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CT and MR imaging after middle ear surgery

Sabrina Kösling [a,*], F. Bootz [b]

[a] *Department of Radiology, Klinik für Diagnostische Radiologie, University of Leipzig, Liebigstr. 20a, D-04103 Leipzig, Germany*
[b] *Department of Otorhinolaryngology, University of Leipzig, Leipzig, Germany*

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Abstract

This article describes the current value of imaging in patients after stapes surgery and surgery after chronic otitis media including cholesteatoma. Possibilities and limits of computed tomography (CT) and MRI are described and most important investigation parameters are mentioned. After otosclerosis surgery, CT is the method of first choice in detection of reasons for vertigo and/or recurrent hearing loss in the later postoperative phase. CT may show the position and condition of prosthesis, scarring around the prosthesis and otospongiotic foci. Sometimes, it gives indirect hints for perilymphatic fistulas and incus necrosis. MRI is able to document inner ear complications. CT has a high negative predictive value in cases with a free cavity after mastoidectomy. Localized opacities or total occlusion are difficult to distinguish by CT alone. MRI provides important additional information in the differentiation of cholesterol granuloma, cholesteatoma, effusion, granulation and scar tissue.

Keywords: Middle ear; Imaging; Mastoidectomy; Stapes surgery

1. Introduction

Middle ear surgery can be subdivided into three main types of procedures based on the underlying diseases. The most common indication of stapes surgery is otosclerosis. Mastoidectomy and reconstruction of ossicular chain were mostly performed because of chronic otitis media including cholesteatoma. Other indications are mastoiditis, tumor of the middle ear, translabyrinthine approach in acoustic neurinoma surgery, exposition of facial nerve in trauma, cochlear implantation and endolymphatic sac surgeries. The third main type is surgery for hearing improvement in malformation of the middle ear and/or external auditory canal. The aim of this article is to represent the current value of computed tomography (CT) and MRI in patients after stapes surgery and surgery because of chronic otitis media.

2. Imaging technique

Imaging of very small middle ear structures demands a high local resolution. The use of thin slice thickness is a basic demand on a high image quality for both CT and MRI. High reconstruction algorithms has to be used in CT. At present, the best image quality is obtained by multislice CT with collimation and slice thickness of 0.5 mm. All bony details including small canals, sutures and stapedial substructures can be visualized. Small increment of 0.3 mm is the prerequisite to get excellent multiplanar reconstruction (MPR). Coronal scanning is not necessary anymore. In single slice and spiral CT the slice thickness should not be beyond 1.5 mm. For the differentiation of opacities and processes exceeding the middle ear, T1- and T2-weighted MRI information is needed. Whereas inner ear structures can be excellently visualised by strong T2*-weighted sequences (3-DFT-CISS, for example) turbo-spin-echo T2-weighted sequences or T2-weighted gradient-echo sequences with lower contrast are more suitable for the analysis of middle ear processes. In MR imaging of the middle ear, slice thickness should be 2–3 mm for T2-weighted sequences and 2 mm for T1-

* Corresponding author. Present address: Martin-Luther Universitat Halle-Wittenberg, Klinik fur Diagnostische Radiologie, Ernst-Grube-Str. 40, D-06097 Halle, Germany. Tel.: +49-345-557-2441.
E-mail address: sabrina.koesling@medizin.uni-halle.de (S. Kösling).

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weighted sequence. T1-weighted images without and with contrast medium are mandatory to detect lesions with high precontrast signal intensity (cholesterol granuloma, fluid with high protein concentration, bleeding, fatty tissue) and to get information about the vascularization of a process. Thin T1-weighted spin-echo images are considered as state of the art. Lesions can be better analyzed if T2-weighted, precontrast and postcontrast T1-weighted images have the same orientation. A second mostly coronal plane have to follow for better spatial assignment. Recently, it is tried to get a better differentiation especially between cholesteatomas and other middle ear inflammations by diffusion-weighted imaging (DWI). By DWI, lesions with normal and disturbed diffusion of water molecules are distinguishable. The disadvantages of DWI of the temporal bone are the limited spatial resolution and artifacts of the skull base.

