

***Middle ear implant
for sensorineural,
conductive and
mixed hearing losses***

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MSAC application 1137

Assessment report

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The Medical Services Advisory Committee (MSAC) is an independent committee which has been established to provide advice to the Minister for Health and Ageing on the strength of evidence available on new and existing medical technologies and procedures in terms of their safety, effectiveness and cost-effectiveness. This advice will help to inform government decisions about which medical services should attract funding under Medicare.

MSAC's advice does not necessarily reflect the views of all individuals who participated in the MSAC evaluation.

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Executive summary

The procedure

Middle ear implants (MEI) are surgically implanted electronic devices which aim to correct hearing loss through stimulation of the ossicular chain or middle ear (Manrique et al 2008). MEI are placed into the middle ear and generally leave the external auditory canal (EAC) open and unobstructed. The basic components of MEI are a microphone, an audio processor, a battery, a receptor and a vibration transducer which attaches to the ossicular chain (Manrique et al 2008). The transducer may be either piezoelectric or electromagnetic and produces vibrational energy that subsequently vibrates the ossicular chain (Kulkarni and Hartley 2008).

MEI are proposed for use in patients with sensorineural, conductive or mixed hearing losses. MEI are not indicated for people with profound hearing loss. All patients eligible for MEI implantation will have failed all appropriate conservative therapies, including an optimally-fitted external hearing aid.

The clinical comparators for the MEI vary according to the type and severity of hearing loss. In patients with mild or moderate sensorineural, conductive or mixed hearing losses, the comparator is the bone anchored hearing aid (BAHA). In patients with severe sensorineural or mixed hearing losses, the comparator is the cochlear implant (CI). In patients with severe conductive hearing loss, the comparator is the BAHA.

Medical Services Advisory Committee – role and approach

The Medical Services Advisory Committee (MSAC) was established by the Australian Government to strengthen the role of evidence in health-financing decisions in Australia. MSAC advises the Minister for Health and Ageing on the evidence relating to the safety, effectiveness and cost-effectiveness of new and existing medical technologies and procedures, and the circumstances under which public funding should be supported.

A rigorous assessment of evidence is thus the basis of decision making when funding is sought under Medicare. A team from the Australian Safety and Efficacy Register of New Interventional Procedures – Surgical (ASERNIP-S) was engaged to conduct a systematic review of literature on middle ear implant for sensorineural, conductive and mixed hearing losses. An advisory panel with expertise in this area then evaluated the evidence and provided advice to MSAC.

MSAC's assessment of middle ear implant for sensorineural, conductive and mixed hearing losses

Clinical need

Hearing loss is very common with approximately 13 per cent of Australians affected by total or partial hearing loss in 2004-05 (ABS 2007). In 2003 adult-onset hearing loss was ranked as the eighth leading specific cause of burden of disease and injury, comprising 2.5 per cent of the total disability-adjusted life-years (Australian Institute of Health and Welfare 2008).

Hearing loss may lead to many adverse outcomes in both adults and children. It can hinder interpersonal communication, which may lead to social isolation, a reduction in quality of life, and stress for family and friends (Moeller 2007). Affected adults may be unable to work productively, while affected children may have language and developmental difficulties. Further, hearing loss has a lifelong impact on educational and employment opportunities (Access Economics 2006; Chang 2005; Coates et al 2002; Moeller 2007).

In many patients the use of an external hearing aid may be unacceptable. Issues relating to external hearing aids many include sound distortion, ear canal occlusion (which is particularly relevant for patients with chronic otitis externa and media), acoustic feedback, autophony, inadequate amplification, discomfort and social stigma (Chang 2005; Manrique et al 2008; Shinnars et al 2008).

Safety

No comparative evidence was available to inform on safety of the MEI compared with either the BAHA or CI. Case series data was used to inform on the absolute safety of each device.

For the **MEI** device safety outcomes were drawn from comparative, case series and case report data for a total of 1222 patients. There were no deaths associated with MEI implantation. Most adverse events were relatively rare and of low severity. Serious adverse events such as facial nerve damage were reported to have occurred rarely. Damage to the chorda tympani nerve was reported more commonly; however, some instances of resulting taste disturbance were reported to have been transient and to have resolved over time. Technical complications related to the device, including device malfunction, migration or insufficient gain were relatively rare. Residual hearing loss after MEI implantation was reported on by most studies, with 13 studies reporting that patients suffered significant declines in mean residual hearing loss after MEI implantation. Communication with the manufacturer of the Vibrant Soundbridge (VSB) device (Med-EL) indicates that this MEI is not magnetic resonance imaging (MRI) safe at any Tesla level, and the device can be removed if necessary.

Twenty case series with a total of 9704 patients were used to inform of the absolute safety of **CI**. Several intracranial adverse events which were reported in CI patients were absent in MEI patients. Meningitis was reported in 44 CI patients, two of whom died. Most of the patients with meningitis were children. Two patients were reported to have received dural damage. Cerebrospinal fluid leak was also reported exclusively in CI

patients. The incidence of tympanic membrane perforation was higher in MEI patients, most likely due to the techniques used for MEI implantation. Haematomas and extrusions also occurred more frequently in MEI than in CI. Rates of damage to the chorda tympani and the facial nerves were similar between the CI and MEI patients. Additionally, the CI and MEI devices appeared to be similar in terms of failure rates.

Seven case series with a total of 619 patients were used to inform on the absolute safety of the **BAHA**. The BAHA appeared to be more technologically consistent than the MEI. Additionally, insufficient gain was more prevalent in MEI studies than in BAHA studies. Once positioned, the MEI appeared to be more stable than the BAHA. The BAHA also appeared to be more susceptible than the MEI to damage or loss due to trauma. Generally, BAHA patients reported more wound healing difficulty than MEI patients. This is likely to be due to the skin grafts employed in BAHA implantation, as well as the additional maintenance care required for the BAHA's abutment area.

Expert clinical opinion endorsed by the Advisory Panel suggests that some safety issues may be more specific to children. Paediatric bone is softer than that of adults and has a longer osseointegration time, and hence may be more susceptible to device loosening or damage. Additionally, children may be less likely to perform BAHA site maintenance and hygiene. In patients reported to have received the MEI, only one adverse event, a haematoma, was reported to have occurred in a child. No association was made between the age of this patient and the complication.

Residual hearing loss (RHL) after implantation was an important adverse event which was only reported in MEI patients. RHL was reported upon by most MEI studies, with 13 studies reporting that patients suffered significant declines in mean residual hearing after MEI implantation. Unlike the CI literature, the MEI literature included many patients with mild or moderate HL. In these patients, any further deterioration in hearing may be of greater clinical importance compared with losses in patients with severe or profound HL. Patients with conductive hearing loss (CHL) did not report significantly worse residual hearing after implantation.

Adverse events were reported inconsistently across the MEI, CI and BAHA studies, with no standardised definitions utilised. The types of adverse events also differed between these devices. As a result, the incidence of some adverse events is highly variable between studies.

The substantial difference in patient numbers available to assess the safety of the MEI, CI and BAHA reflects the relative youth of the MEI procedure. This is particularly the case for CI and reflects the more established nature of CI as a treatment for HL.

In summary, due to the absence of comparative evidence it is not possible to accurately compare the rates of adverse events between patients receiving MEI, CI or BAHA. However, on the limited evidence that is available, it appears that MEI implantation is at least as safe as CI or BAHA implantation.

Effectiveness

There was a paucity of high level evidence with which to assess the effectiveness of the MEI. One comparative study (National Health and Medical Research Council (NHMRC) level III-3) was available to assess the effectiveness of the MEI versus the CI, while no comparative studies were available to assess the effectiveness of the MEI versus the BAHA. Three comparative studies of the MEI device alone were identified; however, these studies generally involved an internal comparator such as MEI attachment method. Hence, most of the evidence for the effectiveness of the MEI has been derived from level IV evidence. Some studies assessed outcomes after MEI implantation, while others assessed outcomes with the MEI switched off and then on.

Eighteen comparative studies were available to assess the effectiveness of the MEI versus the external hearing aid (HA), and these were supplemented by a Food and Drug Administration (FDA) regulatory document.

Generally, MEI implantation and/or activation led to improvements in patients with mild, moderate and severe sensorineural hearing loss (SNHL); SNHL of undefined severity; mild, moderate and severe mixed hearing loss (MHL); MHL of undefined severity; and CHL. The MEI appears to be at least as effective as the HA. However, these conclusions are limited by the paucity of high-level evidence. Many effectiveness outcomes were reported in case series, and subject to bias. The lack of high quality studies may be related to the relative youth of the MEI procedure.

The included studies displayed considerable variability regarding patient enrolment, study design and length of follow-up. Several studies assessed the MEI in patients who had a range of hearing severities, such as mild to severe, which made meaningful reporting of these various severities difficult.

The included studies presented a variety of MEI devices. While most studies assessed the VSB MEI, the Otologics middle ear transducer (MET), Envoy Esteem, Rion device, SOUNDTEC Direct Drive Hearing System (DDHS) and TICA MEIs were also assessed. Additionally, some studies described instances in which the MEI attachment method or the devices themselves had been modified to permit implantation. Hence, differences in components and attachment occurred between the six identified MEI devices and also between patients receiving the same MEI. Expert opinion of the Advisory Panel stated that although there were slight differences between the MEI devices, their method of implantation was similar enough for pooled outcomes to be reported.

The majority of the available studies assessed the MEI in patients with SNHL. This is reflective of the anticipated Australian practice suggested by clinical experts.

The reporting of effectiveness outcomes was compromised by the lack of uniform outcome measurements. While the primary technical outcome measure (functional gain) was identified a priori, not all studies reported this outcome. Patient-related outcomes were not reported in all studies. Where these were reported, different outcome measures such as the Glasgow Benefits Index (GBI) and the SF-36 were used.

Effectiveness outcomes were further compromised by the fact that some studies reported that baseline measurements were taken with a digital, best fit, or state-of-the-art HA, while others used the patient's own HA. Further, in some before/after MEI studies it was not clearly stated whether baseline measures were measured with or without a HA. It appears

that presently there is considerable variability in HA management prior to the consideration of MEI implantation.

Cost-effectiveness

The objective of the economic evaluation was to compare the cost-effectiveness of MEI relative to BAHA and CI. In the absence of conclusive effectiveness data, a cost analysis was conducted to compare the different costs associated with each of the three procedures.

The estimated costs of MEI, BAHA and CI were taken from a number of sources. These included the Medicare Benefits Schedule (MBS), Australian Refined Diagnostic Related Group (AR-DRG) cost, manufacturers of implants and the median charged MBS fee.

Based on a number of estimates and assumptions:

- The total estimated first year cost of an MEI, BAHA and CI is \$23,873, \$15,207 and \$34,466, respectively. The incremental cost of using an MEI as opposed to a BAHA is \$8,666. The incremental cost saving of using an MEI as opposed to a CI is \$10,593.
- Based on 2006-07 MBS data, the total cost of BAHA would be \$1,611,957 (106 patients) and the total cost of CI would be \$11,270,250 (327 patients). This gives a total cost of \$12,882,207. If MEI was used instead of BAHA and CI the total cost would be \$10,336,916. Hence the cost savings of performing MEI as a direct replacement for BAHA and CI would be over \$2.5 million.
- Expert opinion endorsed by the Advisory Panel indicated that MEI would not just replace current CI and BAHA use, but would become another option in meeting the pool of unmet need of those with hearing loss. Expert opinion was that these individuals, currently persisting with hearing loss or a less than optimal hearing aid, may consider MEI implantation while they are not considering or accessing BAHA or CI. The previously mentioned variability in HA management prior to consideration of MEI, and limited data on the pool of 'unmet need', makes this number difficult to quantify. Sensitivity analysis suggests that if one per cent of the estimated pool of individuals with moderate or severe hearing loss elected to have MEI, the additional cost would be \$2,291,787. These estimates are based on prevalence data of hearing loss in Australia and include a large portion of older Australians for whom an MEI would not be viable.

Introduction

The Medical Services Advisory Committee (MSAC) has reviewed the use of middle ear implant, which is a therapy for hearing loss. MSAC evaluates new and existing health technologies and procedures for which funding is sought under the Medicare Benefits Schedule (MBS) in terms of their safety, effectiveness and cost-effectiveness, while taking into account other issues such as access and equity. MSAC adopts an evidence-based approach to its assessments, based on reviews of the scientific literature and other information sources, including clinical expertise.

MSAC's terms of reference and membership are at Appendix A. MSAC is a multidisciplinary expert body, comprising members drawn from such disciplines as diagnostic imaging, pathology, surgery, internal medicine and general practice, clinical epidemiology, health economics, consumer health and health administration.

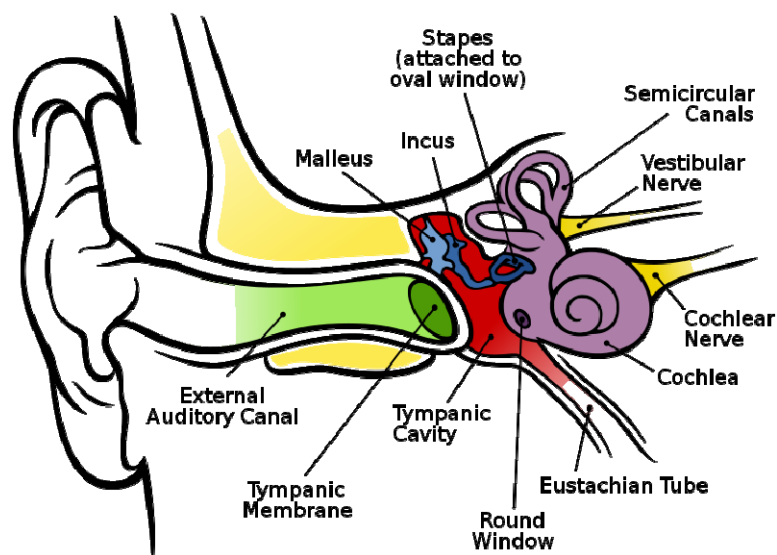
This report summarises the assessment of current evidence for middle ear implant for sensorineural, conductive and mixed hearing losses.

Background

Hearing and hearing loss

The function of the ear is to transduce acoustic energy into electrical energy which may be perceived by the brain as sound. The ear comprises three zones: the outer, middle and inner ear. The outer ear consists of the pinna and the external auditory canal (EAC). Sound is funnelled by the pinna along the EAC to the middle ear. The middle ear comprises the tympanic membrane (eardrum) and a series of three tiny interlocking bones (malleus, incus and stapes) known collectively as the ossicular chain (Weissman 1996), which span an air-filled space called the tympanic cavity. Sound waves cause the tympanic membrane to vibrate, which in turn moves the ossicular chain and amplifies the sound. The air pressure on either side of the tympanic membrane is equalised by the Eustachian tube (Counter 2008), which connects the tympanic cavity to the throat.

Figure 1 The external, middle and inner ear



Source: Perception Space—The Final Frontier, A PLoS Biology Vol. 3, No. 4, e137 doi:10.1371/journal.pbio.0030137

The inner ear is a bony labyrinth containing the fluid-filled cochlea that is responsible for hearing and the vestibular apparatus, which is the organ of balance. The foot of the stapes is connected to the oval window, a flexible membrane of the cochlea (Wilson and Dorman 2008). When the stapes presses into the oval window a disturbance or movement is created in the cochlear fluid; a second window (the round window) flexes to permit such movement. The fluid movement causes sensitive hair cells within the cochlea to bend, generating electrical signals that are sent to the brain via the auditory nerve. Thus, the cochlea transduces the vibrations caused by the stapes into electrical signals. Sound waves may be conducted to the cochlea through air via the middle ear (air conduction) or via the mastoid when the sound source is in contact with the head (bone conduction) (Lalwani 2008; Tjellstrom et al 2001).

The human ear is able to process sound frequencies ranging from 20 Hz to 20 kHz (Yueh et al 2003). Hearing loss is measured in an audiogram which uses the decibels hearing level (dB HL) as the units of measurement. For people with normal hearing the minimal audible level (threshold) of a tone is less than 20 dB across all frequencies. People with higher thresholds are considered to have hearing loss, which may be classified into mild, moderate, severe and profound hearing loss (Table 1) (Kulkarni and Hartley 2008).

