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Adult progressive sensorineural hearing loss: is preoperative imaging necessary before cochlear implantation?

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Abstract

Objective—Pre-operative evaluation of cochlear implant candidate includes routine imaging in order to identify anatomic abnormalities that may preclude or complicate implantation, such as cochlear aplasia, absent/narrowed internal auditory canals, cochlear ossifications, or significant traumatic fracture. The aim of this study is to determine if preoperative imaging is necessary in select cochlear implant candidates thus defraying cost and ionizing radiation.

Study Design—Retrospective chart review.

Setting—Tertiary referral facility.

Patients—Adult patients with progressive sensorineural hearing loss without evidence of head trauma, meningitis, or congenital hearing loss who underwent cochlear implantation.

Interventions—Diagnostic and Therapeutic.

Main Outcome Measures—Pre operative radiologic abnormalities, deviation from standard cochlear implant operation.

Results—118 cochlear implants met inclusion criteria. 23.7% of CT scans had a documented abnormality, including chronic otitis media (14.4%), otosclerosis (4.2%) and an enlarged vestibular aqueduct (3.4%). There were 6 eventful surgeries in patients with normal documented CT scan. Events included multiple insertion attempts (3.4%), CSF leak (2.5%) and no apparent round window (2.5%). In every case, a cochlear implant was able to be placed successfully.

Conclusion—In the appropriately selected patient, pre-operative imaging is not necessary as it does not impact the cochlear implant surgery and will defray cost and ionizing radiation

Keywords

Cochlear implantation; Pre-operative imaging; Sensorineural hearing loss

Introduction

Cochlear implantation is one of the greatest advances of biomedical engineering that has revolutionized treatment of deafness. Appropriate patient selection and pre-operative evaluation is necessary prior to implantation and typically involves otolaryngologic, audiologic and radiographic assessments (1–3). Standard of care for pre-operative assessment involves imaging with CT or MRI to assess for congenital or acquired temporal

bone pathology as well as any anatomic abnormalities that might preclude normal surgical technique and successful implantation. Such conditions include cochlear ossification or fibrosis (2,5), chronic otitis media (10–14) cochlear malformations, and internal auditory canal anomalies (1).

Congenital abnormalities, infections such as meningitis, and head trauma may result in abnormalities detectable on imaging studies. Knowledge and visualization of pathologic lesions of the temporal bone through radiographic studies may profoundly affect the surgical plan and may even change the ear to be implanted. Cochlear aplasia and a narrow internal auditory canal are specific congenital abnormalities that may preclude cochlear implantation (3). Meningitis can cause varying degrees of intracochlear fibrosis and ossification and complicate implantation; therefore, pre-operative imaging can be useful in surgical planning. One study found that the prevalence of ossification of the cochlea in meningitis patients at the time of surgery was 78% (2). Temporal bone fractures and hemosiderosis from trauma can also cause deafness with radiographic findings that could complicate surgical intervention with a cochlear implant (4).

There are many cochlear implant candidates that have a history of bilateral progressive sensorineural hearing loss without a history of congenital deafness, meningitis, or head trauma. Although there is no question whether children with deafness would need a pre-operative imaging assessment to assess for congenital abnormalities, adults with progressive bilateral sensorineural hearing loss may not need imaging prior to implantation thus defraying cost and exposure to ionizing radiation. The purpose of this study was to investigate a series of non-pediatric cochlear implant patients with progressive hearing loss and their pre-operative imaging studies to determine if this imaging was necessary and/or played a role in cochlear implant surgical planning and intraoperative technique.

Methods

The Institutional Review Board approved this study and the review of medical records pertaining to this study. The medical records of all patients receiving cochlear implants at the University of Kentucky between 1989 and 2011 were reviewed. We considered each cochlear implant separately. That is to say, those patients who underwent bilateral implantation, each ear was considered a separate case. All children, defined as age less than 21, were excluded from the study. Additionally, patients were excluded for having incomplete charts which included lack of radiology available for review, missing audiograms and/or operative reports. Patients with progressive symmetric sensorineural hearing loss demonstrated by audiogram and history who underwent pre-operative CT scan of the temporal bone only for the purpose of routine pre-operative imaging were included. Patients with congenital hearing loss, mixed hearing loss or hearing loss of a sudden onset were excluded. Patients with hearing loss secondary to temporal bone fracture or meningitis were excluded. Patients with a history of progressive hearing loss that developed following an episode of meningitis were also excluded. Patients with a significant degree of subjective tinnitus or asymmetric hearing loss defined as greater than 10dB asymmetry across 3 consecutive frequencies, 15dB in 2 consecutive frequencies, or 20dB in one frequency and/or marked differences in speech discrimination between the two ears were not included

as these patients were advised to undergo MRI to rule out retrocochlear pathology and that imaging was used as their pre-operative imaging. Patients were not excluded from this study if they had abnormal otoscopic findings or previous otologic surgery.