3. Imaging after stapes surgery

Microsurgical treatment of otosclerosis includes stapedectomy and stapedotomy. The latter is considered as the method of choice because of better hearing results and less postoperative vertigo and nystagmus [1,2]. In stapedotomy, stapes suprastructure is resected and the footplate is perforated. The piston of the prosthesis is placed into the perforation of footplate and the loop of the wire is crimpted over the long process of the incus. The material of inserted prostheses changed over the years. Today mostly prostheses consist of a platinum wire and a teflon piston or are entirely made of gold (Fig. 1).

Each stapedioplasty has a risk of damaging inner ear structures [3]. A progressive loss of inner function within the early postoperative phase is a clear indication for surgical revision independent on imaging results if it would be performed. Vestibular symptoms were observed in about two thirds of patients within the first postoperative week [3]. Usually they clear spontaneously or under conservative therapy. Imaging seldom

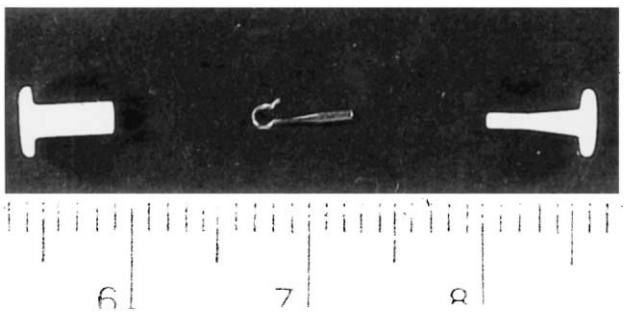

Fig. 1. Usual prostheses from left to right: PORP, stapes prosthesis, TORP.

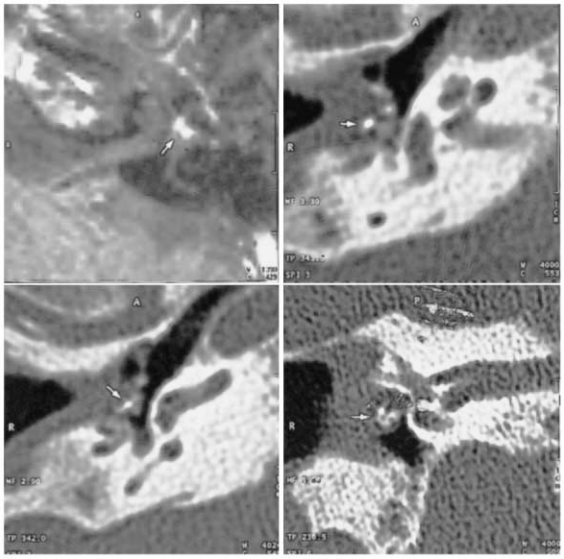

Fig. 2. Two patients with acute facial nerve palsy after middle ear surgery within the first postoperative week. Upper line left: a patient after stapedotomy because of otosclerosis (CT, not shown, documented a correct position of the prosthesis). Axial postcontrast T1-weighted image shows strongly enhancing inflammatory tissue in the oval window contacting the facial nerve (arrow). Intraoperatively, the bony canal was partially damaged. Symptoms cleared under conservative therapy. Upper line right, lower lines: a patient after mastoidectomy and insertion of PORP because of chronic otitis media. Two axial and one coronal CT scans show a dislocation of PORP (arrow) contacting the second knee of the facial nerve. CT finding was confirmed by retympanotomy.

is needed in this period. A relative indication is given in acute facial nerve palsy that is a very seldom postoperative complication. As possible cause CT can reveal a dislocation of prosthesis. With this information the indication for reoperation can be supported. Only MRI is able to demonstrate acute inflammatory tissue near the facial nerve as further possibility (Fig. 2). Such cases were treated conservatively.