Table 1 Guidelines for interpreting hearing loss

Hearing threshold (dB)	Interpretation
20-39	Mild hearing loss
40-69	Moderate hearing loss
70-94	Severe hearing loss
95+	Profound hearing loss

Source: Newton 2009

Hearing loss may be broadly grouped into three categories: sensorineural, conductive and mixed. Sensorineural hearing loss (SNHL) occurs where there is damage to either the hair cells of the cochlea (sensory) or to the nerve pathway from the inner ear to the brain (neural) (American Speech-Language-Hearing Association 2009). SNHL may be congenital or acquired and is usually permanent (Access Economics 2006). SNHL can be caused by damage or malformation of the cochlea and the sensitive hairs, exposure to excessive noise, vestibular schwannomas, viral infections, temporal bone fractures, Meniere's disease, ototoxic medications and the ageing process (presbycusis hearing loss) (Access Economics 2006; Lalwani 2008). Additionally, patients with idiopathic SNHL may have experienced a viral infection of the inner ear or a vascular accident (Lalwani 2008). As there is currently no method for repairing damaged cochlear hairs, treatment for SNHL usually involves amplifying the incoming sound (Yuen et al 2003).

Conductive hearing loss (CHL) occurs when sound is not conducted efficiently through the EAC to the tympanic membrane and ossicular chain (American Speech-Language-Hearing Association 2009). This is generally caused by a blockage or damage in the outer or middle ear (or both) and may be transient or permanent (Access Economics 2006; Australian Hearing 2008). Potential causes of CHL include outer ear infection; malformation of the outer or middle ear; blockages of the EAC by cerumen or foreign objects; blockage of the Eustachian tube (e.g. otitis media); perforation of the tympanic membrane; and damage of the tympanic membrane, EAC or ossicular chain. Many causes of CHL are mechanical in nature; hence, the treatment is often surgical (Yueh et al 2003).

Mixed hearing loss (MHL) occurs when there are interruptions in both the conductive and the sensorineural pathways. Patients may have damaged outer or middle ears as well as an impaired cochlea or auditory nerve (American Speech-Language-Hearing Association 2009; Australian Hearing 2008).

Pure-tone air conduction testing is used to measure the function of a person's entire hearing system (external, middle and inner ear). The testing is done by presenting pure tones ranging from 250 to 8000 Hz to the person. When plotted on an audiogram, the person's pure-tone thresholds indicate the severity of their hearing loss. Pure-tone

average (PTA) thresholds between 0-20 dB are considered normal, whereas thresholds greater than 20 dB represent various levels of hearing loss (Table 1).

Bone conduction testing is used to measure the function of a person's inner ear, as it is unaffected by damage to the outer or middle ear. The testing is generally conducted by touching the base of a vibrating tuning fork to the person's forehead (Counter 2008). Any differences between air-conduction (AC) and bone-conduction (BC) thresholds allow classification of the person's type of hearing loss. When the AC thresholds are higher than normal BC thresholds (i.e. an air bone gap is present), the loss is classified as CHL. When AC and BC thresholds are equivalent, the loss is classified as SNHL. When AC thresholds are higher than abnormal BC thresholds, the loss is classified as MHL (Cummings 2005).

The procedure

Middle ear implants (MEI) are surgically implanted electronic devices which aim to correct hearing loss through stimulation of the ossicular chain or middle ear (Manrique et al 2008). MEI are placed into the middle ear and generally leave the EAC open and unobstructed. The basic components of MEI are a microphone, an audio processor, a battery, a receptor and a vibration transducer which attaches to the ossicular chain (Manrique et al 2008). The transducer may be either piezoelectric or electromagnetic and produces vibrational energy that subsequently vibrates the ossicular chain (Kulkarni and Hartley 2008). Secure attachment of the transducer to the ossicular chain is important as separation will result in device failure (Shinners et al 2008). Among the many attachment options are: creating an opening in the incus and using an adhesive; crimping the device to the incus; or disarticulation and placement of the device at the incudostapedial joint (Shinners et al 2008).

MEI may remove many issues relating to hearing aid use such as sound distortion, ear canal occlusion (particularly relevant for patients with chronic otitis externa and media), acoustic feedback, autophony, inadequate amplification, discomfort and social stigma (Chang 2005; Manrique et al 2008; Shinners et al 2008). Some fully implantable MEI also allow patients to swim and wash while wearing the device (Backous and Duke 2006).

However, there may be hazards associated with MEI. Implantation requires surgery (usually requiring a general anaesthesia), and device failure will require a further operation. There is a risk of perioperative damage to the chorda tympani nerve, which can result in a change in the sensation of taste (dysgeusia), or can affect the facial nerve, which can lead to facial paralysis (Lloyd et al 2007). Cochlear function may actually decline due to the noise generated (drilling and sucking) during the surgical procedure (Snik and Cremers 2000). Mass loading of the ossicular chain may lead to residual hearing loss, the extent of which is directly related to the weight of the MEI and to the location of its placement in the middle ear (Hough et al 2001; Vincent et al 2004). Further, there is a potential risk of damage to the ossicular chain, and the use of magnetic resonance imaging, electroconvulsive therapy and radiotherapy of the head may be restricted with some devices (Manrique et al 2008).

Clinical need/burden of disease

Hearing loss is very common with approximately 13 per cent of Australians affected by total or partial hearing loss in 2004-05 (Australian Bureau of Statistics 2007). Among South Australians aged 15 and older, 20.2 per cent have SNHL, 1.6 per cent have MHL and 0.4 per cent have CHL (Wilson et al 1998). In 2003 adult-onset hearing loss was ranked as the eighth leading specific cause of burden of disease and injury, comprising 2.5 per cent of the total disability-adjusted life-years (Australian Institute of Health and Welfare 2008).

The most common type of SNHL is presbycusis or age-related hearing loss (Lalwani 2008; National Institute for Health and Clinical Excellence 2009). As the Australian population ages it is likely that the number of people suffering from hearing loss will increase (Australian Institute of Health and Welfare 2008).

Otitis media is a very common childhood infection (Rovers 2008). Between 2004 and 2005, two per cent of children receiving medical treatment were non-indigenous children with otitis media, compared with four per cent for indigenous children (Australian Institute of Health and Welfare 2007).

Hearing loss may lead to many adverse outcomes in both adults and children. It can hinder interpersonal communication, which may lead to social isolation, a reduction in quality of life, and stress for family and friends (Moeller 2007). Affected adults may be unable to work productively, while affected children may have language and developmental difficulties. Further, hearing loss has a lifelong impact on educational and employment opportunities (Access Economics 2006; Chang 2005; Coates et al 2002; Moeller 2007).

Existing procedures

Conservative treatments

There are many pharmacologic and medical therapies for managing SNHL, CHL and MHL. Depending on the type of hearing loss, current conservative clinical management includes intra-tympanic inner ear steroid perfusion, antibiotics, hyperbaric oxygen or carbon gas; or external hearing aid or listening device use (Bennett et al 2006).

During 2006-07 the fitting of 124,657 hearing aids was subsidised by the Office of Hearing Services (Australian Institute of Health and Welfare 2008). While hearing aids may provide adequate amplification for many patients with hearing loss, there are some common problems with the devices which may lead to discontinuation of their use. These include control of acoustic feedback, discomfort, ear occlusion, inadequate amplification, regular maintenance tasks, hygiene of the ear canal and perceived social stigma (Backous and Duke 2006; Chang 2005; Counter 2008). Further, patients may be concerned about a hearing aid's ease of use, reliability and frequency of battery changes. People with high-frequency hearing loss may find that a hearing aid does not perform well when there is background noise (Counter 2008). Additionally, occlusion of the ear canal may exacerbate conditions such as otitis media or otitis externa. Some patients may be unable to use conventional hearing aids due to absence or malformation of the external ear (Chang 2005).

Recently digital technology has led to advancements in hearing aid technology. Digital hearing aids are now able to provide more sophisticated sound processing through improved amplification control, situation-specific sound processing, noise reduction and improved sound localisation (O'Leary and Chang 2008). New, more sophisticated devices which aim to address specific issues such as the occlusion effect have also been developed. These 'open-fit' hearing aids consist of a very small component that is placed in the ear canal, leaving it unobstructed (Harvard Health Letter 2007).

Surgical treatments

Surgical treatments may be explored for hearing losses which are refractory to conservative medical treatment. Table 75 shows the comprehensive range of surgical interventions related to hearing loss, with the choice of surgical procedure dependent upon the cause of hearing loss.

Surgical procedures for CHL include the following:

- Ossiculoplasty (repair or reconstruction of the middle ear)

This procedure may restore middle ear function damage due to trauma, neoplasms, inflammatory processes or cholesteatomas (Javia and Ruckenstein 2006) and can include:

- total ossicular replacement prosthesis (TORP)
- partial ossicular replacement prosthesis (PORP)
- tympanoplasty (repair of the tympanic membrane)
- stapedectomy or stapedotomy (replacement of part, or all, of the stapes, generally performed in patients with otosclerosis or congenital malformation).

Ossiculoplasty may be performed using general or local anaesthetic (Yung 1996) and currently has several MBS item numbers (see Table 75).

- Myringotomy or insertion of tympanostomy tubes

These procedures drain fluid from the middle ear in patients with severe ear infection or otitis media with effusion. The procedures are generally performed under general anaesthetic (Koopman et al 2004). Currently, myringotomy and insertion of tympanostomy tubes each have an MBS item number (see Table 75).

- Mastoidectomy

This is indicated for patients with cholesteatomas or tumours which extend into the mastoid bone (Bennett et al 2006). Mastoidectomy currently has several MBS item numbers (see Table 75).

The following surgical procedures aim to correct hearing loss:

- Transcutaneous air conduction hearing aid system

This system comprises an implanted titanium tube and an external digital hearing aid (Chang 2005). The titanium tube is surgically implanted through the soft tissue of the external ear into the external ear canal. The implantation procedure takes approximately 30 minutes and is usually performed under local anaesthetic (Chang

2005). The post-auricular external hearing aid connects to the titanium tube and selectively amplifies high-frequency sounds, which are then sent through the tube. The system is suitable for patients with high-tone SNHL (Chang 2005; Murugasu 2005; Winter and Lenarz 2005). Transcutaneous air conduction hearing aid systems currently have an MBS item number (see Table 75); however, expert clinical opinion suggests that this procedure has not been performed widely in Australia.

- Cochlear implant

The cochlear implant bypasses missing or damaged cochlear hair cells and directly stimulates the auditory nerve to provide auditory sensation (Chang 2005; Wilson and Dorman 2008). The implantation procedure takes approximately two hours and is performed under a general anaesthetic (Chang 2005). The cochlear implant consists of an external and an implanted component. The external component contains a microphone that detects sound and transforms it from an acoustic signal to an electromagnetic signal. This signal is then sent to the implanted component via communicating magnetic coils. The implanted component (consisting of a receiver and stimulator) is placed within the cranium, behind the auricle, and generates stimulation. A cable delivers this stimulation to the electrodes placed in the scala tympani chamber of the cochlea, which then stimulate the auditory nerve (Wilson and Dorman 2008). Cochlear implants presently have an MBS item number (see Table 75). During 2006-07, 682 public and 390 private cochlear implantations were performed (Australian Institute of Health and Welfare 2009; Medicare Australia 2009).

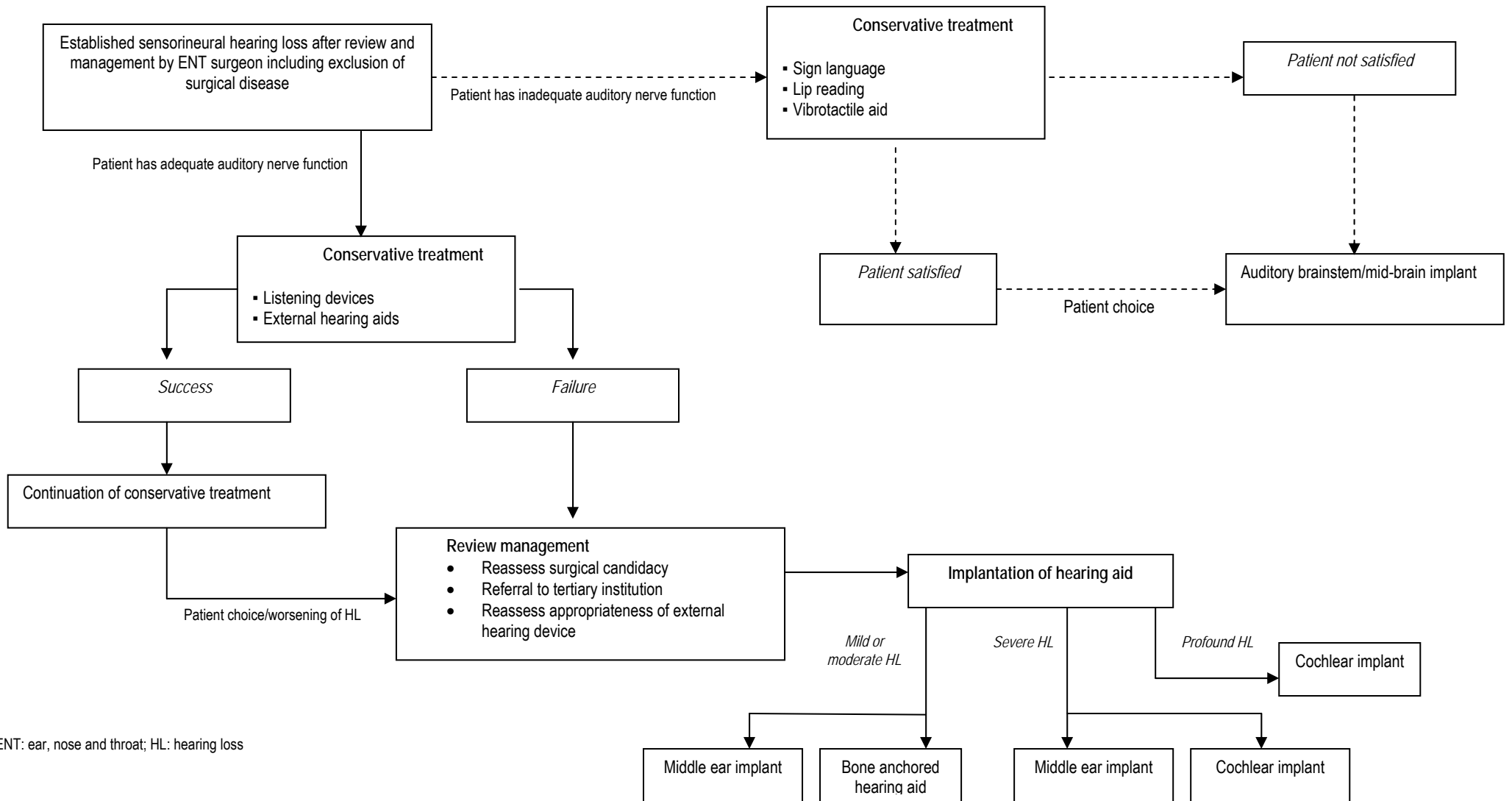
- Bone anchored hearing aid (BAHA)

A BAHA has a titanium plate which is implanted and anchored to the patient's skull. The implantation procedure generally takes less than 45 minutes using local anaesthesia (Wade 2002). An external hearing aid attaches to the implanted plate. The hearing aid detects sound waves and transforms them into vibratory signals which are transmitted to the underlying plate and bone, so that bone conduction hearing can then take place. As the BAHA bypasses both the external and the middle ear it can be used in patients with CHL (Chang 2005). Patients with SNHL or MHL may also be candidates for a BAHA if their bone conduction thresholds do not exceed 45 dB (Chasin 2002). BAHA currently has an MBS item number (see Table 75). During 2006-07, 40 BAHA implantations were performed in the private hospital system in Australia, which rose to 123 during 2007-08 (Medicare Australia 2009). Data for the public health system are unavailable.

