient's right ear suffering from a progressive conductive hearing loss revealed an activity enhancement related to the oval window which is seen by superimposition with the X-ray photograph and its mask. In the weighted image, the clivus region showing a comparatively lower activity is pushed into the background. The corresponding coronal CT scan (Figure 7b) revealed a spot of demineralization measuring about 3 mm at the oval window of the right ear.

Figure 8a shows the correlative images of a temporal bone X-ray photograph and its mask combined with the tympano-cochlear scintigrams of another patient suffering from severe, mixed hearing loss and rotatory vertigo attacks. In the scintigrams, the activity enhancement is related to both the entire cochlea and the lateral and anterior semicircular canals. The axial CT (Figure 8b) confirmed the TCS findings regarding both the presence of otospongiosis and the localization of the foci surrounding the cochlea and the anterior and lateral semicircular canals.

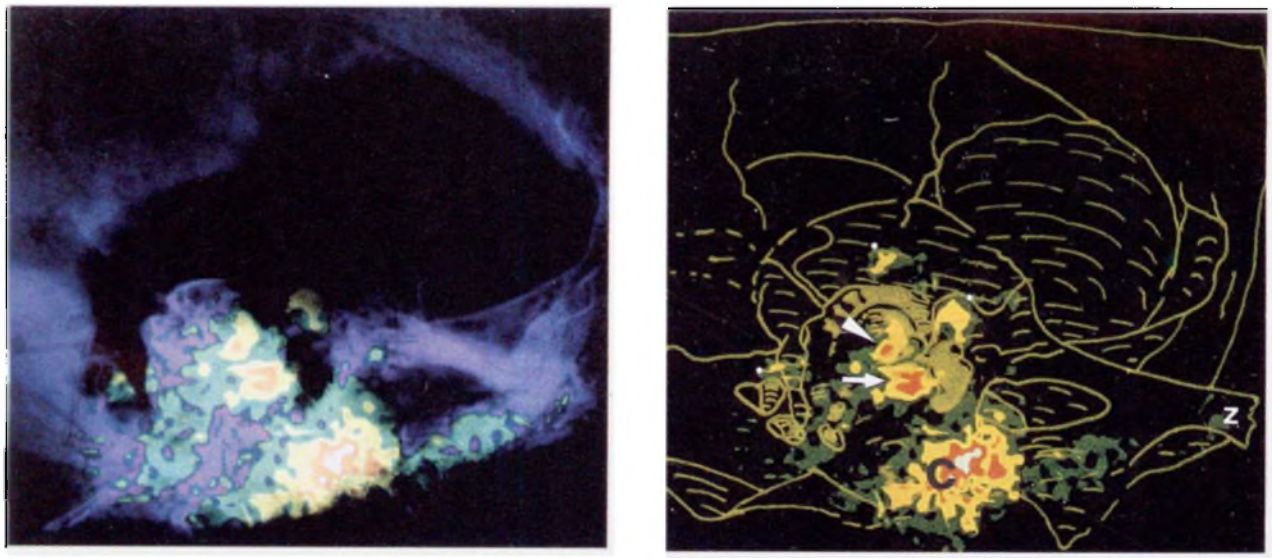


FIG. 5

Correlative imaging of model scintigrams over 10 min. with a conventional X-ray photograph (left) and superimpositon with the corresponding mask (right): The zygomatic process (z) and the clivus region (c) are first recognizable in the native scintigrams after incubation of the temporal bone. With additional marks the facies of the petrous pyramid (points), the lateral semicircular canal (arrowhead) and the oval window (arrow) also become apparent.