Demographic data including age at implantation, gender, brand of implant and side of surgery were recorded. Bilateral progressive hearing loss was determined by patient/family history and/or sequential audiograms. All procedures were performed by the same surgeon. Non-contrasted CT scan of the temporal bone was used as the standard imaging modality in this group of patients during the study and the scan and the report were examined for each patient in the study. Radiology report findings were recorded as normal or abnormal studies. A description of the abnormality was described and recorded. The operative report and clinical notes were reviewed for each patient to determine if any alteration of surgical technique or abortion of the procedure occurred.

All statistical analysis was performed using GraphPad Statistical Software (GraphPad Software, INC, La Jolla, CA, USA). A two-tailed Fisher's Exact Test was used to compare eventful, uneventful surgeries, abnormal and normal scans.

Results

Chart review resulted in 362 cochlear implants performed at the University of Kentucky between 1989 and 2011. Of these 362 cochlear implants, 120 implants were excluded secondary to being implanted in children. Of the 242 adult implants remaining, an additional 45 implants did not have radiology available for review, complete operative notes or audiograms, and were excluded. A remaining 79 implants were excluded because they were implanted in patients with sudden sensorineural hearing loss or after episodes of meningitis. This resulted in 118 implants that met inclusion criteria. All demographic data is demonstrated in Table 1. The study was nearly perfectly split in regards to gender and implant manufacturer. The average age of implantation was 56.9 years old.

Of the 118 CT scans, three major temporal bone pathology categories were demonstrated. This included evidence of chronic otitis media (COM) in 14.4%, otosclerosis in 3.4% and enlarged vestibular aqueduct in 3.4%. These results are in Table 2. Of the 17 radiologic reports consistent with evidence of chronic otitis media, the findings included middle ear opacification, mastoid opacification, atelectatic middle ear space, and previous mastoidectomy. Cochlear implantation that was performed in these patients occurred without event or complication. The only intraoperative variations included a fat myringoplasty at the time of implantation in a patient with a residual tympanic membrane perforation and high implant impedances during intraoperative testing in another patient. A group of 4 patients had radiographic evidence of otosclerosis. 2 patients had previously undergone stapedotomy and had prostheses in place. Of these, there was preoperative radiographic evidence of round window obliteration in one patient and this was confirmed intraoperatively. A cochleostomy was drilled without complication and an implant was placed without difficulty. There were no cases of severe obliterative cochlear otosclerosis in this series of patients. A third group consisting of 4 patients had radiographic evidence of enlarged vestibular aqueducts on imaging studies. Of these, one patient had preoperative

selection in the surgical site to the side with less enlargement of the vestibular aqueduct based on the CT findings. Of the 118 patients, this was the only patient that had their site of surgery changed based on CT findings. This represents 0.85% of the total group. In 6 months post-implantation period, no subject had device extrusion or malfunction and there is no evidence of meningitis or surgical complication. All patients had successful subsequent activation implant performance was satisfactory.

Five other imaging studies were read as abnormal but represented alterations of normal anatomy and suspected middle ear pathology. The CT imaging findings included: dehiscent facial nerve, dehiscent jugular bulb, hypoplastic horizontal semicircular canals, asymmetric internal auditory canals, ossicular malformation or absence, a mass overlying the jugular bulb suspicious for glomus tumor. All patients within this group underwent uneventful surgeries and the suspected glomus tumor in the one patient turned out to be a mucosal cyst.

91 CT scans were read as normal. There were 7 eventful surgeries in this group. 3 people had CSF leaks, one of these occurred during the creation of the well for the implant. The CSF leaks were all controlled intraoperatively and there no further complications. Other complications included multiple insertion attempts and absence of a definite round window. An implant was successfully placed in both of these cases as well.

Out of 118 total patients, 11 had eventful surgeries. 7 of these events occurred in patients with normal scans, 4 with abnormal. Contingency table of this data is available in Table 3. Fisher's exact test yields a two-tailed p value equal to 0.2713, indicating that there is no statistically significant association between eventful surgeries and pre-operative CT scan findings.