- Auditory brainstem implant (ABI) or auditory mid-brain implant (AMI)

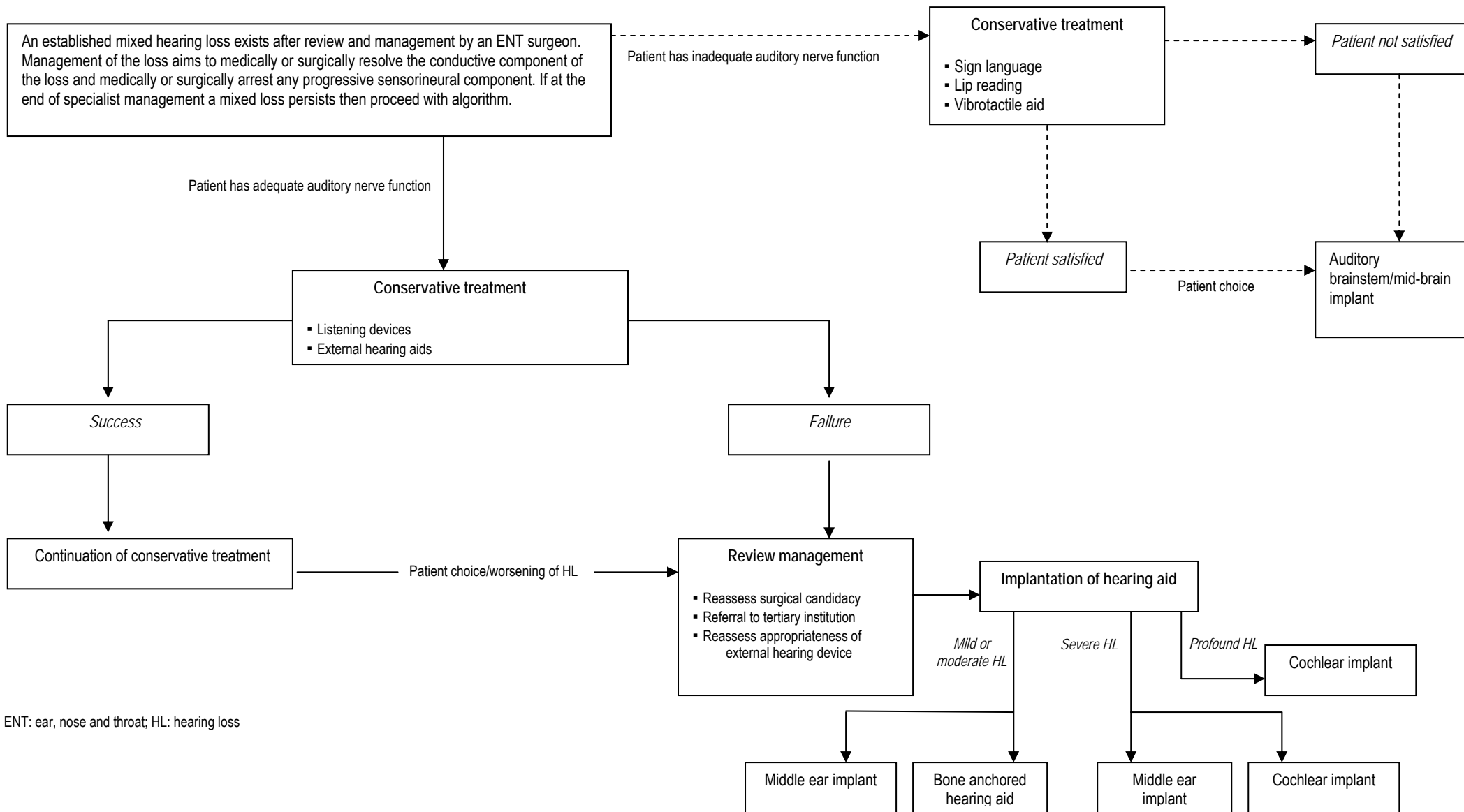
These procedures are designed for patients with insufficient auditory nerve function (Kulkarni and Hartley 2008). They are intended primarily for patients with neurofibromatosis type 2 (NF2), but may also prove useful for other conditions such as cochlear nerve aplasia (Kulkarni and Hartley 2008; Murugasu 2005). ABI and AMI are similar to cochlear implants, although the electrodes are implanted either on the surface of the brainstem (ABI) or the mid-brain nuclei (AMI) (Kulkarni and Hartley 2008). The time taken to implant the ABI depends upon auditory brainstem response testing performed intraoperatively (Murugasu 2005). ABI and AMI do not presently have MBS item numbers.

Figure 2 Clinical decision tree for middle ear implant for sensorineural hearing loss



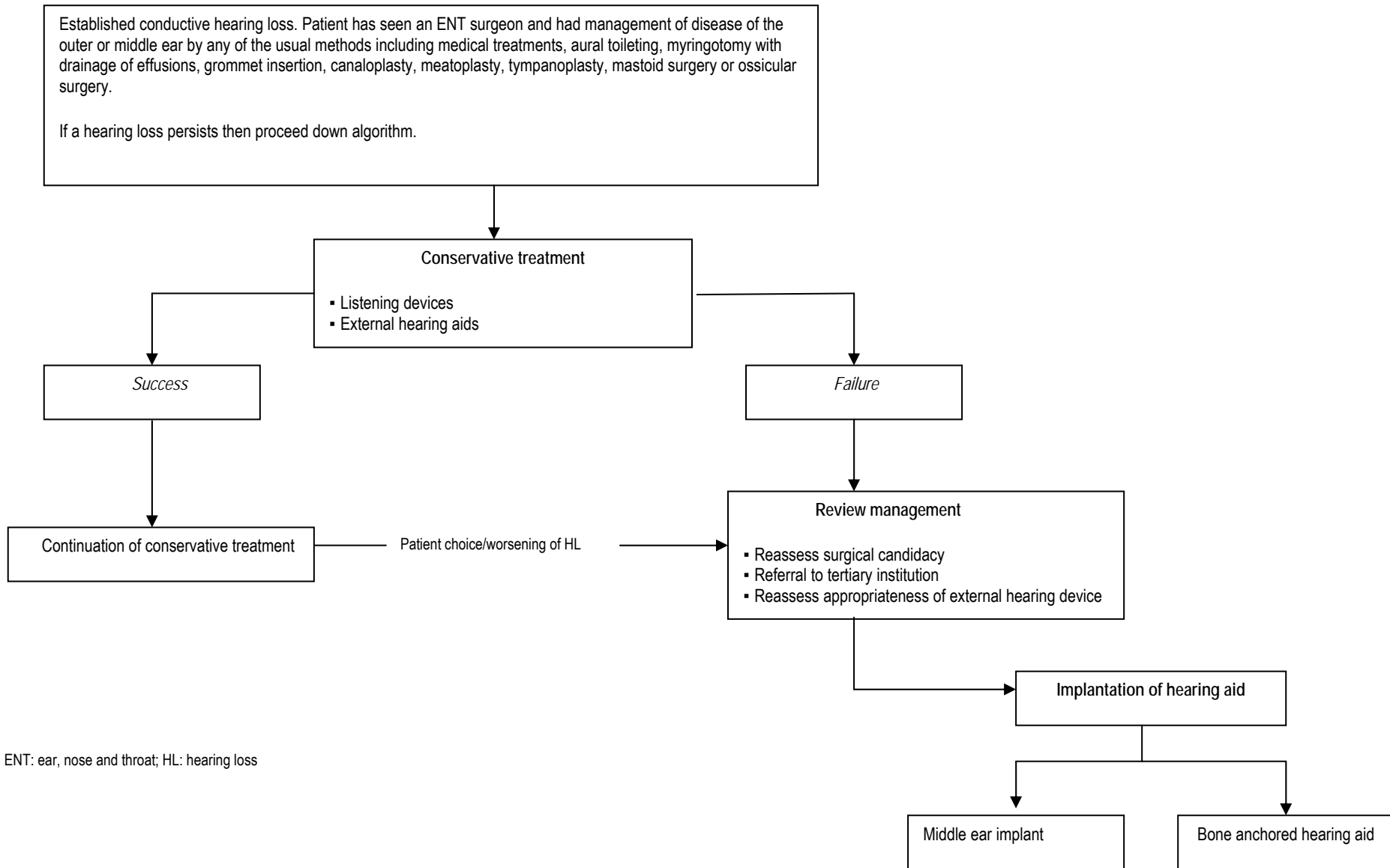
ENT: ear, nose and throat; HL: hearing loss

Figure 3 Clinical decision tree for middle ear implant for mixed hearing loss



ENT: ear, nose and throat; HL: hearing loss

Figure 4 Clinical decision tree for middle ear implant for conductive hearing loss



ENT: ear, nose and throat; HL: hearing loss

Comparator

The clinical comparators to the MEI are considered to be the bone-anchored hearing aid (BAHA) and the cochlear implant (CI). Expert clinical opinion advises that the BAHA is indicated in patients with mild or moderate SNHL or MHL, and in patients with stabilised CHL. The CI is indicated in patients with severe SNHL or MHL. Expert clinical opinion advises that the CI is similar to the MEI in terms of operative complexity and technique, whereas the BAHA implantation procedure is relatively simpler.

Marketing status of the device/technology

The current Therapeutic Goods Administration (TGA) listings for middle ear implant equipment are described in Table 2. The current Food and Drug Administration (FDA) listings for middle ear implants are described in Table 3.

Table 2 Items relating to middle ear implants listed by the TGA

ARTG number	ARTG Label name	Date Approved	Indication
119161	Progressive Medical - The Soundbridge System – Unclassified	12/05/2005	The Vibrant Soundbridge is indicated for use in patients who have mild to severe hearing impairment and cannot achieve success or adequate benefit from traditional therapy. This device is also indicated for conductive or mixed hearing loss using pure-tone bone-conduction.
161702	Pacing Importers Pty Ltd – Vibrant Soundbridge System Vibrating Ossicular Prosthesis (VORP) 502X – Hearing aid, middle ear implant	12/05/2009	The intended purpose of this device is for use in patients who have mild to severe hearing impairment and cannot achieve success or adequate benefit from traditional therapy. 1) For sensorineural HL, the VORP is crimped to the long process of the incus to directly drive the ossicular chain. 2) For mixed and conductive HL, the VORP is attached with fascia to the round window niche in the middle ear. The Soundbridge is clinically proven to provide benefit for both patient groups.
162596	Pacing Importers Pty Ltd – AP 404 Audio Processor – Middle ear implant sound processor	19/06/2009	The intended purpose of this device is for use in patients who have mild to severe hearing impairment and cannot achieve success or adequate benefit from traditional therapy. It is indicated for both sensorineural and mixed and conductive hearing loss. The AP is the external component of the Soundbridge System. The Soundbridge is clinically proven to provide benefit for both patient groups.

Australian Therapeutic Goods Administration database accessed 7/09/2009. Available at: <https://www.ebs.tga.gov.au/ebs/ANZTPAR/PublicWeb.nsf/cuDevices?OpenView>
HL: hearing loss; VORP: vibrating ossicular replacement prosthesis; AP audio processor

Table 3 Items relating to middle ear implants listed by the FDA

FDA number	FDA Label name	Date Approved	Indication
P990052	Vibrant Soundbridge	31/08/2000	The Vibrant Soundbridge is intended for use in adults, 18 years of age or older, who have a moderate to severe sensorineural hearing loss and desire an alternative to an acoustic hearing aid.
P010023	SOUNDTEC® Direct Drive Hearing System	7/09/2001	This device is indicated in adults, 18 years of age or older, who have a moderate to severe sensorineural hearing loss and desire an alternative to an acoustic hearing aid.

United States Food and Drug Administration database accessed 7/09/2009. Available at: <http://www.fda.gov/default.htm>

On 17 March 2010 the FDA approved the Esteem®-Hearing Implant™ (Envoy Medical Corporation, Saint Paul, Minneapolis, USA) (<http://www.fda.gov/NewsEvents/Newsroom/PressAnnouncements/ucm204956.htm>).

Other MEI devices identified in the international literature include the SOUNDTEC® Direct Drive Hearing System (SoundTec, Inc., Oklahoma City, OK, USA), the Carina™ Fully Implantable Hearing Device (Otologics, LLC, Boulder, Colorado, USA), the Rion Implantable hearing aid (RION Co., Ltd., Tokyo, Japan) and the Totally Implantable Cochlea Amplifier (Cochlear™, Melbourne, Australia). Although these devices are not registered with the TGA they shall be considered a part of this report, as the Advisory Panel considers the devices to be essentially the same as the device produced by Progressive Medical (above). Differences between these devices in terms of mode of action and surgical technique shall be highlighted in the results section (Table 21).

Current reimbursement arrangement

There are no current MBS listings for MEI procedures.

Outcome measurement tools

A wide variety of outcome tools are utilised in the available literature. A brief description of the most common tools is provided below.

Hearing device performance

- **Functional gain:** a measure of the benefit provided by the MEI. It is calculated by determining the difference between the unaided preoperative and aided postoperative pure-tone average thresholds (Lefebvre et al 2009).
- **Profile of Hearing Aid Performance (PHAP):** a questionnaire comprising 66 items scored in seven subscales. The PHAP attempts to capture an individual's experiences when using their hearing aid (Cox 1997).
- **Profile of Hearing Aid Benefit (PHAB):** this questionnaire builds upon the PHAP by including responses to the items from the point of view of an

unaided listener. The listener's opinion of the benefits and costs of their hearing aid use is shown by determining the difference between responses for "with my hearing aid" and 'without my hearing aid' (Cox 1997).

The PHAP and the APHAB are generally considered too lengthy for many clinical applications. In response, the Abbreviated Profile of Hearing Aid Benefit was developed (Cox 1997).

The **Abbreviated Profile of Hearing Aid Benefit (APHAB)** comprises 24 items scored in four subscales:

- **Ease of Communication (EC):** ease or difficulty of communicating under relatively favourable conditions
- **Reverberation (RV):** communication in reverberant settings (e.g. classrooms)
- **Background Noise (BN):** communication in settings with high background noise levels
- **Aversiveness (AV):** the unpleasantness of environmental sounds (Cox 1997).

Each item is answered in the context of 'without my hearing aid' and 'with my hearing aid', thus providing a score for both unaided and aided listening and allowing the calculation of a score for benefit (Cox 1997).

- **Client-oriented scale of improvement:** an outcome measure comprising two phases. In the first phase the individual with hearing loss identifies listening situations that he/she would like to have improved with new amplification. The hearing aid is then fitted. In the second phase the change in hearing function for the identified listening situation is recorded (National Acoustic Laboratories 2000-05).

Speech outcomes

- **Speech detection level:** the softest level at which a person detects (rather than understands) speech sounds. The person is not required to recognise the sound, but rather to acknowledge its presence (Lalwani 2008).
- **Speech reception threshold:** the lowest intensity level at which a patient can correctly repeat 50 per cent of common bisyllabic words like 'hotdog' or 'baseball' (Cummings 2005).
- **Speech intelligibility in quiet:** determined using monosyllabic words presented at the conversational level (between 40-65 dB SPL). One error is counted each time a phoneme is mispronounced or not repeated, and the final score is converted to a percentage (Truy et al 2008).
- **Speech Perception in Noise (SPIN):** developed in the 1970s and revised in the mid 1980s, the test consists of eight lists of 50 sentences. The test items are the last words in these sentences. The SPIN test allows separate

scores for understanding of sentences that contain contextual information and of those that do not.

Sentences are accompanied by a background noise and can be presented at various signal/noise ratios (Elliott 1995; Gelfand 2009; Smoski 2008).

Patient related outcomes

- **Glasgow Benefit Inventory (GBI):** a measure of a patient's change in health status as a result of a health care intervention, which was developed especially for otorhinolaryngological interventions. The GBI is an 18-item questionnaire which is completed by the patient after the intervention either at home or in the outpatient clinic (Robinson et al 1996).
- **Hearing Device Satisfaction Scale (HDSS):** a questionnaire which was developed by the company Symphonix Devices. Comprising 21 questions, the HDSS assesses a listener's satisfaction associated with use of their hearing device and their hearing ability in various listening situations. Listener satisfaction is rated upon a five-point response scale, from very satisfied to very dissatisfied (Uziel et al 2003).
- **Hough Ear Institute Profile (HEIP):** a questionnaire assessing a person's satisfaction with their current hearing device. This measures several aspects including tinnitus, masking effect, sound quality perceptions, presence of feedback and occlusion; and device preference (Matthews 2002).
- **Gothenburg Profile:** a tool which permits quantification of subjectively experienced hearing disability (e.g. speech intelligibility, localisation skills) and any accompanying social and emotional handicap (e.g. social relationships, self-confidence) (Zenner et al 2003).