Five to eight percent of patients show persistent or recurrent vertigo after stapes surgery [2,4,5]. Often recurrent vertigo occurs suddenly and it is accompanied with recurrent hearing loss. With each reoperation the risk of damaging inner ear structures increases. Clinical tests can find objective symptoms of vestibular and/or hearing disorders but not actual causes. Medico legal causes are another point. Today most patients want to have sophisticated investigations done to reveal the causes of their symptoms with a high security before they agree to a reoperation. Imaging can demonstrate in a high percentage the causes of symptoms as hearing loss and vertigo [3,5,6]. Thus it makes the consultation with the patient easier.

The imaging method of first choice is CT in the later postoperative period [6]. Axial and coronal plane are mandatory. CT clearly reveal dislocation of the prosthesis (deep dip into the vestibule, no contact with the

oval window), scarring around the prosthesis, fracture of prosthesis and extent of otospongiotic foci (Fig. 3). On coronal images an incus necrosis can be suggested as late complication (Fig. 3). The main causes of vertigo are dislocation of prostheses into the vestibule and perilymphatic fistulas. An air bubble at the end of the prosthesis is an indirect sign of a perilymphatic fistula (Fig. 4). Intraoperatively introduced air has to be resorbed at that time of imaging. In an own study all suggested perilymphatic fistulas were confirmed by retympanotomy [6]. It cannot be expected that there is always air in the vestibule in each perilymphatic fistula but when it is found it is a clear sign. In gold prostheses, the detection of an air bubble can be difficult because they make more artifacts than prostheses from platinum and teflon. Strongly disturbed tubal ventilation can cause a deep dip of the prosthesis into the vestibule and may lead by that to vestibulocochlear symptoms. After years cochlear otosclerosis may develop in patients that had only stapes fixation at the time of operation. Such patients develop a progressive sensorineural hearing loss. On CT demineralization of the otic capsule has been proved as a sign of cochlear otosclerosis [7].

If CT cannot clear the symptoms especially in deaf ear, MRI should follow. Modern prostheses are not a contraindication for MRI [8]. Most patients with otosclerosis do not have any signs of inflammation. Occasionally granulation tissue develops as reaction to foreign material. It may spread into the inner ear and via the fundus of the internal acoustic meatus into the intracranial space. Only MRI can outline the whole extension of the disease. Furthermore, MRI can visualize fibrous obliteration of the labyrinth.

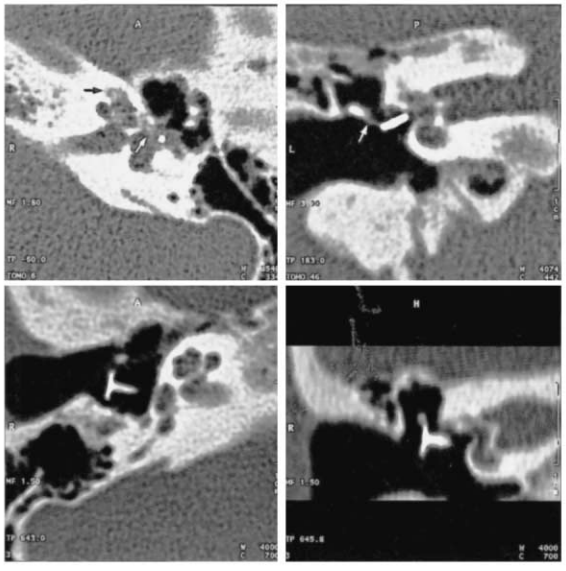

Fig. 3. Three patients with hearing loss after stapes surgery. Upper line left: a patient after stapedotomy because of otosclerosis and progressive combined hearing loss. Axial CT shows cochlear (black arrow) and fenestral (white arrow) otospongiotic foci. The position of the prosthesis is correct. Upper line right: a patient after stapedotomy because of otosclerosis and conductive hearing loss. Coronal CT shows a thinning of long process of incus (arrow). An incus necrosis was suggested. CT finding was confirmed by retympanotomy. Lower lines: a patient after insertion of TORP because of stapes aplasia. Axial CT and coronal MPR show TORP without contact to the oval window.