Discussion

Cochlear implantation offers immense rehabilitative potential for patients with severe hearing loss. As technology has progressed and safety information has been documented, the indications for cochlear implantation have vastly expanded and this will likely continue into the future. Candidacy is determined, in part, by the presence and patency of the cochlea as demonstrated on radiographic studies. Also, this imaging can alert the surgeon to anatomic variants in the temporal bone as well as insidious pathologic processes. Imaging studies can clearly inform the surgeon to impending difficulty or complication and may affect patient care, however mandatory radiographic studies in all patients regardless of clinical history may not be cost effective. This study demonstrates that cochlear implantation in adult patients who develop progressive post-lingual hearing loss is rarely altered by pre-operative imaging studies.

Clearly, imaging in cochlear implant candidates is a vital component of the preoperative evaluation in many patients. Children with congenital hearing loss should always have imaging performed as anatomic malformations are possible and identification of malformations may alter the side of surgery and even candidacy (1–3). Even adults that have a history of congenital hearing loss regardless of severity could potentially benefit from imaging. There are some important considerations also in the setting of pediatric hearing

loss that delayed in presentation in late childhood and adolescence. One may argue that an 18 year old with progressive SNHL that has met implant criteria is quite different from the 75 year old with progressive SNHL and may raise the concern for obtaining pre-operative imaging. There wasn't any evidence in our study that indicated that the imaging changed the plan or technique significantly; however, the majority of the patients in this study were older patients (mean of 56.9) and further investigation is warranted to investigate if imaging findings affects implantation in younger adult patients and in adolescents. Adults with sudden hearing loss, whether traumatic or idiopathic, and those with significant asymmetries in pure tone audiometry or speech discrimination may need imaging to look for an etiology of the hearing loss. This has the potential to alter surgical technique or side of surgery.

Cochlear implantation in patients with chronic otitis media represents a challenging situation. Patients with asymptomatic chronic mucoid or serous effusion or thickened mucosa in the mastoid and/or the middle, as were identified in our study, are relatively insignificant in implantation; however, many surgeons rightfully would be concerned about placing an implant in an infected field. This increases the potential for complications such as implant extrusion and meningitis (11–15). Gray and Irving presented a small case series in which patients with chronic suppurative otitis media and draining ear were treated with a staged procedure. First, a radical mastoidectomy was performed, the eustachian tube was plugged and the ear canal was obliterated. 6 mos later, a cochlear implant was placed (11). A study with mean of 7.05 years of long term follow up in patients who also underwent a 2 stage procedure, but without plugging of the Eustachian tube yielded good results without device extrusion or serious complications (12). Another case series presented 9 patients with COM and 8 of these patients had simple perforation or previous mastoidectomies. Patients with dry perforations underwent staged myringoplasties followed by cochlear implantation. The patients with cholesteatoma-free canal wall down mastoid cavities underwent obliteration and placement of the cochlear implant. The one patient with cholesteatoma underwent a staged procedure with oblitative mastoidectomy, blind sac closure of the external auditory canal and secondary implantation. No major complications were observed at 18 month follow-up (15). In all of these patients with a history of chronic suppurative otitis media with or without cholesteatoma, imaging is vital for planning surgical technique and even the side of surgery. No patients with chronic suppurative otitis media were identified in this study but radiographic evidence of COM was demonstrated in 14.4% of the patients. All surgeries proceeded in an uneventful manner per the operative reports and no patient required a staged procedure. None of our patients had physical exam findings of drainage or cholesteatoma as present in the other case series mentioned. Only one patient required fat myringoplasty for a dry perforation. No patient has had extrusion of their device or meningitis.

Otosclerosis, another cause of progressive hearing loss in adulthood can be radiographically evident and present surgical challenges. Previous studies have reported that the sensitivity of high resolution CT imaging in detect otosclerosis is between 71–78% (16,17). In a case series of nine patients, ossification of the round window was evident on imaging in 4/9 patients. Intraoperatively, 8/9 patients demonstrated ossification of the round window. In 1/3 of patients the scala tympani was partially ossified. In all of these cases, the fluid filled scala tympani was able to be identified and an implant was placed without difficulty(18). In our

series, one patient with normal imaging study had evidence of round window ossification. Only one patient with otosclerosis identified on imaging demonstrated intraoperative findings of no definite round window. In every case, an implant was able to be placed successfully. Even though no complications were encountered, considering the potential of ossification, pre-operative imaging in patients with otosclerosis should be performed. Additionally, patients with a mixed hearing loss who are cochlear implant candidates should also undergo imaging as otosclerosis may be hearing loss etiology.