Approach to assessment

Review of literature

PICO (population, intervention, comparator, outcome) criteria were developed with the assistance of the Advisory Panel (Table 4, Table 5, Table 6). These criteria assisted in specifying the search strategy.

Table 4 PICO criteria for middle ear implants for sensorineural hearing loss

Population	Intervention	Comparator	Outcomes
Patients with mild or moderate sensorineural hearing loss of any aetiology, who have failed all other conservative medical, pharmaceutical and behavioural treatments	Middle ear implant (MEI)	Bone anchored hearing aid (BAHA)	<i>Effectiveness:</i> Abbreviated Profile of Hearing Aid Benefit (APHAB) client-oriented scale of improvement functional gain
Patients suffering from severe sensorineural hearing loss of any aetiology, who have failed all other conservative medical, pharmaceutical and behavioural treatments	Middle ear implant (MEI)	Cochlear implant (CI)	speech recognition real ear insertion gain sound-field assessment speech comprehension scores tympanometric and acoustic reflex measures self-assessment scales/patient preference <i>Safety:</i> complication/adverse event rates infection taste disturbance fibrosis aural fullness acoustic trauma dizziness damage to the middle ear revision surgery/explant rate/device failure mortality

Table 5 PICO criteria for middle ear implants for mixed hearing loss

Population	Intervention	Comparator	Outcomes
Patients with mild or moderate mixed hearing loss of any aetiology, who have failed all other conservative medical, pharmaceutical and behavioural treatments	Middle ear implant (MEI)	Bone anchored hearing aid (BAHA)	<p><i>Effectiveness:</i></p> <p>Abbreviated Profile of Hearing Aid Benefit (APHAB)</p> <p>client-oriented scale of improvement</p> <p>functional gain</p>
Patients suffering from severe mixed hearing loss of any aetiology, who have failed all other conservative medical, pharmaceutical and behavioural treatments	Middle ear implant (MEI)	Cochlear implant (CI)	<p>speech recognition</p> <p>real ear insertion gain</p> <p>sound-field assessment</p> <p>speech comprehension scores</p> <p>typanometric and acoustic reflex measures</p> <p>self-assessment scales/patient preference</p> <p><i>Safety:</i></p> <p>complication/adverse event rates</p> <p>infection</p> <p>taste disturbance</p> <p>dizziness</p> <p>aural fullness</p> <p>acoustic trauma</p> <p>fibrosis</p> <p>damage to the middle ear</p> <p>revision surgery/explant rate/device failure</p> <p>mortality</p>

Table 6 PICO criteria for middle ear implants for conductive hearing loss

Population	Intervention	Comparator	Outcomes
Patients suffering from established stabilised conductive hearing loss of any aetiology, who have failed all other conservative medical, pharmaceutical and behavioural treatments	Middle ear implant (MEI)	Bone anchored hearing aid (BAHA)	<p><i>Effectiveness:</i></p> <p>Abbreviated Profile of Hearing Aid Benefit (APHAB)</p> <p>client-oriented scale of improvement</p> <p>functional gain</p> <p>speech recognition</p> <p>real ear insertion gain</p> <p>sound-field assessment</p> <p>speech comprehension scores</p> <p>tympanometric and acoustic reflex measures</p> <p>self-assessment scales/ patient preference</p> <p><i>Safety:</i></p> <p>complication/adverse event rates</p> <p>infection</p> <p>taste disturbance</p> <p>dizziness</p> <p>aural fullness</p> <p>acoustic trauma</p> <p>fibrosis</p> <p>damage to the middle ear</p> <p>revision surgery/explant rate/device failure</p> <p>mortality</p>

The PICO criteria have defined five patient subgroups dependent on the type and severity of hearing loss (two each for sensorineural and mixed and one for conductive hearing loss). The effectiveness results have been presented according to these populations where possible.

Clinical questions

1. In patients with mild or moderate SNHL is the MEI more effective than the BAHA?
2. In patients with severe SNHL is the MEI more effective than the CI?
3. In patients with mild or moderate MHL is the MEI more effective than the BAHA?
4. In patients with severe MHL is the MEI more effective than the CI?
5. In patients with CHL is the MEI more effective than the BAHA?

Relevant electronic databases were searched to identify relevant studies and reviews for the period between database inception and August 2009. Searches were conducted via PubMed, EMBASE, the Cochrane Library and Current Contents. The search terms used included MeSH terms and textwords:

MeSH terms

Hearing loss, conductive/ OR Hearing loss, sensorineural/ OR Hearing loss, noise-induced/ OR Hearing loss, mixed conductive-sensorineural/ OR Hearing loss, high frequency/ OR Hearing loss, unilateral/ OR Hearing loss, bilateral/ OR Hearing loss, central/ OR Deafness/ OR Retrocochlear Diseases/ OR Ear, middle/ OR Ossicular prosthesis OR Otologic surgical procedures.

Textwords

((Middle and ear) or (ossicle* or ossicular or malleus or incus* or stapes or eardrum or tympanic membrane)) and (implant* or transduce* or stimulat* or aid or equipment or appliance* or device* or prosth*) or Soundbridge or Floating Mass Transducer or FMT or Vibrating Ossicular Prosthesis or Envoy or Esteem or SoundTec or Middle Ear Transducer or Carina or MET Ossicular Stimulator or TICA or Totally Implantable Cochlea* Amplifier or Rion or e-type.

Inclusion criteria

Case reports were not considered for effectiveness outcomes, but were included for the assessment of safety outcomes for the MEI. Where comparative evidence did not inform on the safety of the BAHA or CI, case series information for these interventions was included and assessed. This information was limited to recent studies (post-2006) of consecutive patients with populations of 20 or more, and a minimum of six months follow-up. The detailed inclusion criteria which were applied to all retrieved studies are in Table 7.

Table 7 Inclusion criteria for identification of relevant studies

Characteristic	Criteria
Publication type	<p><i>Effectiveness:</i> systematic reviews and clinical studies including randomised and non-randomised comparative studies and case series will be included. Non-systematic reviews, case reports, letters, editorials, and animal, in-vitro and laboratory studies will be excluded.</p> <p><i>Safety:</i> systematic reviews and clinical studies including randomised and non-randomised comparative studies, case series and case reports will be included. Non-systematic reviews, letters, editorials, and animal, in-vitro and laboratory studies will be excluded.</p>
Patient	Male or female patients diagnosed with mild, moderate or severe sensorineural, mixed or conductive hearing loss who are refractory to medical or surgical management.
Intervention	Middle ear implant
Comparator	<p><i>Patients with mild or moderate sensorineural hearing loss:</i> bone anchored hearing aid</p> <p><i>Patients with severe sensorineural hearing loss:</i> cochlear implant</p> <p><i>Patients with mild or moderate mixed hearing loss:</i> bone anchored hearing aid</p> <p><i>Patients with severe mixed hearing loss:</i> cochlear implant</p> <p><i>Patients with mild, moderate or severe conductive hearing loss:</i> bone anchored hearing aid</p>
Outcome	<p><i>Effectiveness:</i> APHAB, client-oriented scale of improvement, patient-related outcomes, quality of life</p> <p><i>Safety:</i> Complication/adverse event rate, mortality, revision surgery</p>
Language	Non-English articles will be excluded unless they appear to provide a higher level of evidence than English language articles. Translation of such articles will significantly increase the timeframe of the review.

Literature databases

Initial eligibility on the basis of the collated study citations was conservatively determined by one reviewer (i.e. if unclear from the abstract, or if the reviewer was unsure, the full text paper was ordered). One reviewer then assessed each of the retrieved full text articles for eligibility, with another assessing those over which there was doubt. When consensus could not be reached, a third reviewer independently assessed the paper in question and the majority decision prevailed. A list of studies which met the inclusion criteria but were subsequently excluded from the report is provided at Appendix E. The bibliographies of all included studies were hand-searched for any relevant references which may have been missed through the literature searching (pearling).

Data extraction

Data were extracted by one researcher and checked by a second using standardised data extraction tables developed a priori. Data were only extracted and reported if stated in the text, tables, graphs or figures of the study, or if they could be accurately extrapolated from the data presented.

Description and methodological quality of included studies

The evidence presented in the selected studies was assessed and classified using the dimensions of evidence defined by the National Health and Medical Research Council (NHMRC 2000). These dimensions (Table 8) consider important aspects of the evidence supporting a particular intervention and include three main domains: strength of the evidence, size of the effect and relevance of the evidence. The first domain is derived directly from the literature

identified as informing a particular intervention. The last two require expert clinical input as part of its determination.

Table 8 Evidence dimensions

Type of evidence	Definition
Strength of the evidence	
Level	The study design used, as an indicator of the degree to which bias has been eliminated by design.*
Quality	The methods used by investigators to minimise bias within a study design.
Statistical precision	The <i>P</i> -value or, alternatively, the precision of the estimate of the effect. It reflects the degree of certainty about the existence of a true effect.
Size of effect	The distance of the study estimate from the "null" value and the inclusion of only clinically important effects in the confidence interval.
Relevance of evidence	The usefulness of the evidence in clinical practice, particularly the appropriateness of the outcome measures used.

*See Table 9

The three sub-domains (level, quality and statistical precision) are collectively a measure of the strength of the evidence. The designations of the levels of evidence are shown in Table 9.

Table 9 Designations of levels of evidence* according to type of research question (including tablenotes) (NHMRC 2000)

Level	Intervention §
I *	A systematic review of level II studies
II	A randomised controlled trial
III-1	A pseudorandomised controlled trial (ie alternate allocation or some other method)
III-2	A comparative study with concurrent controls: Non-randomised, experimental trial † Cohort study Case-control study Interrupted time series with a control group
III-3	A comparative study without concurrent controls: Historical control study Two or more single arm study ‡ Interrupted time series without a parallel control group
IV	Case series with either post-test or pre-test/post-test outcomes

Tablenotes

* A systematic review will only be assigned a level of evidence as high as the studies it contains, excepting where those studies are of level II evidence.

§ Definitions of these study designs are provided on pages 7-8 How to use the evidence: assessment and application of scientific evidence (NHMRC 2000).

† This also includes controlled before-and-after (pre-test/post-test) studies, as well as indirect comparisons (i.e. utilise A vs B and B vs C, to determine A vs C).

‡ Comparing single arm studies i.e. case series from two studies.

Note 1: Assessment of comparative harms/safety should occur according to the hierarchy presented for each of the research questions, with the proviso that this assessment occurs within the context of the topic being assessed. Some harms are rare and cannot feasibly be captured within randomised controlled trials; physical harms and psychological harms may need to be addressed by different study designs; harms from diagnostic testing include the likelihood of false positive and false negative results; harms from screening include the likelihood of false alarm and false reassurance results.

Note 2: When a level of evidence is attributed in the text of a document, it should also be framed according to its corresponding research question e.g. level II intervention evidence; level IV diagnostic evidence.

Expert advice

An Advisory Panel with expertise in hearing loss was established to evaluate the evidence and provide advice to MSAC from a clinical perspective. In selecting members for advisory panels, MSAC's practice is to approach the appropriate medical colleges, specialist societies and associations and consumer bodies for nominees. Membership of the Advisory Panel is provided at Appendix B.

Results of assessment

Descriptive characteristics of included studies

Table 10 Included middle ear implant studies

Indication	Study type	Number of studies
Sensorineural hearing loss		
	<i>Comparative Studies</i>	
	MEI vs CI	1
	MEI vs BAHA	0
	MEI vs MEI	3
	MEI vs HA	14 ^a
	<i>Case Series</i>	
	Total	33
Mixed hearing loss		
	<i>Comparative Studies</i>	
	MEI vs CI	0
	MEI vs BAHA	0
	MEI vs MEI	0
	MEI vs HA	1 ^b
	<i>Case Series</i>	
	Total	16
Conductive hearing loss		
	<i>Comparative Studies</i>	
	MEI vs CI	0
	MEI vs BAHA	0
	MEI vs MEI	0
	MEI vs HA	0
	<i>Case Series</i>	
	Total	3
Undefined hearing loss (included for safety data only)		
	<i>Comparative Studies</i>	
	MEI vs CI	0
	MEI vs BAHA	0
	MEI vs MEI	1
	MEI vs HA	3
	<i>Case Series</i>	
	Total	4

a: Includes one FDA regulatory document

b: One cohort had two associated studies

c: Two cohorts had two associated studies

Effectiveness data for the MEI in comparison with the BAHA, CI or HA were extracted from comparative studies. Further effectiveness data for the MEI alone were extracted from comparative studies and case series studies. Effectiveness data were not extracted from case reports due to the inherent risk of bias in these studies.

Studies which included patients with profound hearing loss, but did not report outcomes for these patients separately, were excluded from the report. Those studies in which individual profound patient data could be excluded were included in the report.

Studies for assessment of safety and effectiveness

Middle ear implant compared with the cochlear implant

Safety

One study which compared the CI with the MEI was identified; however, this study did not include any safety data (Verhaegen et al 2008). A total of 20 case series were eligible for inclusion in this report (Table 11). No studies reported upon the severity of hearing loss in their cohorts.

Effectiveness

The systematic literature search identified one comparative study that directly compared the effectiveness of the MEI to the CI (Verhaegen et al 2008) (Table 11). All patients had SNHL of undefined severity.

Table 11 Included studies for cochlear implant

Study ID	Country	N	Follow-up (range)	Losses to follow-up	Outcomes assessed	
					Safety	Effectiveness
Bibas 2006	UK and Canada	650	-	-	✓	-
Biernath 2006	USA	4265 (3436 with implants without positioners; 829 with implants with positioners)	Patients without positioners: median 59 months Patients with positioners: median 42 months	-	✓	-
Brown 2009	USA	806 (44 revision procedures)	-	4 ^a	✓	-
Cote 2007	Canada	41 (45 cochlear implant revision surgeries)	-	-	✓	-
Cullen 2008	USA	952 implantations	Initial to revision procedure: mean 31.5 months (1.5-104.2)	-	✓	-
Dodson 2007	USA	345	-	-	✓	-
Hopfenspirger 2007	USA	268	-	-	✓	-
Lassaletta 2006	Spain	36	-	6 ^c	✓	-
Lin 2006	Taiwan	169	(3-11 years)	-	✓	-
Lloyd 2007a	UK	141	Mean 51 months (2-99 months)	45 ^d	✓	-
Migirov 2006	Israel	405	Minimum 6 months	-	✓	-
<i>Same cohort reported in Migirov 2007</i>						
Ovesen 2009	Denmark	313 implantations	Paediatric patients (n=180) median 44 months (5-115) Adult patients (n=120) median 32 months (5-114)	-	✓	-
Postelmans 2007	Netherlands	112	Paediatric patients (n=32) mean 26.7 months (1-48.2) Adult patients (n=80) mean 16.9 months (1-47.5)	2	✓	-
Ramsden 2007	UK and Netherlands	106 ears	-	-	✓	-
Shoman 2008	Canada	110	Mean 5.25 years (1-19 years) [SD 4.4 years]	-	✓	-
Stalfors 2008	Sweden	75 (45 u-shaped graft, 25 Dermatome)	Mean 36 months (28-74 months)	5 ^b	✓	-

Stratigouleas 2006	USA	176	Mean 289 days, median 154 days	-	✓	-
Taibah 2009	Saudi Arabia	131	Not reported (2-46 months) (visits every 3-6 months after surgery)	-	✓	-
Verhaegen 2008	Netherlands	202 (CI 123, MEI 32)	CI: 12 months MEI: minimum 8 weeks	-	✓	✓
Viccaro 2007	Italy	70	3 years	-	✓	-
Wootten 2006	USA	529	For 6 patients with CSF leak mean 40.2 months (5-52)	-	✓	-

a: Four patients had contralateral ear implanted and the original device was not available for analysis

b: Outcomes of five patients were not reported because they had graft types other than U-shaped or Dermatome

c: Six of 36 had incomplete questionnaire

d: 45 of 141 did not return the questionnaire

CI: cochlear implant; MEI: middle ear implant; - indicates not reported

Middle ear implant compared with the bone anchored hearing aid

Safety

No studies comparing the safety of both the BAHA and the MEI were identified. A total of seven case series which assessed the safety of BAHA implantation in a total of 619 patients were eligible for inclusion in this report (Table 12). A variety of hearing losses were treated including SNHL (Badran et al 2009; Gillett et al 2006; Yuen et al 2009), CHL (Badran et al 2009; Davids et al 2007; Gillett et al 2006; Lloyd et al 2007), MHL (Badran et al 2009; Lloyd et al 2007) and undefined hearing loss (Tjellstrom et al 2007). Four of the six studies stated that patients had either mild or moderate hearing loss (Badran et al 2009; Davids et al 2007; Lloyd et al 2007; Yuen et al 2009). The remaining studies did not provide any data on hearing loss severity.