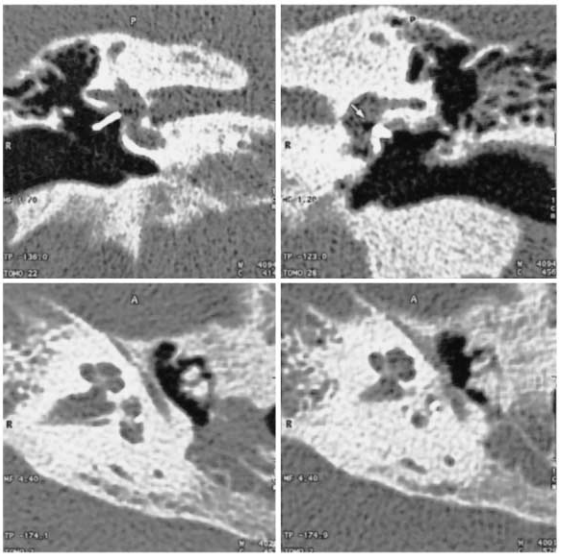

Fig. 4. Two patients with vertigo after middle ear surgery. Upper lines: a patient after bilateral stapedotomy because of otosclerosis. Left: coronal CT shows a correct position of the prosthesis. Right: coronal CT shows a small air bubble at the end of the prosthesis (arrow) as an indirect sign of a perilymphatic fistula. CT finding was confirmed by retympanotomy. Lower lines: a patient after mastoidectomy and insertion of TORP because of cholesteatoma. Two axial CT scans show a dislocation of the prosthesis into the vestibule by recurrent inflammatory tissue and a partial ossification of labyrinth.

4. Imaging after mastoidectomy and tympanoplasty

Dependent on the extent of cholesteatoma two main types of surgical procedures can be differentiated: the open (canal-wall-up) and closed (canal-wall-down) technique of mastoidectomy. In contrary to the closed technique, the posterior wall of the external auditory canal is removed in open technique and a communication between the mastoid cavity and external auditory canal is established. The incidence of recurrence is about 3% in open technique and up to 18% in closed technique [9]. Five different types of tympanoplasty were distinguished in the past [10]. Today mainly type I and III were performed. Type I refers to a closure of a perforation in the tympanic membrane. If ossicles are eroded type III reconstruction is performed to preserve ossicular continuity. Different prostheses may be used for ossicular replacement (Fig. 1). In partial ossicular replacement prosthesis (PORP), the prosthesis rests on the head of stapes and attaches to the tympanic mem-

brane. Total ossicular replacement prosthesis (TORP) is inserted if the head and crura of stapes are missing. The prosthesis is placed onto the footplate. Incus and malleus may be resected. PORP and TORP are made from hydroxyapatite, polytetrafluroethylene-vitreous carbon (Proplast I), polyethylene sponge (Plastipore), titanium and gold [11]. With exception of type I tympanoplasty, CT has been proven to excellently visualize the different surgical middle ear procedures and prostheses (Fig. 5) [10,11].

Whereas there are contrary opinions about the necessity of preoperative crossectional imaging in chronic middle ear inflammation including cholesteatoma postoperative imaging is established [12–14]. In non-operated patients, the diagnosis of a secondary cholesteatoma is clinically evident in over 90%. Especially in closed technique, the diagnosis of recurrence is often difficult. Recurrence of cholesteatoma requires a reoperation in any case. In chronic otitis media, revision surgery is not always necessary.