An enlarged vestibular aqueduct is an anatomic abnormality associated with progressive sensorineural hearing loss that usually begins in childhood. This abnormality can occur in conjunction with other cochleovestibular malformations such as Mondini deformity and patients with these malformations may experience CSF gusher during cochlear implantation. Despite this, implantation can often occur without difficulty and CSF leakage can be controlled with packing. An enlarged vestibular aqueduct is not a reason to avoid implantation (18). An enlarged vestibular aqueduct was present in four of our patients in this series. The side of surgery was changed secondary to this finding in one patient. This implant was one of the first performed at our center and this choice was based on surgeon preference to minimize the potential of CSF leakage.

Recently, there has been increasing concern over the impact of ionizing radiation that is received from radiographic studies. Radiation of all types, including radiation from radiographic imaging, can increase the risk of developing cancers. CT temporal bones, in particular, can also increase the risk of cataracts (6–9). The average radiation dose from one CT temporal bone with a normal acquisition algorithm is 49.9mGy (8). The lens of the eye which is often caught in the radiation field for a CT temporal bone is one of the most radiosensitive organs in the body. It has been shown that cataracts can form at 0.10Gy (9), which is essentially the radiation dose from two CT temporal bone studies using a normal acquisition protocol. There have been studies performed that show a significant decrease in radiation exposure to the lens. One study from a group in China demonstrated a 74.3% reduction in radiation exposure to the lens with a modified acquisition technique with axial, coronal and sagittal reformatting (19). While this is a significant reduction, revised protocols do not completely eliminate radiation exposure to the lens. Given the potential for exposure over a lifetime, it is important to consider ways to eliminate even the smallest dose of unnecessary radiation.

This study examined the imaging and clinical history of 118 adult patients with post-lingual hearing loss that was progressive in nature. All but 1 patient underwent implantation according to the standard technique without alteration of technique or side of surgery. The 1 patient had their surgical site changed but only based on surgeon preference and not due to definite radiographic contraindications. Currently, the charge for a CT scan of the temporal bone without contrast in our institution without hospital charges or interpretation is approximately \$480. In this era of healthcare resource conservation we may be able to develop more cost-effective protocols. We have developed an algorithm that we plan to investigate in further prospective studies when considering pre-operative cochlear implantation imaging (Figure 1). Certainly, if any suspicion is raised for temporal bone pathology or if the clinical history is unknown then imaging should be performed. This

study, as well as, the algorithm is based on the current retrospective data, which is a significant limitation. A subsequent prospective controlled trial is recommended to determine if a proposed protocol such as this could be cost-effective and avoid unnecessary imaging studies.

Conclusion

Radiographic assessment has been a cornerstone in the evaluation of cochlear implant patients. While there is no question that children, those with congenital hearing loss, and those with specific disease processes need imaging to assist with surgical planning, adult patients with post-lingual progressive hearing loss may not need such measures. In the properly selected adult patient with progressive sensorineural hearing loss without history of meningitis or trauma, an imaging study may not be necessary. In the presented series, all 118 patients were able to be implanted successfully and the imaging results did not affect surgical planning or intraoperative surgical technique.

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Figure 1.

Table 1**Demographics**

Age (at implant)	
Range (yrs)	21–90
Mean (yrs)	56.85
Median (yrs)	55.5
Sex	
Male	58
Female	60
Device	
Cochlear	59
Advance Bionics	59
Side of Implant	
Right	60
Left	58

Table 2**Radiographic and Surgical Pathology in Cochlear Implant Patients**

	Number of Patients	% of Total (118)
Abnormal Temporal Bone Pathology	28	23.7
Chronic Otitis Media	17	14.4
Middle ear pathology	4	3.4
Mastoid opacification	9	7.6
Atelectatic Middle ear	2	1.7
Previous Mastoidectomy	2	1.7
Otosclerosis	5	4.2
Previous Stapedectomy	2	1.7
Enlarged Vestibular Aqueduct	4	3.4
Other	2	1.7
Dehiscence CN VII, jugular bulb	1	.8
Assymetric IAC	1	.8
Surgical Events	11	9.3
CSF leak	3	2.5
Well site	1	.8
Cochleostomy	2	1.7
Multiple Insertion	4	3.4
No apparent round window	3	2.5
Fat Myringoplasty	1	.8

Table 3

Correlation of Radiographic Abnormalities and Cochlear Implantation Complications

	Normal CT	Abnormal CT	Total
Surgery			
Uneventful	90	28	107
Eventful	6	5	11