Effectiveness

No comparative studies which directly compared the effectiveness of the MEI and the BAHA in patients with SNHL, MHL or CHL could be identified.

Table 12 Included studies for bone anchored hearing aid

Study ID	Country	N	Follow-up	Losses to follow-up	Outcomes assessed	
					Safety	Effectiveness
Badran 2009	UK	176 (178 BAHA)	Mean 50 months	2	✓	-
Davids 2007	Canada	40	-	-	✓	-
Gillett 2006	UK	63	> 6 months	Questionnaire returned by 41/59 patients ^a	✓	-
Lloyd 2007	UK	85 ears implanted	Mean 4.5 years	-	✓	-
Stalfors 2008	Sweden	75	Mean 36 months	5 ^b	✓	-
Tjellstrom 2007	Sweden	144	Mean 22.3 months	3	✓	-
Yuen 2009	Canada	34	Mean 22.4 months	13 ^c	✓	-

a: Only 38 or 40 replies were recorded for some questions because some patients felt questions were not applicable to them

b: Outcomes of five patients were not reported because they had graft types other than U-shaped or Dermatome

c: Complete 1-year data were only available for 21 patients

BAHA: bone anchored hearing aid; - indicates not reported

Middle ear implant

Safety

A total of 49 studies reported safety outcomes in patients receiving MEI. Twenty seven studies assessed patients with SNHL (Table 13), 15 studies assessed patients with MHL (Table 14) and three studies assessed patients with CHL (Table 15). An additional four studies assessed safety outcomes in patients with hearing loss that was not clearly defined (Table 16; Table 19). All patients who received the MEI had mild, moderate or severe hearing loss.

Effectiveness

Effectiveness outcomes after MEI implantation were reported for a total of 450 patients. For SNHL three level III studies were included (Snik et al 2004; Snik and Cremers 2004a; Snik et al 2007). In these studies all patients received the MEI and further comparisons were made either between different MEIs or different attachment types. Nine level IV studies were also assessed (Table 13) including two studies reporting upon one cohort (Mosnier et al 2008; Sterkers et al 2003).

For MHL and CHL only level IV studies were identified and assessed. For CHL four studies reported upon two cohorts, with each cohort reported upon twice (Suzuki et al 1994 and Suzuki et al 1995; Yanagihara et al 1997 and Yanagihara et al 2001).

Effectiveness outcomes were not included for an identified study which assessed the effectiveness of MEI yet did not clearly state the type of hearing loss (Stieve et al 2009).

Table 13 Included studies for middle ear implant for sensorineural hearing loss

Study ID	Country	N	Follow-up	Losses to follow-up	HL severity	MEI implanted	Outcomes Assessed	
							Safety	Effectiveness
Level III								
Snik 2004	Netherlands	13	>12 months	-	Severe	VSB n=8 and MET n=5	✓	✓
Snik 2004a	Netherlands	13	Minimum 6 months	2	Moderate	VSB	✓	✓
Snik 2007	Netherlands	23	12 months	1	Moderate	VSB n=14 and MET n=9	-	✓
Level IV								
Barbara 2009	Italy	6	-	3	Moderate	Envoy Esteem	✓	✓
Cremers 2008	Netherlands	1	6 years after original surgery; 26 months after revision	0	Moderate	VSB	✓	-
Fisch 2001	Switzerland; Netherlands; Germany; Italy; France; UK (10 centres)	47	12 weeks	0	Mild to severe	VSB	✓	✓
Foyt 2006	USA	8	MI group mean 2 years; traditional group mean 3.7 years	0	Moderate	VSB	✓	✓
Garin 2002	Belgium (2 centres)	9	Mean 15.6 months	0	Moderate to severe	VSB	-	✓
Snik 1999	Netherlands	7	Minimum 2 months after AP fitting	0	Moderate to severe	VSB	✓	✓
Snik 2000	Netherlands	6	8-19 months	-	Moderate	VSB	✓	-
Snik 2006	Netherlands	21	6-24 months	4	-	VSB n=13 and MET n=8	✓	✓
Sterkers 2003	France (21 centres)	125	3-5 months	30	Mild to severe	VSB	✓	✓
<i>Same cohort reported in Mosnier 2008</i>								
Todt 2005	Germany	2	-	0	-	VSB	✓	-
Vincent 2004	France (several centres)	39	16 months	-	Moderate	VSB	✓	-
Zenner 2000	Germany	20	6 months	1	Moderate to severe	TICA	✓	✓
Zenner 2003	Germany	13	Minimum 6 months	-	Moderate to severe	TICA	✓	✓
Zenner 2004	Germany	20	6 months	1	Moderate to severe	TICA	✓	✓

MET: Otologics Middle Ear Transducer; TICA: Totally Implantable Cochlea Amplifier; VSB: Vibrant Soundbridge; - indicates not reported

Table 14 Included studies for middle ear implant for mixed hearing loss

Study ID	Location	N	Follow-up	Losses to follow-up	HL severity	MEI implanted	Outcomes assessed	
							Safety	Effectiveness
LEVEL IV								
Colletti 2006	Italy	7	9 months	-	Severe	VSB	✓	✓
Colletti 2009	Italy	19	36 months	-	Moderate to severe	VSB	✓	✓
Cuda 2009	Italy	8	Mean 12 months	0	Moderate	VSB	✓	✓
Dumon 2009	France	13	6 months after implantation, then annually	0	Moderate	VSB	✓	✓
Dumon 2007	France	1	-	-	Severe	VSB with a stapedotomy piston	✓	-
Foyt 2006	USA	1	Mean 2 years	0	Moderate	VSB	✓	✓
Lefebvre 2009	France and Belgium	6	12 months	0	Moderate	MET	✓	✓
Streitberger 2009	Italy	40	3 months post-surgery, then 6-9 months	0	Severe	VSB	✓	✓
Suzuki 1989	Japan	9 (10 ears)	-	0	Moderate	Rion device	✓	✓
Suzuki 1994 <i>Same cohort reported in Suzuki 1995</i>	Japan	30	Mean 4 years 4 months	11	-	Rion device	✓	-
Tono 2000	Japan	3	2-4 years postoperatively	0	Moderate to severe	Rion device	✓	-
Tringali 2009	France	1	15 months	0	Severe	Carina with MET V transducer	✓	-
Venail 2007	France	4	-	0	Moderate to severe	VSB and MET	✓	-
Yanagihara 1997 <i>Same cohort reported in Yanagihara 2001</i>	Japan	9	Mean 54 months	1	Moderate	Rion device	✓	✓

MEI: middle ear implant; MET: Otologics Middle Ear Transducer; VSB: Vibrant Soundbridge; - indicates not reported

Table 15 Included studies for middle ear implant for conductive hearing loss

Study ID	Location	N	Follow-up	Losses to follow-up	HL severity	MEI implanted	Outcomes assessed	
							Safety	Effectiveness
LEVEL IV								
Frenzel 2009	Germany; Italy	7	8 months	-	Moderate	VSB	✓	✓
Siegert 2007	Germany; USA	5	Minimum 3 months	-	Moderate to severe	MET	✓	✓
Tringali 2008	France	1	15 months	0	Severe	Carina	✓	-

MEI: middle ear implant; MET: Otologics Middle Ear Transducer; VSB: Vibrant Soundbridge; - indicates not reported

Table 16 Included studies for middle ear implant for undefined hearing loss

Study ID	Location	N	Follow-up	Losses to follow-up	HL severity	MEI implanted	Outcomes assessed	
							Safety	Effectiveness
LEVEL III								
Stieve 2009	Germany	34	Minimum 12 months	-	-	MET n=19 and VSB n=15	✓	-

MEI: middle ear implant; MET: Otologics Middle Ear Transducer; VSB: Vibrant Soundbridge; - indicates not reported

Middle ear implant vs external hearing aids

Expert opinion from the Advisory Panel suggested that the external hearing aid (HA) should not be considered as a direct comparator for the purposes of this report. From the clinical decision flow charts (see Figure 2, Figure 3, Figure 4) it can be seen that patients must have failed a trial of external hearing aid before being considered for MEI. However, the Advisory Panel also recognised that if MEI became more widely available some patients may consider it an attractive option and that demand for MEI may be greater than current BAHA or CI procedures. Therefore the Advisory Panel felt that a brief comparison of the HA and the MEI may prove to be informative, and that a discrete assessment should be provided.

A total of 18 comparative studies were identified which directly compared the effectiveness of the MEI and the HA, and these were analysed by hearing loss type and severity. Fourteen studies assessed patients with mild to severe SNHL (Table 17) and one assessed patients with severe MHL (Table 18). No comparative studies informed upon patients with CHL.

Effectiveness outcomes were not included for three identified studies which assessed the effectiveness of MEI vs HA yet did not clearly state the type of hearing loss (Kodera et al 1994; Schmuziger et al 2006; Truy et al 2008).

Table 17 Comparative studies for the middle ear implant versus hearing aid in sensorineural hearing loss

Study ID	Country	N	Follow-up	Losses to follow-up	HL severity	MEI implanted	Outcomes assessed	
							Safety	Effectiveness
Chen 2004	USA	7	12 months	0	Mild to severe	Envoy	✓	✓
Fraysse 2001	France	25	6 months	-	Mild to severe	VSB	✓	✓
Hough 2001	USA	10	6 months	-	Moderate to moderately severe	SOUNDTEC	✓	✓
Jenkins 2004	USA, Europe	282	12 months	NR ^a	Moderate, moderately severe or severe	MET	✓	✓
Jenkins 2007	USA	20	3 months	-	Moderate	MET	✓	✓
Luetje 2002	USA, Europe	53 ^b	5 months	-	Severe	VSB	✓	✓
Matthews 2002	USA	103	20 weeks	8 ^c	Severe	SOUNDTEC	✓	✓
Roland 2001	USA	23	20 weeks	-	Severe	SOUNDTEC	✓	✓
Snik 2001	Netherlands	15	2 months	1	Moderate to severe	VSB	✓	✓
Thill 2002	Belgium	13	3 months	-	Moderate	VSB	✓	✓
Todt 2002	Germany	5	1.5 years	-	Mild to severe	VSB	✓	✓
Todt 2005	Germany	23	-	-	Mild to severe	VSB	✓	✓
Uziel 2003	France	6	3 months	0	Mild to moderate	VSB		✓
Verhaegen 2008	Netherlands	202 (HA n=47; CI n=123; MEI n=32)	MEI and HA: minimum 8 weeks; CI: 1 year	-	-	MET		✓

a: Speech scores reported for only US patients. Various patient numbers are reported throughout results with no details provided e.g. 178, 214, 160

b: 50/53 were fitted with the D audio processor

c: Eight patients had not completed testing at time of publication

CI: cochlear implant; HA: hearing aid; MEI: middle ear implant; MET: Otologics Middle Ear Transducer; VSB: Vibrant Soundbridge; - indicates not reported

Table 18 Comparative studies for the middle ear implant versus hearing aid in mixed hearing loss

Study ID	Location	N	Follow-up	Losses to follow-up	HL severity	MEI implanted	Outcomes assessed	
							Safety	Effectiveness
Tos 1994 <i>Same cohort reported in Caye-Thomasen 2002</i>	Denmark	9	3 months	3	Severe	Heide System	✓	✓

HL: hearing loss; MEI: middle ear implant; - indicates not reported

Table 19 Comparative studies for the middle ear implant versus hearing aid in undefined hearing loss

Study ID	Location	N	Follow-up	Losses to follow-up	HL severity	MEI implanted	Outcomes assessed	
							Safety	Effectiveness
Kodera 1994	Japan	6	-	-	Moderate	Rion device	✓	-
Schmuziger 2006	Switzerland	24	Mean 42 months	4	Moderate	VSB	✓	-
Truy 2008	France	6	3 months of MEI use	-	Moderate	VSB	✓	-

MEI: middle ear implant; VSB: Vibrant Soundbridge; - indicates not reported

In addition to the identified level III studies one Food and Drug Authority (FDA) regulatory document was identified (Symphonix Devices, Incorporated 2000) (Table 20). This document assessed the effectiveness of MEI compared with the HA in a cohort of 54 patients with mild to moderate SNHL. As this document has not been published in a peer-reviewed journal and was authored by an MEI manufacturing company, the data from this cohort have been presented separately throughout the report.

Table 20 FDA regulatory document for middle ear implant for sensorineural hearing loss

Study ID	Country	N	Follow-up	Losses to follow-up	HL severity	MEI implanted	Outcomes assessed	
							Safety	Effectiveness
Symphonix Devices, Incorporated, 2000	USA	54	5 months postoperatively plus an additional 6 weeks to acclimatise to the Vibrant D audio processor	1 ^a	Moderate to severe	VSB with the D audio processor	✓	✓

^a One patient's device did not activate and patient was not evaluated
HL: hearing loss; MEI: middle ear implant; VSB: Vibrant Soundbridge

Variation in middle ear implant devices

The comprehensive literature searching identified several different MEI devices (Table 21). Each device aimed to directly drive the ossicular chain through vibrations produced by either piezoelectric or electromagnetic transducers (Kulkarni and Hartley 2008). The major characteristics of the different devices have been summarised in Table 21.

Table 21 Middle ear implant devices identified in the literature search

MEI	Fully or semi implantable	Transducer	Surgical technique	Attachment method	Other details
Envoy Esteem	Fully	P	The transducer is fixed within a mastoidectomy cavity by hydroxyapatite cement. The transducer drives a rod which is connected to the head of the stapes. The device both drives and senses on the ossicular chain, leading to feedback issues. The long process of the incus is removed to prevent this (Counter 2008).	Glass ionomeric cement (Counter 2008)	Expert opinion indicates that this device is presently undergoing clinical trials in the UK, India and the USA, with Australian patients recruited. If this MEI is turned off, the patient has a conductive hearing loss due to the removal of the long process of the incus Activities such as swimming and diving are possible whilst using the implant.
Otologics MET	Semi	E	The device is implanted within the temporal bone and middle ear space via an extended atticotomy.	A laser creates a hole within the body of the incus and the transducer's tip is inserted. Upon healing the transducer tip becomes fixed to the incus via a flexible fibrous union (Bankaitis and Fredrickson 2002)	This device was previously known as the Carina.
Rion device	Semi	P	The device is implanted via a transmastoid approach (Yanagihara et al 2001). A retroauricular skin incision is made, and the mastoid cortex widely exposed to allow implantation. The fixing plate of the vibrator element is attached to the temporal bone with titanium screws (Yanagihara et al 1997)	A hydroxyapatite tube is glued between the tip of the vibrator and the head of the stapes (Counter 2008)	
SOUNDTEC	Semi	E	The implantation may be performed as a day procedure under local anaesthesia through a transcanal stapedotomy approach (Murugasu 2005; Wade 2002). A tympanomeatal flap provides access to the middle ear. The magnet is placed on the incudostapedial joint and the eardrum flap is closed (Murugasu 2005). The magnet is driven via a coil placed in a mould placed within the external ear canal.	The incudostapedial joint is disarticulated and the attachment loop of the magnet is placed over the neck of the stapes (Counter 2008).	The patient has to wear a hearing aid-type device in the middle ear.