CT has been proven as method with a high negative predictive value when it shows a free cavity [15]. If opacities are found CT may demonstrate erosions of the wall of mastoid cavity, ossicles and semicircular canals (Fig. 6). In CT, the analysis of the margin of opacities helps sometimes in the further differentiation (Figs. 5 and 6) but MRI can provide a better differentiation. Cholesterol granuloma has a high signal intensity in all sequences and do not enhance. Granulation tissue

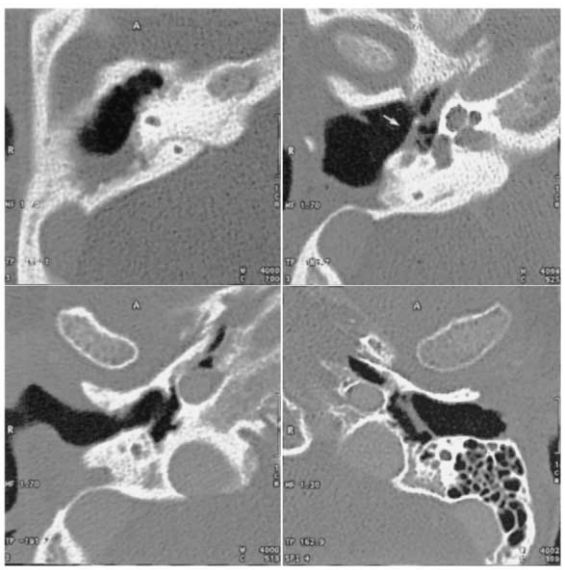

Fig. 5. Upper lines, lower line left: a patient with open cavity and tympanoplasty type III because of cholesteatoma. Three axial CT scans show completely resected mastoid, resected posterior wall of external auditory canal and peripheral scar tissue. Incus and malleus were resected. The tympanic membrane was connected to the stapes (arrow). Lower line right: a patient after tympanoplasty type I. Axial CT shows a thickened double-layered tympanic membrane. Incidental finding.

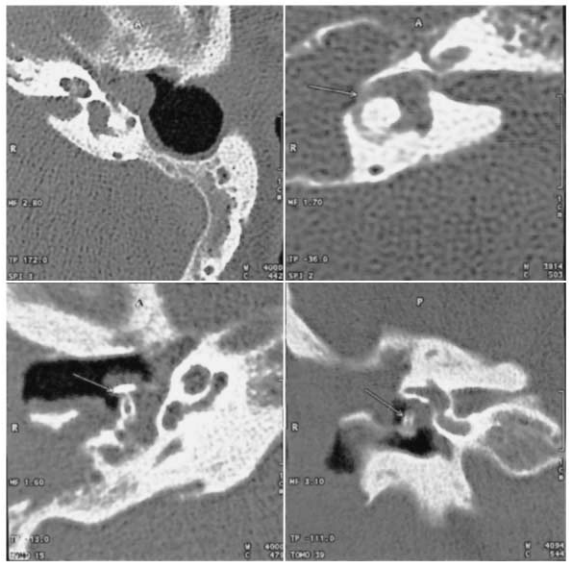

Fig. 6. Three patients after mastoidectomy because of cholesteatoma. Upper line left: axial CT shows a convex opacity at the medial tympanic wall, that might be a recurrent cholesteatoma, cholesterol granuloma or inflammatory polyp. Intraoperatively, it was a cholesteatoma. Upper line right: the diagnosis of cholesteatoma was clinically evident. The patient suffered from acute vertigo. Axial CT shows a total opacity and erosion of lateral semicircular canal (arrow). Intraoperatively, a huge cholesteatoma and granulations were found. Lower lines: axial and coronal CT show a dislocation of PORP (arrow) due to recurrent inflammation.