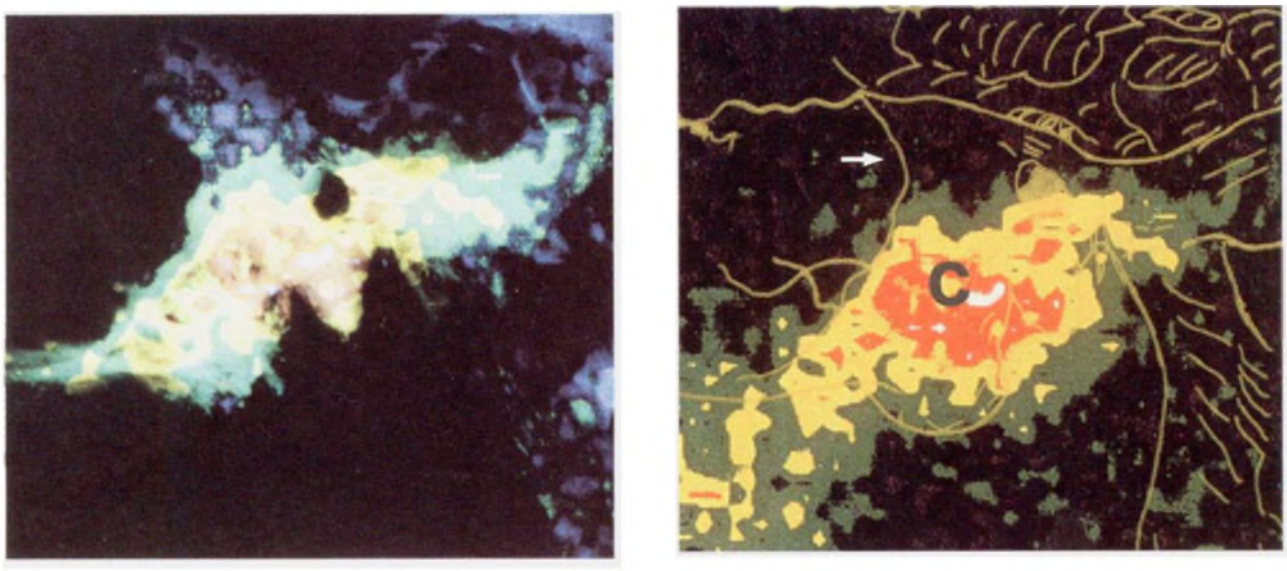


FIG. 6

Normal, clinical TCS finding of the right ear in correlative imaging with a conventional X-ray photograph from a human skull (left) and its mask (right); The region of the petrous bone (arrow) is hardly visible compared to the clivus region (c) and the cervical spine of higher metabolic activity.

Discussion

Apart from high-resolution CT, alterations of labyrinthine bone metabolism due to active otosclerosis, osteogenesis imperfecta or Paget's disease can be visualized by means of tympano-cochlear scintigraphy (Bornemann *et al.*, 1981; Ross *et al.*, 1993). Based on clinical experiences so far tympano-cochlear scintigraphy (TCS) seems to be a useful tool for follow-up studies of the pathological bone metabolism in otospongiotic changes, since the bone uptake of ^{99m}Tc-linked diphosphonates (MDP, DPD) commonly used in bone scanning