TICA	Fully	P	The device is implanted via a postauricular incision and mastoidectomy (Wood 2002). The transducer is placed in the mastoid cavity and coupled to the incus. The sensor is implanted subcutaneously in the posterior bony wall of the auditory canal. The battery and audio processor are enclosed in a capsule which, similar to a cochlear implant receiver, is implanted subcutaneously behind the ear in a recess created in the temporal bone (Zenner et al 2003).	A titanium coupling rod is connected to the long incus process or the incus body. This attachment may be accompanied by a reversible malleus neck dissection, which produces an air-bone gap to intensify the volume and suppress feedback (Zenner 2000; Zenner et al 2004)	Activities such as swimming and diving are possible whilst using the implant (Zenner et al 2003). If the device is turned off, the patient has a conductive hearing loss due to the dissection of the malleus neck.
Vibrant Soundbridge	Semi	E	The VORP is implanted under the skin posterior-superior to the pinna at a 45° angle to the ear canal. The VORP's electromagnetic transducer is electrically connected to the internal receiver (Wade 2002).	The FMT is attached to the incus by a titanium clip, which is formed around the long process of the incus with a specialised forceps (Counter 2008).	This MEI is considered to be reversible as attachment does not permanently alter the middle ear (Arthur 2002). FMT attachment may lead to erosion of the incus (Hough et al 2001)

E: electromagnetic; P: piezoelectric; FMT: floating mass transducer; MEI: middle ear implant; MET middle ear transducer; TICA: Totally Implantable Cochlea Amplifier; VORP vibrating ossicular prosthesis

Expert clinical opinion advises that the placement of any MEI device in the middle ear, regardless of attachment method, may lead to a conductive hearing loss. Additionally the above table represents the typical attachment method for each MEI. Nine included studies reported that atypical measures, such as bone cement or fascia, were necessary to ensure MEI stability (Colletti et al 2009; Cremers et al 2008; Dumon et al 2009; Frenzel et al 2009; Lefebvre et al 2009; Snik and Cremers 2004a; Streitberger et al 2009; Todt et al 2002). Further, nine included studies reported upon instances in which the MEI device itself was modified (Table 22). Generally the titanium clip of the MEI was removed or shortened to permit implantation, and this was mostly performed in patients with mixed or conductive hearing loss due to particular anatomic constraints. Hence, differences in components and attachment may either occur between the six identified different MEI devices (Table 21) or between patients receiving the same MEI (Table 22).

Table 22 Studies which reported modification of the middle ear implant

Study ID	MEI type	Modification
SNHL		
Cremers 2008	VSB	The grip of the FMT was removed and the FMT was attached to the stapes head with SerenoCem
MHL		
Colletti 2009	VSB	The titanium clip of the FMT was cut
Cuda 2009	VSB	The titanium clip of the FMT was cut
Lefebvre 2009	MET	A modified TORP was clipped to the end of the transducer
Streitberger 2009	VSB	The titanium clip of the FMT was cut
Tos 1994	Heide system	The hydroxylapatite shaft of the PORP was cut nearly totally off
CHL		
Frenzel 2009	VSB	The titanium clip of the FMT was removed
Siegert 2007	MET	The coupling device was modified. A prosthesis specially produced for this study by Kurz Co., Munich, Germany, was used for sound transmission

CHL: conductive hearing loss; FMT: floating mass transducer; MEI: middle ear implant; MET: Otologics Middle Ear Transducer; MHL: mixed hearing loss; SNHL: sensorineural hearing loss; TORP: total ossicular replacement prosthesis; VSB: Vibrant Soundbridge

Systematic reviews

No systematic reviews which assessed the middle ear implant were identified. Two horizon scanning documents were identified (Canadian Coordinating Office for Health Technology Assessment (CCOHTA) 2003; Comité d'Évaluation et de Diffusion des Innovations Technologiques (CEDIT) 2002).

One document was published in France in 2002 and provided a concise overview of the MEIs which were available in that market at the time (CEDIT 2002). Neither a search strategy nor a list of references was provided. The devices considered were the Vibrant Soundbridge, the Otologics Middle Ear Transducer and the SOUNDTEC Direct Drive Hearing System, all of which are also considered in MSAC Application 1137. The document stated that the MEI is for '...adults suffering from stable hearing loss, which is bilateral and relatively symmetrical, without fluctuation, in the mild (41 to 70 dB) to severe range (71 to 90 dB) with normal tympanometry, normal middle ear anatomy with no previous history of chronic middle ear disease or middle ear surgery, no inner ear disorder, and who are dissatisfied with a hearing aid.' The population considered by this document is more limited than that considered in MSAC Application 1137. A simple economic analysis was performed which stated that the cost of hospital-based management of the MEI in adults is approximately €10,000, of which 56 per cent was the cost of the device itself. This document noted that the undebatable medical indications for receiving the MEI are skin pathology or anatomical abnormality in the ear canal, due to the fact that this makes the use of the HA more difficult. It recommended the establishment of the defined audiological parameters for the use of the MEI.

The second document was published in Canada in 2003 and assessed the devices which were available at that time (CCOHTA 2003). A search strategy was not provided; however, a list of references was provided which included FDA information, clinical studies and newspaper articles. This document was primarily concerned with the SOUNDTEC Direct System, and briefly referred to the Vibrant Soundbridge and Otologics Middle Ear Transducer technologies, all of which are included in MSAC Application 1137. The population considered in this document was broad, comprising adult patients with moderate to severe deafness due to disorders of the auditory nerve. The SOUNDTEC manufacturer provided the cost of the device for the Canadian market. No further analysis was performed. The document concluded that semi-implantable MEI may be appropriate for those with moderate to severe hearing loss whom also experience difficulties with conventional hearing aids. It also highlighted the need for clinicians to undertake manufacturer-provided, specialised training in the use of the device.

Searches were also conducted for current ongoing trials, which are listed at Appendix F.

Critical appraisal

A total of 24 comparative studies (NHMRC level III) were identified and included in this report (Table 63). One study compared the CI with the MEI in patients with SNHL of undefined severity (Verhaegen et al 2008). No additional comparative studies assessed the MEI versus the CI or BAHA. Three comparative studies assessed the MEI with a further internal comparison (Snik et al 2004; Snik and Cremers 2004a; Snik et al 2007). These studies assessed the VSB MEI versus the MET MEI (Snik et al 2004; Snik et al 2007) and the crimping attachment alone versus crimping attachment plus cement (Snik and Cremers 2004a).

Nineteen comparative studies assessed the MEI versus the external HA. Thirteen of these studied patients with SNHL, two studied patients with MHL, and four studied patients with CHL. One additional comparative cohort assessed the MEI versus the HA in patients with SNHL (Symphonix Devices Incorporated 2000). This study was an FDA regulatory document which was produced by an MEI device manufacturer. This study was not reported in a peer-reviewed journal and has been presented separately throughout this report.

A total of 35 level IV studies were identified and included in this report (Table 64; Table 65; Table 66). Fifteen studies assessed the MEI in patients with SNHL; 16 assessed the MEI in patients with MHL; and three assessed the MEI in patients with MHL. The safety data from one additional case series which studied patients with undefined hearing loss was also included (Stieve et al 2009).

Critical appraisal of the level III and level IV studies has been performed separately, to reflect the methodological differences between these study types.

Critical appraisal of level III studies

A summary of the quality of the 25 comparative studies included in the report is reported in Table 63, and briefly outlined below. The criteria used were based on the CONSORT statement of Altman et al (2001).

Participants

One study reported retrospective data collection (Verhaegen et al 2008); however, the remaining 24 studies did not report study design. Six of the included studies reported that participants were consecutively enrolled (Fraysse et al 2001; Hough et al 2001; Luetje et al 2002; Matthews 2002; Snik and Cremers 2004a; Uziel et al 2003).

Eleven studies reported explicit inclusion and exclusion criteria (Chen et al 2004; Fraysse et al 2001; Hough et al 2001; Jenkins et al 2004; Jenkins et al 2007; Luetje et al 2002; Matthews 2002; Snik and Cremers 2001; Symphonix Devices, Incorporated 2000; Verhaegen et al 2008; Zenner et al 2004), while eight studies reported only inclusion criteria (Roland et al 2001; Snik et al 2007; Snik et al 2004; Snik and Cremers 2004a; Thill et al 2002; Todt et al 2005; Todt et al 2002; Truy et al 2008). Six studies failed to report inclusion or exclusion criteria (Caye-Thomasen et al 2002; Kodera et al 1994; Schmuziger et al 2006; Stieve et al 2009; Tos et al 1994; Uziel et al 2003).

Inclusion criteria used to recruit participants generally included symmetrical sensorineural hearing loss and chronic, therapy-resistant external otitis. Patients were generally excluded if they suffered from any physical, psychological or emotional disorder that would interfere with surgery or the ability to perform on test or rehabilitation procedures, or diseases of the EAC/middle ear/temporal bone.

Interventions and outcomes

The interventions were well described, with most of the 25 studies detailing both the implantation procedure and the implant utilised. However, studies generally lacked detail with regards to the technical settings of the implant. Only four studies reported upon this issue (Luetje et al 2002; Snik and Cremers 2001; Snik et al 2007; Snik et al 2004).

Most studies provided objective measurements of success in terms of functional gain/speech recognition and some included subjective measures of success such as the APHAB and quality of life scales (either validated or non-validated). Adverse events, if present, were generally adequately described.

Statistical methods

Statistical tests were generally employed in most of the studies, with 15 out of 25 comparative studies providing significance levels (*P*-values).

Follow-up and losses to follow-up

The length of follow-up amongst the 21 studies that reported follow-up ranged from two months to 9.5 years. Four studies did not report the length of follow-up (Hough et al 2001; Kodera et al 1994; Snik et al 2007; Todt et al 2005). Ten of the studies reported losses to follow-up (Caye-Thomasen et al 2002; Matthews 2002; Schmuziger et al 2006; Snik et al 2007; Snik and Cremers 2004a; Snik and Cremers 2001; Symphonix Devices, Incorporated 2000; Tos et al 1994; Uziel et al 2003; Zenner et al 2004), with eight studies detailing reasons for these losses (Matthews 2002; Schmuziger et al 2006; Snik et al 2007; Snik and Cremers 2004a; Snik and Cremers 2001; Symphonix Devices, Incorporated 2000; Uziel et al 2003; Zenner et al 2004).

Critical appraisal of level IV studies

An appraisal of the quality of the 29 level IV studies included in this report for effectiveness and safety is reported below and represented in Table 64; Table 65; and Table 66.

Participants

Of the 29 level IV studies selected for inclusion, seven were retrospective while the remaining were prospective studies. Sample sizes ranged from one to 125 patients; however, the majority of studies (22 out of 29) had less than 20 patients. Most studies provided clear inclusion criteria; however, only one study provided an exclusion criterion for patient selection.

Interventions and outcomes

The interventions were well described, with most studies (22 of 29 studies) detailing both the implantation procedure and the implant utilised. However, studies generally lacked detail with regards to the technical settings of the implant.

Most studies provided objective measurements of success in terms of hearing gain/speech recognition and some included subjective measures of success such as quality of life scales (validated and non-validated). Adverse events, if present, were generally adequately described.

Statistical methods

Statistical tests were generally not employed in most of the studies, with only five out of 29 studies providing significance levels (*P*-values).

Follow-up and losses to follow-up

Follow-up durations varied substantially between studies, from two to 62 months. Losses to follow-up were generally rare, with most studies successfully retaining patients. However, it is important to note that most studies had small sample sizes.

Is it safe?

One comparative study assessed patients who received either CI or MEI implantation; however, this study did not include any safety data (Verhaegen et al 2008). Twenty three comparative studies did provide safety data; however, as these studies did not assess the comparators of interest for this report (CI or BAHA), they were unable to inform on the relative safety of these procedures compared with MEI implantation (Table 63). Therefore, safety has been reported in an absolute manner.

Throughout the safety section event rate has been reported in two manners, both of which may be at risk of bias. The rate has been presented as a proportion of patients in the studies which specifically reported this outcome, which may be an over-inflated representation of the outcome, especially for rare events. The rate has also been presented as a proportion of the total patient number in all studies included for safety. This may be an under-representation of some outcomes, such as common outcomes which may not have been of interest in all studies (such as mild pain or infection).

Middle ear implant

Fifty studies reported upon safety outcomes in a total of 1222 patients receiving MEI. These patients had mild, moderate or severe SNHL, MHL or CHL. The fifty included studies comprised comparative studies (which assessed the VSB versus the MET; crimping attachment alone versus crimping attachment plus cement; and MEI versus the HA), case series, case reports and an FDA regulatory cohort. Safety data were included from four studies in which the HL indication was undefined (Kodera et al 1994; Schmuziger et al 2006; Stieve et al 2009; Truy et al 2008). Overall, patient populations ranged from one (Cremers et al 2008; Dumon 2007; Foyt and Carfrae 2006; Tringali et al 2009; Tringali et al 2008) to 282 (Jenkins et al 2004). Follow-up ranged from two months (Snik and Cremers 2001) to eight years (Mosnier et al 2008).

Mortality

Only three studies reported on mortality in their patient cohort (Mosnier et al 2008; Schmuziger et al 2006; Snik et al 2006). Seven patients were reported to have died in a total of 170 patients (4.1 per cent) (Table 23). This equates to an incidence of 0.57 per cent across all 1222 patients who received MEI. Where stated reported deaths were not attributed to the implantation; however, one study did not provide any detail (Mosnier et al 2008).

Table 23 Mortality after MEI implantation

Study ID	N	n	Rate where reported %	Rate across total number of patients %	Details
Mosnier 2008	125	5	4%	0.4%	-
Schmuziger 2006	24	1	4.1%	0.08%	unrelated causes
Snik 2006	21	1	4.8%	0.08%	manifested a degenerative disease

- indicates not reported

Adverse events

Table 24 details the reported adverse events which accompanied MEI implantation. Several studies reported upon adverse events or issues which were addressed and subsequently resolved by the device manufacturers, such as inability to charge the device (Jenkins et al 2007); upside-down implantation due to unclear packaging (Fisch et al 2001); and device failure (Mosnier et al 2008). These incidents have not been included in the calculations of adverse events as they occurred in the versions of devices which are clearly no longer available.

Event rate has been reported in two manners, both of which may be at risk of bias. The rate has been presented as a proportion of patients in the studies which specifically reported this outcome, which may be an over-inflated representation of the outcome, especially for rare events. The rate has also been presented as a proportion of the total patient number in all studies included for safety. This may be an under-representation of some outcomes, such as common outcomes which may not have been of interest in all studies (such as mild pain or infection).

Table 24 Adverse outcomes in 1222 patients receiving MEI implant

Outcome	Number of studies	Patients N=	Incidence n=	Rate where reported (%)	Rate across total number of patients (%)
Technical adverse events					
Facial nerve damage	8	296	3	1%	0.2%
Chorda tympani nerve damage	7	381	38	10%	3.1%
Extrusion	7	122	4 ^e	3.3%	0.3%
Migration	5	98	4 ^b	4.1%	0.3%
Device malfunction or failure	8	312	11 ⁱ	3.5%	0.9%
Electromagnetic interference	3	117	18	15.3%	1.5%
Insufficient gain	4	76	20 ^c	26.3%	1.6%
Clinical adverse events					
Stroke	1	9	1*	11.1%	0.1%
TM perforation	4	189	9 ^g	4.8%	0.7%
TM retraction	3	79	2	2.5%	0.2%
Infection	9	282	8 ^a	2.8%	0.7%
Pain	6	225	30	13.3%	2.5%
Haematoma	4	151	15 ^{h**}	9.9%	1.2%
Tinnitus	7	349	7 ^f	2%	0.6%
Vertigo	5	274	14	5.1%	1.1%
Aural fullness	3	199	45	22.6%	3.7%
Wound healing difficulties	4	54	0	0%	0%
Other	13	418	60 ^j	14.4%	4.9%
Device explant for other reasons	4	178	6 ^d	3.4%	0.5%

*This outcome was reported in a level III study with limited reporting. Expert clinical opinion suggests that MEI implantation causation is unlikely

** One patient was 14 years of age at implantation. The haematoma developed in the surgical site postoperatively and required minor surgical intervention to clean and evacuate. This follow-up included a 10-day course of antibiotics to prevent infection. Following the revision and antibiotics, the postoperative outcome was satisfactory with no further complications

a: One patient's MEI was explanted due to non-device related infection

b: One migration was due to MRI and revision surgery was required to reattach the MEI. One patient's MEI was removed and replaced by a homograft incus; two further patients underwent revision surgery

c: Two MEIs were explanted; one additional MEI was explanted and replaced with a CI

d: Two MEIs were explanted due to patient demand (these were functioning devices), one was explanted due to acute psychiatric problems, one was explanted due to a retroauricular fistula, one was explanted due to a developing perisynaptic defect and was replaced with a CI, one was removed due to ineffective repeated surgery

e: Three cases were revised with soft tissue coverage and healed without difficulty; one not reported

f: One MEI was explanted due to tinnitus

g: One perforation successfully repaired with patch; one perforation repaired by fascia; seven not reported

h: Two patients required revision surgery

i: One MEI was explanted, one MEI was replaced

j: Revision in eight patients, unsuccessful revision in one patient

Twelve studies with a total of 145 patients reported that there were no complications (Colletti et al 2009; Cuda et al 2009; Dumon et al 2009; Frenzel et al 2009; Lefebvre et al 2009; Siegert et al 2007; Snik and Cremers 1999; Suzuki et al 1995; Todt et al 2002; Todt et al 2005; Venail et al 2007; Vincent et al 2004). Three studies included children (Dumon et al 2009; Frenzel et al 2009; Tringali et al 2009). No adverse events were reported in children in two of these studies (Dumon et al 2009; Frenzel et al 2009). Tringali et al (2009) was a case study which assessed a 14-year-old child. This child developed a haematoma in the surgical site postoperatively and required minor surgical intervention to clean and evacuate. This follow-up included a 10-day course of antibiotics to prevent infection. Following the revision and antibiotics, the postoperative outcome was

reported to be satisfactory with no further complications. No association was made between the patient's age and this complication.