and inflammatory mucosa are hyperintense on T2-weighted images and have an intermediate or hypointense signal on precontrast T1-weighted images. The similar appearance may have cholesteatomas and scars, but granulation tissue shows a strong enhancement, cholesteatomas only a rim of enhancement and scars a poor enhancement. New studies documented a high accuracy in the diagnosis of cholesteatoma by DWI [16,17]. High signal intensity was seen in cholesteatoma, all other middle ear tissues should have low signal intensity [18]. In the own patient population also cholesterol granuloma had a high signal intensity on DWI but it can be differentiated from cholesteatoma by means of other sequences (Fig. 7). The appearance of malignancies as possible differential diagnosis can not be documented at present. Due to limited local resolution small cholesteatomatous masses may be undetectable by MRI and thus make it a less valid alternative to second look operation in cholesteatomas at present [17,19,15,20]. MRI is clearly superior in other complications after middle ear surgery as meningoencephalocele and sinus thrombosis. MRI can detect an extension of cholesteatoma into the middle or posterior cranial fossa whereas a dural perforation never occurs.

Sometimes tympanoplasty type I is seen on CT (Fig. 5). Usually, it is an incidental finding. Different kinds

of tympanoplasty type III are well demonstrable. Dislocation of prostheses occurs often in combination with recurrence of inflammation (Fig. 6). In the early postoperative phase, a dislocated prosthesis may cause an acute peripheral facial nerve palsy (Fig. 2).

5. Conclusion

Crossectional imaging is of high diagnostic value in the postoperative middle ear. Within the first week after stapes surgery most symptoms clear spontaneously or with conservative therapy. If progressive loss of inner ear function occurs, a clear indication for retympanotomy is given. Imaging is not needed in this period. CT should be chosen in symptomatic patients in the late postoperative phase at first. In a high percentage the cause of symptoms is detectable. MRI provides additional information in selected cases. Due to low late complication rates, unnecessary radiation exposition and economic reasons we cannot recommend routine CT after stapes surgery.

A high recurrence rate and worse conditions for clinical investigation emphasizes the need of safe noninvasive diagnostic method after closed technique in cholesteatoma surgery. Only if the cavity is free imaging can be restricted to CT. In opacities, MRI should be additionally performed because for their differentiation and for estimation of the extension of the disease.

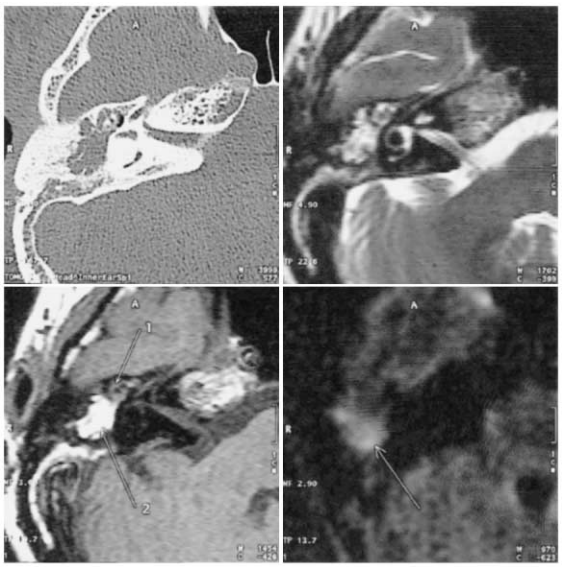

Fig. 7. A patient after middle ear surgery because of chronic otitis media. Upper line left: axial CT shows a nearly complete filling of the epitympanum and antrum. Upper line right: on axial T2-weighted image, this region has a high signal intensity. Lower line left: on precontrast axial T1-weighted image, there are two different signal intensities: a smaller hypointense area (1); and a strong hyperintense area (2). Postcontrast T1-weighted image, not shown, had a similar appearance. Lower line right: axial DWI ($b = 1000$, 3 mm slice thickness) shows a hyperintensity of the area 2 (arrow). A hyperintensity of area 1 could not be recognized. The high signal on T1-weighted and T2-weighted images corresponds to a cholesterol granuloma. Intraoperatively, a cholesterol granuloma (area 2) and a cholesteatoma (area 1) of about 8 mm were found.

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