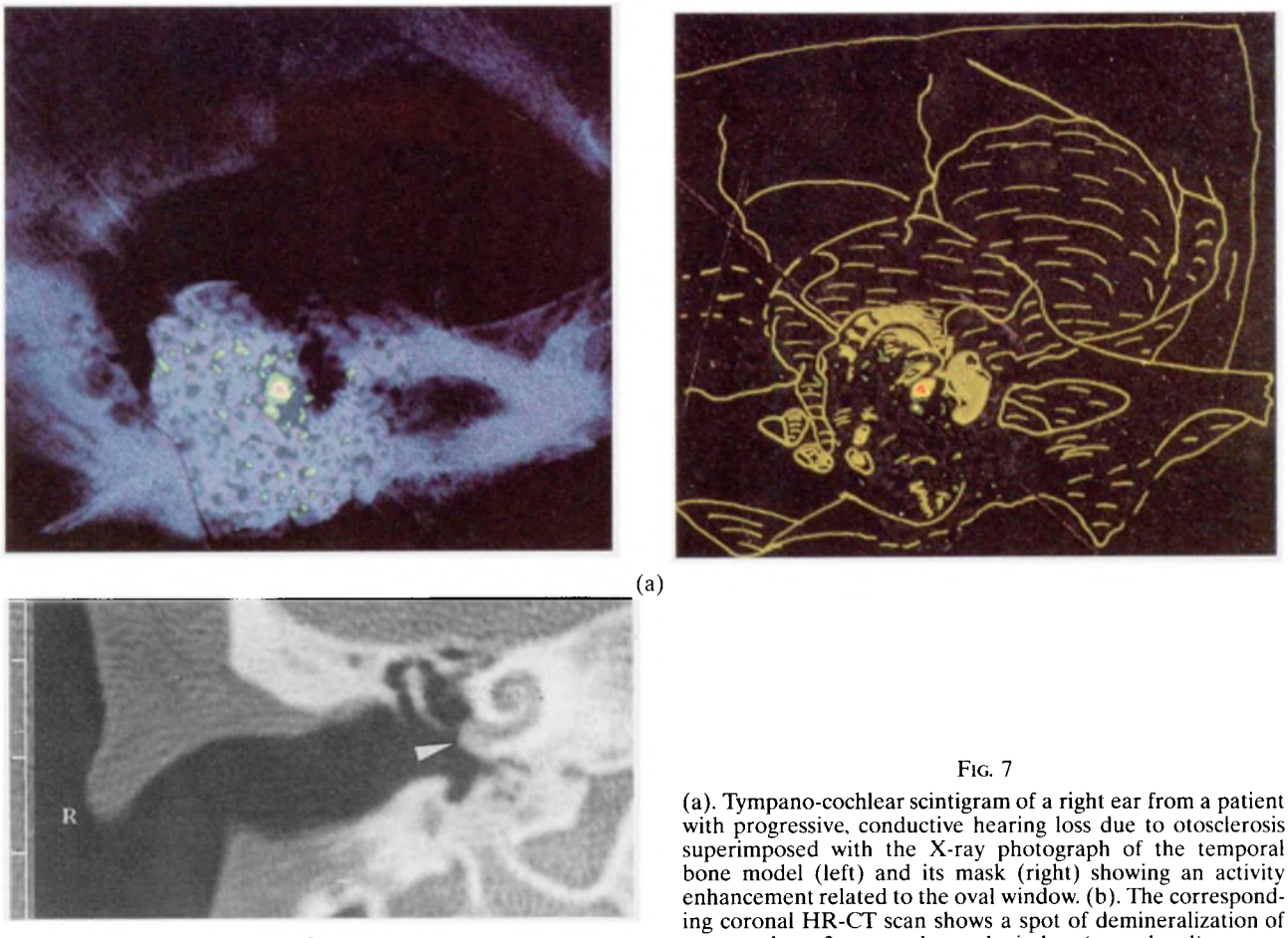


FIG. 7

(a). Tympano-cochlear scintigram of a right ear from a patient with progressive, conductive hearing loss due to otosclerosis superimposed with the X-ray photograph of the temporal bone model (left) and its mask (right) showing an activity enhancement related to the oval window. (b). The corresponding coronal HR-CT scan shows a spot of demineralization of about 3 mm at the oval window (arrowhead).