Several studies reported upon serious adverse events such as stroke and nerve damage (Table 24). One patient was reported to have had a stroke and was lost to follow-up (Tos et al 1994). Tos et al (1994) provided very limited reporting and did not include any information regarding this patient's age or comorbidities. Expert clinical opinion endorsed by the Advisory Panel felt that there was insufficient clinical information on which to assess whether the stroke was related to the MEI implantation process. Eight studies reported upon facial nerve damage (Cuda et al 2009; Fisch et al 2001; Fraysse et al 2001; Mosnier et al 2008; Sterkers et al 2003; Schmuziger et al 2006; Symphonix Devices, Incorporated, 2000; Thill et al 2002), with most reporting that there was no damage to the facial nerve (or no facial palsy). A total of three patients (1 per cent of patients in studies which reported this outcome; 0.2 per cent across all MEI patients) suffered facial palsy after MEI implantation (Fraysse et al 2001; Symphonix Devices, Incorporated 2000). All three patients suffered from SNHL and received a VSB implant. One case of palsy resolved spontaneously six weeks after onset while the other two cases were resolved with medical management. One study recommended the routine use of a facial nerve monitor to help prevent facial nerve damage (Fraysse et al 2001).

Seven studies reported upon damage to the chorda tympani nerve (Fisch et al 2001; Matthews 2002; Mosnier et al 2008; Sterkers et al 2003; Schmuziger et al 2006; Snik et al 2007; Symphonix Devices, Incorporated 2000). Seven studies used the VSB device and the remaining study used the SOUNDTEC device. The chorda tympani was severed in six patients, while possible damage to the chorda tympani occurred in 32 patients and was characterised by transient taste disturbance. Several studies reported that this resolved over time (Fisch et al 2001; Mosnier et al 2008; Symphonix Devices, Incorporated 2000).

Two studies reported that the MEI was removed and replaced with a cochlear implant (Colletti et al 2009; Todt et al 2005). In one patient this exchange was due to insufficient gain from the VSB MEI (Colletti et al 2009) and in the second patient was due to a developing perisynaptic defect (Todt et al 2005). No other studies reported replacement of the MEI with either the BAHA or the CI. However, in an additional study one patient discontinued use of their Heide system MEI due to misfitting, pain and apoplexia and subsequently used a HA in the operated ear (Caye-Thomassen et al 2002).

Residual hearing

In addition to these adverse events MEI implantation may cause a decline in residual hearing due to either the noise generated during the surgical procedure (Snik and Cremers 2000) or mass loading of the ossicular chain. For example the Otologics MET includes a push rod which may compromise the mobility of the ossicular chain, whereas the VSB may affect residual hearing primarily by the added mass (Stieve et al 2009). Additionally, manipulation of the ossicular chain may introduce CHL.

Most included studies reported upon residual hearing loss and considered a mean threshold change of greater than 5 dB across all frequencies to be clinically significant (Fisch et al 2001). Twenty four studies reported that no significant decline in mean residual hearing loss occurred after MEI implantation (Cuda et al

2009; Dumon 2007; Dumon et al 2009; Fisch et al 2001; Foyt and Carfrae 2006; Fraysse et al 2001; Frenzel et al 2009; Hough et al 2001; Jenkins et al 2004; Jenkins et al 2007; Lefebvre et al 2009; Luetje et al 2002; Matthews 2002; Roland et al 2001; Sterkers et al 2003; Siegert et al 2007; Stieve et al 2009; Streitberger et al 2009; Suzuki et al 1995; Thill et al 2002; Todt et al 2004; Todt et al 2005; Tringali et al 2009; Truy et al 2008). However, thirteen studies reported significant declines in mean residual hearing loss after MEI implantation (Table 25). MEI implantation in patients with CHL did not have a significant negative effect upon residual hearing.

Table 25 Description of studies in which there was a mean residual hearing loss

Study ID	Patients N	HL severity	MEI device	Location of MEI attachment
SNHL				
Barbara 2009	3	Moderate	Envoy	Incus and stapes
Chen 2004	7	Mild to severe	Envoy	Incus and stapes
Mosnier 2008	125	Mild to severe	VSB	-
Symphonix 2000	54	Moderate to severe	VSB	-
Todt 2002	5	Mild to severe	VSB	Incus
Snik 2004a	13	Moderate	VSB	Incus
Vincent 2004	39	Moderate	VSB	-
Zenner 2003	13	Moderate to severe	TICA	Incus
MHL				
Colletti 2006	7	Severe	VSB	Round window
Suzuki 1995	19	-	Rion device	-
Undefined				
Schmuziger 2006	24	Moderate	VSB	-
Stieve 2009	34 (19 MET, 15 VSB)	-	MET and VSB	Mastoid and incus

CHL: conductive hearing loss; HL: hearing loss; MEI: middle ear implant; MHL: mixed hearing loss; MET: Otologics Middle Ear Transducer; SNHL: sensorineural hearing loss; - indicates not reported

Several studies also reported clinically significant changes in the hearing of individual patients after MEI implantation (Table 26). Again, implantation did not negatively affect the residual hearing of patients with CHL.

Table 26 Individual patients with significant residual hearing loss after middle ear implantation

Study ID	N patients	HL severity	MEI type	Incidence of significant hearing loss	
				n	%
SNHL					
Fraysse 2001	25	Mild to severe	VSB	5	20%
Luetje 2002	50	Severe	VSB	2	4%
Snik 2001	14	Moderate to severe	VSB	1	7.1%
Symphonix 2000 ^a	54	Moderate to severe	VSB	2	3.7%
Fisch 2001	47	Mild to severe	VSB	7 ^b	14.9%
Snik 1999	7	Moderate to severe	VSB	1	14.3%
Sterkers 2003	125	Mild to severe	VSB	3	2.4%
Vincent 2004	39	Moderate	VSB	6	15.4%
MHL					
Caye-Thomasen 2002	6	Severe	Heide system	4	66.7%
Cuda 2009	8	Moderate	VSB	1	12.5%
Dumon 2009	13	Moderate	VSB	1	7.6%
Suzuki 1989	9 ^c	Moderate	Rion device	3	33.3%
Suzuki 1995	16	-	Rion device	2 ^d	12.5%
Undefined					
Schmuziger 2006	15	Moderate	VSB	4	26.7%

a: Not published in a peer-reviewed journal

b: Patients with significant changes in unaided thresholds in the implanted ear did not demonstrate changes to the same degree in the nonimplanted ear. Thus, these changes cannot be attributed to systematic influences such as anaesthesia, measurement error, or patient-specific influences.

c: 10 ears in nine patients

d: Patients continued to use the device all the time

MEI: middle ear implant; MHL: mixed hearing loss; SNHL: sensorineural hearing loss; VSB: Vibrant Soundbridge

Air-bone gap

As placement of the MEI may affect conductive hearing, the presence and extent of a postoperative air-bone gap (ABG) may inform further upon the safety of implantation. One study reported upon postoperative ABG in patients with SNHL (Foyt and Carfrae 2006). The mean ABG (4 dB) is consistent with the equivalent air and bone conduction present in SNHL, suggesting that a conductive hearing loss was not introduced to these patients. Five studies reported upon the ABG in patients with MHL (Colletti et al 2009; Dumon 2007; Dumon et al 2009; Streitberger et al 2009; Suzuki et al 1989) (Table 27). Generally MEI implantation reduced the ABG, suggesting that conductive hearing was improved. Two studies reported overclosure of the ABG, which occurs when the postoperative AC threshold is lower than the preoperative BC threshold (Fucci et al 1998). The ABG was overclosed by 15 to 17 dB (Colletti et al 2009; Streitberger et al 2009). Overall, where reported, mean ABG was improved after implantation.

Table 27 Air bone gap after MEI implantation in patients with MHL

Study ID	MEI type	Site of attachment	Mean preoperative ABG	Mean postoperative ABG	Improvement or decline
Colletti 2009	VSB	Round window	38.28 dB [SD 11.9]	-19.38 [SD 7.5]	Overclosure
Cuda 2009	VSB	Round window	23.6 dB	32.3 dB	Decline
Dumon 2007	VSB	Incus	32 dB	11 dB	Improvement
Dumon 2009	VSB	Round window/incus	17 dB	20 dB	Decline
Streitberger 2009	VSB	Round window niche, stapes footplate, stapes superstructure, cochlear fenestration	-	Not reported (overclosure of the ABG of approximately 17 dB)	Overclosure
Suzuki 1989	Rion device	-	36.6 dB	3.5 dB	Improvement

ABG: air bone gap; dB: decibels; MEI: middle ear implant; SD: standard deviation; VSB: Vibrant Soundbridge; - indicates not reported

In two studies the ABG worsened postoperatively (Cuda et al 2009; Dumon et al 2009). In one study the AC threshold was significantly worse after MEI implantation ($P < 0.05$) although there was no significant change in BC threshold (Cuda et al 2009). The authors attributed this to a modification of the transfer function of the middle ear induced by the FMT on the round window membrane. In the second study a variety of mixed hearing losses presented, but only patients with chronic otitis whose MEI was implanted on the round window ($n=2$) displayed this decline (Dumon et al 2009). However, in a further study in which all patients had chronic otitis media and round window implantation of the MEI, the ABG was over-closed by 15 dB (Colletti et al 2009).

The stapedius reflex occurs when the stapedius muscle contracts in reaction to a loud sound. The reflex thresholds refer to the softest intensity levels that can trigger the response. Two studies reported upon stapedius reflex thresholds (Luetje et al 2002; Snik and Cremers 2000). One study found that in patients with recordable acoustic reflexes before surgery, there were no absent reflexes at the same frequencies at three months postactivation (Luetje et al 2002). The second study reported that an increase in stapedius reflex thresholds was generally found shortly after surgery (Snik and Cremers 2000).

Summary of safety for middle ear implant

No comparative evidence was available to inform on safety of the MEI compared with either the BAHA or CI. Comparative, case series and case report data on a total of 1222 patients who received MEI were available. The comparative studies compared the VSB with the MET, or the MEI with the HA, and drew no safety-related comparisons between these devices. There were no deaths associated with MEI implantation. Most adverse events were relatively rare and of low severity. Serious adverse events such as facial nerve damage were reported to have occurred rarely (0.2 per cent across all MEI patients). Damage to the chorda tympani nerve was reported more commonly (3.1 per cent across all MEI patients); however, some instances of taste disturbance were reported to have been transient and to have resolved over time. Technical complications related to the device, including device malfunction, migration, or insufficient gain were relatively rare (0.3 to 1.6 per cent across all patients).

Residual hearing loss after MEI implantation was reported upon by most studies, with 13 studies reporting that patients suffered significant declines in mean residual hearing loss after MEI implantation.

Expert clinical opinion suggests that some safety issues may be more specific to children. Across the identified studies only one adverse event, a haematoma, was reported to have occurred in a child. No association was made between the age of this patient and the complication.

Cochlear implant

One comparative study included patients who received either MEI or CI implantation (Verhaegen et al 2008). However this study did not provide any safety data. In the absence of comparative data, all safety outcomes for CI implantation were sourced from case series. Twenty case series with a total of 9704 participants met the inclusion criteria and were included (Table 11). Several studies implanted the CI only in children (Bibas et al 2006; Biernath et al 2006; Cullen et al 2008; Hopfenspirger et al 2007; Lin et al 2006) and the remaining studies implanted either in adults, or in both adults and children. None of the included case series reported upon the severity of hearing loss. Due to the indications for this procedure it is likely that some patients were afflicted with profound hearing loss.

The included case series were all retrospective; however, all enrolled patients consecutively. Sixty two patients were lost to follow-up; however, 45 of these patients were lost in one study through a failure to return the questionnaire (Lloyd et al 2007a). Where reported, follow-up ranged from one to 115 months.

Event rate has been reported in two manners, both of which may be at risk of bias. The rate has been presented as a proportion of patients in the studies which specifically reported this outcome, which may be an over-inflated representation of the outcome, especially for rare events. The rate has also been presented as a proportion of the total patient number in all studies included for safety. This may be an under-representation of some outcomes, such as common outcomes which may not have been of interest in all studies (such as mild pain or infection).

Mortality

One study with a total of 4265 participants reported upon patient mortality, and found that two children died after CI implantation due to bacterial meningitis (Biernath et al 2006).

Table 28 Clinical adverse events in 9704 patients receiving a cochlear implant

Outcome	Number of studies	Patients N=	Incidence n=	Rate where reported (%)	Rate across total number of patients (%)
Meningitis	4	5380	44 ^a	0.82%	0.45%
MRSA in radical cavity	1	313	1	0.32%	0.01%
Cerebrospinal fluid leak	4	1320	13 ^b	0.98%	0.13%
Dural injury	1	952	2 ^c	0.21%	0.02%
Chorda tympani nerve sectioning	1	141	14	9.92%	0.14%
Mastoiditis	3	750	15 ^d	2%	0.15%
Infection	10	2637	48 ^e	1.82%	0.49%
Perilymphatic fistula	2	450	2 ^f	0.44%	0.02%
Implant rejection	1	952	1	0.11%	0.01%
Taste disturbance	4	522	49 ^g	9.39%	0.50%
Abscess formation	5	1656	14 ^h	0.85%	0.14%
Haematoma	2	457	2 ⁱ	0.43%	0.02%
Temporal muscle spasms with trismus	1	45	1 ^j	2.2%	0.01%
Flap/wound healing difficulties	4	1839	48 ^k	2.6%	0.49%
Injury to the EAC	1	952	2	0.21%	0.02%
Tympanic membrane perforations	2	243	6 ^l	2.47%	0.06%
Vestibular symptoms	1	110	64 ^m	58.18%	0.66%
Light-headedness	1	110	31 ⁿ	28.18%	0.32%
Unsteadiness	2	286	55 ^o	19.23%	0.57%
Myringoplasty	1	131	1 ^p	0.76%	0.01%
Tinnitus	4	1276	13	1.02%	0.13%
Vertigo	4	328	31 ^q	9.45%	0.32%
Other	7	2646	42 ^r	1.7%	0.43%
Revision surgery (other reasons)	1	176	6 (reason not documented)	3.41%	0.06%

a: 41 episodes of bacterial meningitis in 38 children, two of whom died; one case of meningitis in a patient with cerebrospinal fluid (CSF) gusher at time of surgery, the patient recovered completely with the implant in place. Two cases resulted in electrode migration

b: One had CSF leak intraoperatively while the bony well was drilled and was immediately sealed (healed well with good outcomes); one delayed CSF leak; five CSF gushers, six all controlled at initial surgery (three required only electrode insertion, hyperventilation, and cochleostomy packaging with fascia or periosteum. In two cases cochleostomy packaging was augmented with partial or complete middle ear packing. One also required packing of the Eustachian tube and supplemental fibrin glue. No patient required lumbar puncture, and all patients received perioperative antibiotics)

c: Two repaired intraoperatively

d: One required mastoidectomy and hardware removal and consequently elected not to undergo reimplantation; one patient treated with mastoidectomy

e: One subsequent to a fall and necessitated removal of the implant; eight wound infections (three cases required antibiotic therapy), two infections around the pedestal site; implant removal in 21 cases and followed with successful reimplantation in 14 cases; one wound infection and device extrusion requiring explantation; one flap infection requiring oral antibiotics and topical ointment and resolved after four weeks; one pseudomonas infection which was most likely due to intra-operative fluid contamination (controlled with medical and surgical treatment but device explanted due to reoccurrence of infection); one infection as a result of injured skin at the receiver site (implant explanted after failure of debridement of the wound and extensive antimicrobial therapy)

f: One led to revision surgery

g: Three managed by observation, 18 patients had long-term taste disturbance, one resolved after first postoperative visit

h: 10 required revision surgery, one was an incision stitch abscess which resolved with oral antibiotics and topical wound care

i: One was a subdural haematoma which required burr-hole craniotomy and evacuation of the haematoma without permanent neurological sequelae

j: Healed well with good outcomes

k: 24 required revision; three managed with rotational flap, frequent dressing changes and oral antibiotics

l: TM perforations in four children after acute otitis media, all healed spontaneously after medication administration

m: Preoperatively 53 patients had symptoms and postoperatively 64 patients showed symptoms

n: Preoperatively 23 patients had symptoms and postoperatively 31 patients had symptoms

o: In one study preoperatively 35 patients had symptoms and postoperatively 51 patients had symptoms. In the other study one patient had symptoms with device use only while three patients had transient postoperative vestibulopathy

p: No details provided

q: Shoman preoperatively 30, postoperatively 40 (counted as 10 in the table). Viccaro n=8, seven occurred in the implanted side and one in the opposite side (was overcome via surgery in six, one patient presented chronic symptoms regardless of the manoeuvres performed)

r: Led to explantation n=5; led to contralateral implantation n=5; led to revision n=7; led to reimplantation n=3