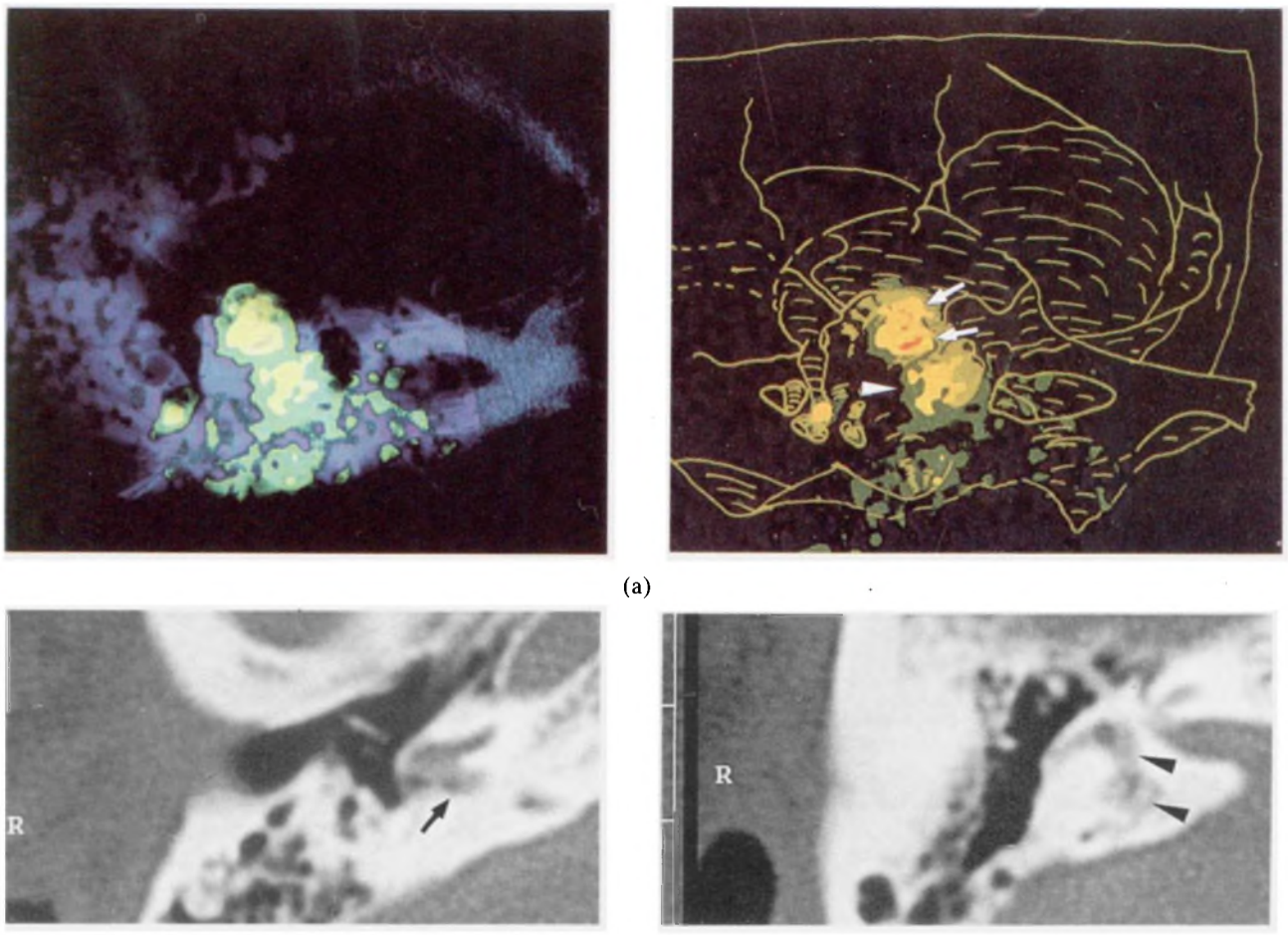


FIG. 8

(a). Correlative images of a tympano-cochlear scintigram (right ear) with the temporal bone X-ray photograph (left) and its mask (right) from a patient suffering from severe, mixed hearing loss and rotating vertigo attacks: The activity enrichment is related to both the entire cochlea (arrowhead) and the lateral and anterior semicircular canal (arrows) as well. (b). The axial HR-CT scan shows severe otospongiosis surrounding the cochlea (left, arrow) and the anterior and lateral semicircular canal (right, arrowheads).

today, mostly depends on the respective calcium-phosphate ratio and the matrix rather than vascularity of the bone. The adsorption of diphosphonates is nearly twice as high in immature, highly hydrated calcium phosphate than in the mature, crystalline hydroxyapatite. There is also a pronounced selectivity of adsorption for the inorganic (mineral) rather than the organic component of the bone (Francis and Fogelman, 1987). Therefore, in our experimental study with TCS, the non-vital temporal bone model could be used to reproduce activity patterns corresponding to the *in vivo* situation.

Chemical characteristics of the above diphosphonates are also the reason for the activity of the clivus region which is mostly pronounced in normal persons (Figure 6) being pushed into the background in presence of an active otosclerotic lesion of an abnormal, immature bone quality (Figures 7, 8).

Since the first reports on TCS in 1981 the activity patterns have until now been only approximately assigned to the labyrinthine structures. The results of our experimental study on TCS indicate that active otosclerotic foci can more precisely be localized by correlative imaging. Using the described pinhole collimator system with tracers of 0.5–1 mm in diameter a spatial resolution of 3–4 mm was achievable.

Clinical application of the visualization technique described here, combining functional with structural images, confirm the experimental results providing a useful method for the detection and localization of small active otosclerotic foci. Besides audiometry and HR-CT, this method can also furnish further parameters for the evaluation of therapeutic results of fluoride treatment in cases of active otosclerosis and may help to determine the optimal time for a stapes operation.

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