Table 29 Technical adverse events in 9704 patients receiving a cochlear implant

Outcome	Number of studies	Patients N=	Incidence n=	Rate where reported (%)	Rate across total number of patients (%)
CI migration	4	2037	6 ^a	0.3%	0.06%
Device exposure	2	1119	4 ^b	0.36%	0.04%
Facial nerve paralysis	5	1388	8 ^l	0.36%	0.08%
Non-use of CI	2	762	2 ^c	0.26%	0.02%
Electrode migration	3	1464	4 ^d	0.4%	0.04%
Electrode extrusion	3	1128	9 ^e	0.8%	0.09%
Stimulator extrusion	1	45	1 ^f	2.2%	0.01%
Cable erosion	1	45	1	2.2%	0.01%
Misplacement of electrode	6	1939	15 ^g	0.8%	0.15%
Device failure	8	3278	126 ^h	3.83%	1.3%
Unable to replace electrode	1	952	2 ⁱ	0.2%	0.02%
Electrode kinked in cochlea	1	952	1 ⁱ	0.1%	0.01%
Fragility and weight of the processor	1	36	1	2.8%	0.01%
Poor discrimination	1	36	1	2.8%	0.01%
Magnet issues	3	1247	5 ^j	0.4%	0.05%
Device breakage	1	169	1 ^k	0.6%	0.01%
Electrode malfunction	1	112	1	0.9%	0.01%
Partial insertion	1	57	7	12.3%	0.07%

a: Three required repositioning, two repositioning not required, one required revision surgery

b: Two due to device infection and one due to development of bony overgrowth under the implant; one in a diabetic patient with a skin defect, whose device was explanted

c: One non-user due to abnormal cochlear nerve adaption, one no details

d: Two not reported, one required replacement; one required complete drill-out procedure due to fibrosis and ossification of the basal turn of the cochlea

e: Included one child

f: Extrusion at wound in paediatric patient

g: Seven required revision, five required repositioning

h: Six re-implanted; 27 revised

i: Required revision

j: Three patients magnet was displaced and required revision surgery

k: Required reimplantation

l: Five were transient facial palsy (three of which were reported to have resolved), one was a result of thermal injury where initially a House-Brackmann II-IV progressed to a VI/VI and then recovered to a II/IV.

Meningitis

A total of 44 episodes of meningitis, including 41 episodes in children, were reported (Biernath et al 2006; Brown et al 2009; Ovesen and Johansen 2009) (Table 28). Twenty seven (71 per cent) of the children with meningitis had CI implantation with positioners (wedges inserted next to the CI in earlier device models which were voluntarily removed from the market in 2002 in response to reports received by the FDA). A 2002 study indicated that the incidence of meningitis among patients who had received a CI with a positioner remained higher than the incidence among those whose CI did not have a positioner for the duration of 24 months post-implantation follow-up (Reefhuis et al 2003). This finding was supported by the results in Biernath et al (2006), as the incidence rate of ≥ 24 month post-implantation meningitis for children with positioners was 450 cases per 100,000 person-years (95% CI 165-980 cases per 100,000 person-years) compared with none for those without positioners. However, six children also had factors other than a CI that might have predisposed them to meningitis such as inner ear malformations, CSF leak, previous meningitis, history of recurrent

otitis media, tympanostomy tubes, and acute otitis media at the time of presentation.

Soft failure

Several studies described ‘soft failure’ as an adverse event (Brown et al 2009; Cullen et al 2008; Lin et al 2006; Ramsden et al 2007). Generally, soft failure encompassed events of nonauditory stimulation such as unwanted twitching of the facial nerve, pain and dizziness (Ramsden et al 2007). A total of 70 adverse events were attributed to soft failure (0.72 per cent of all patients who received CI). Several of these events were managed by remapping (switching off certain electrodes) or through medication.

Some adverse events were reported which appeared to be related to the patients’ anatomy. One patient with an absent auditory nerve required revision surgery (Cullen et al 2008). Difficult insertion of the CI was encountered in 15 patients (0.8 per cent of patients in studies which reported this outcome; 0.15 per cent of all patients who received CI). Two children experienced a foreign body reaction while one child had an allergic reaction to the CI, and all three patients required revision surgery (Migirov et al 2007). One adult also had a foreign body reaction and required revision surgery (Migirov et al 2007).

Wound healing

One study provided extensive information on wound reactions and classified these using the system described by Holgers et al (1988) (Stalfors and Tjellstrom 2008). Briefly, the scale comprises 0=no irritation, 1=slight redness, 2=red and moist tissue, 3=red and moist with granulation tissue, 4=revision of skin penetration necessary (Lloyd et al 2008). These were analysed with respect to the surgical technique employed used when implanting the CI (Table 30). As the dermatome method creates an elevated skin graft without hair follicles, patients may find it easier to maintain the implant site area. The U-shaped graft had 19.6 per cent more skin reaction episodes than the dermatome group, but this was not significantly different ($P=0.14$).

Table 30 Skin reaction grades according to surgical technique

Grade	Dermatome n=25		U-graft n=45	
	Observations	%	Observations	%
0	86	95	234	91.4
1	1	1.1	18	7.0
2	3	3.3	4	1.6
3	0	0	0	0
4	0	0	0	0
Total	90	100	256	100

Summary of safety for cochlear implant

Twenty case series with a total of 9704 patients were available to inform of the absolute safety of CI for hearing loss. This increased number of patients compared with MEI study information reflects the more established nature of CI as a treatment for hearing loss.

Several intracranial adverse events which were reported in CI patients were absent in MEI patients. Importantly meningitis was reported in 44 CI patients, two of whom died. Most of the patients with meningitis were children. Two CI patients were reported to have received dural damage during drilling of the receiver/stimulator well which was repaired intraoperatively (Dodson et al 2007). This study suggested that CIs which require a smaller well to accommodate the receiver/stimulator necessitate less drilling near the dura, which is likely to lead to fewer dural injuries. Cerebrospinal fluid leak was also reported exclusively in CI patients (13 patients).

Conversely, several events were reported more frequently in MEI than in CI patients. The incidence of tympanic membrane perforation was higher in the MEI patients (0.7 per cent for all MEI patients compared with 0.06 per cent for all CI patients), most likely due to the techniques used for MEI implantation. Haematomae also occurred more frequently in MEI than in CI patients (1.2 per cent for all MEI patients compared with 0.02 per cent for all CI patients). Extrusions also occurred more frequently in MEI than in CI patients.

Rates of damage to the chorda tympani and the facial nerves were similar between the CI and MEI patients. Additionally, the CI and MEI devices appeared to be similar in terms of failure rates.

None of the included CI studies reported upon residual hearing outcomes after implantation. This may be because the patients considered for CI implantation are likely to have severe or profound HL; therefore, any further deterioration in hearing may be of lesser clinical importance compared with losses in patients with mild or moderate HL. Expert clinical opinion advises that CI implantation is not usually performed in patients with residual hearing.

Due to the lack of comparative evidence it is not possible to accurately compare the rates of adverse events between patients receiving the MEI or CI. Overall, there was some variability in outcomes between CI and MEI. However, in terms of absolute number and general severity, the safety issues between MEI and CI are similar both in terms of clinical and technical outcomes.

Bone anchored hearing aid

No comparative studies were available to inform on the safety of BAHA implantation. Seven case series with a total of 619 patients met the inclusion criteria for this report and were included. One study implanted the BAHA in adults only (Yuen et al 2009); and the six remaining studies included children in their population. Two studies included children exclusively (Davids et al 2007; Lloyd et al 2007). Although the included case series were retrospective, all enrolled patients consecutively. Patient populations tended to be larger in the BAHA studies than in the MEI studies, ranging from 34 (Yuen et al 2009) to 178 (Badran et al 2009).

Event rate has been reported in two manners, both of which may be at risk of bias (Table 31). The rate has been presented as a proportion of patients in the studies which specifically reported this outcome, which may be an over-inflated representation of the outcome, especially for rare events. The rate has also been presented as a proportion of the total patient number in all studies included for safety. This may be an under-representation of some outcomes, such as common outcomes which may not have been of interest in all studies (such as mild pain or infection).

Mortality

Only one study reported upon mortality (Gillett et al 2006). This study reported that one patient died, but did not provide any further details. It was unclear whether or not the death was due to BAHA implantation.

Table 31 Adverse events in 619 patients receiving BAHA implantation

Outcome	Number of studies	Patient N=	Incidence n=	Rate where reported (%)	Rate across total number of patients (%)
BAHA loss	1	85	8 ^d	9.4%	1.29%
Traumatic fixture loss	3	303	23	7.6%	3.72%
Traumatic loss of osseointegration	3	407	10 ^{a,b}	2.5%	1.62%
Loss of osseointegration	4	425	28 ^{a,c}	6.6%	4.52%
Failed osseointegration	1	85	6 ⁱ	7.1%	0.97%
Extrusion	1	21	0	0%	0%
Skin growth over abutment	4	347	55 ^e	14.3%	8.89%
Loss of skin graft	1	178	4 ^f	2.2%	0.65%
Patient unsatisfied with gain	2	229	3 ^g	1.3%	0.48%
Infection	5	491	39 ^h	7.9%	6.3%
Intraoperative haemorrhage	1	21	0	0%	0%
Cerebrospinal fluid leakage	1	21	0	0%	0%
Hair growth over graft	2	148	3 ⁱ	2%	0.48%
BAHA use cessation for other reasons	2	263	18 ^k	6.8%	2.91%
Bony overgrowth	2	263	14 ^l	6.8%	2.26%
Pain in BAHA region	1	178	7 ^m	3.9%	1.13%
Incorrect placement of BAHA	1	85	5 ⁿ	5.9%	0.81%
BAHA revision (other reasons)	1	85	1 (reason not documented)	1.2%	0.16%
Bleeding	1	178	31 ^o	17.4%	5.01%
Incision of the jugular vein	1	178	1 ^p	0.6%	0.16%
Dura exposed	1	178	3 ^q	1.7%	0.48%

a: Four patients decided to abandon their BAHA and 27 requested revision

b: In one patient reosseointegration took place and the patient was wearing the implant at the time of follow-up, in two patients the abutment was tightened

c: One patient had a nontraumatic loss with multiple revisions (and also traumatic losses) and had a suspected bone disorder; three led to loss of implant

d: The mean age of children experiencing fixture loss was significantly less (7.8 years SD 4 years) compared with mean age in those without fixture loss (9.6 years SD 3.5 years) ($P=0.05$)

e: Generally managed patients with debridement and local wound care; one patient required minor flap revision; 13 had revision stage II, one had BAHA resited, three had BAHA implanted in opposite ear, three awaiting revision, two no intervention

f: Three patients had partial failures (grafts healed within one month without further complications) and one patient had total necrosis of the skin flap (healed by primary intention). In one study children with split grafts from fixture site were less likely to develop hypertrophy of the graft than those with full thickness Wolfe grafts or split grafts taken from other areas (11 vs 36%, $P<0.01$) (Lloyd et al 2007)

g: Two couplings were removed but the fixtures left in place; one child realised he heard better with his original air conduction hearing aids

h: One patient had repeat infections around the implant site (conservative treatment and removal of the coupling was unsuccessful in providing infection resolution and consequently the implant was removed); 21 patients responded well to antibiotics, regular cleaning and Tri-Adcortyl ointment; three resulted in loose abutment; six resulted in abutment loss; three resulted in fixture loss; three resulted in contralateral BAHA; two patients were admitted to hospital for intravenous antibiotic treatment for severe infection of granulations

i: Electrolysis required in one patient; revision stage II required in two patients

j: All led to fixture loss; two failed osseointegration on the initial side (led to contralateral insertion of BAHA); one child never used the aid due to failed osseointegration

k: One child developed progressive SNHL which became unaidable with BAHA; one child played regular sport and found BAHA a hindrance; four abandoned by patient, 12 BAHAs removed

l: Six required revision stage II; four led to BAHA implantation in opposite ear; one awaiting intervention; one no intervention; two required removal by drilling

m: Four patients required removal of the abutment and flange fixture

n: BAHAs were implanted in an inappropriate position to allow auricular reconstruction or bone-anchored auricular prosthesis placement, and were all revised with contralateral insertion of BAHA

o: Three patients planned as day cases had to stay overnight because of bleeding; five patients had bleeding from the bone which was controlled using bone wax; 23 patients had recurrent bleeding around the abutment after 24 hours after operation

p: Sealed with a fibromuscular plug from the vastus lateralis and the operation was abandoned. The operation was subsequently completed with the placement of the fixture and the abutment somewhat more superiorly than usual

q: Did not lead to adverse events

Damage to jugular vein

One patient suffered damage to the jugular vein during BAHA implantation (Badran et al 2009). The incision was sealed with a fibromuscular plug and this operation was abandoned. A subsequent operation resulted in placement of the fixture and the abutment more superiorly than usual.

Wound healing

Two studies provided more extensive information on wound reactions, and classified these using the system described by Holgers et al (1988) (Badran et al 2009; Lloyd et al 2007). Briefly, the scale comprises 0=no irritation, 1=slight redness, 2=red and moist tissue, 3=red and moist with granulation tissue, 4=revision of skin penetration necessary (Lloyd et al 2008). In one study of children (n=85) 37 per cent had a score ≥ 2 at some stage, 91 per cent of which had settled by the subsequent appointment (Lloyd et al 2007). Eighty per cent of children with thickening of graft required revision surgery. In the second study (n=178 implantations) 37 reactions took place within the first postoperative year (Badran et al 2009). Twenty six of these (70 per cent) were type 2 reactions which were managed with local ointments and oral antibiotics. A total of 11 type 3 reactions were reported. These were managed with either silver nitrate cautery to the granulations in five cases or granulation tissue excised under general anaesthetic in six cases (followed by grafting in three cases). A total of three type 4 reactions were reported, all requiring temporary removal of the abutment. One of these patients subsequently abandoned their BAHA. Forty two patients had incomplete healing of the graft at the first follow-up visit, but no treatment was required (Badran et al 2009).

Generally, BAHA patients reported more wound healing difficulty than MEI patients. This is likely to be due to the skin grafts employed in BAHA implantation, as well as the additional maintenance care required for the BAHA's abutment area.

Children receiving BAHA

Paediatric bone is softer than that of adults, and has a longer osseointegration time, and hence may be more susceptible to device loosening or damage. Four studies reported specifically on fixture loss in children (Badran et al 2009; Davids et al 2007; Lloyd et al 2007; Tjellstrom et al 2007). In one study (n=178) 36 per cent of patients aged less than 16 had failed fixture, compared with 16 per cent of patients older than 16 (Badran et al 2009). Another study (n=40) reported five traumatic fixture losses in children and one failure of osseointegration (this child suffered multiple revisions and traumatic losses, and was suspected to have a bone disorder) (Davids et al 2007). A third study (n=85) reported that 22 children experienced fixture loss (Lloyd et al 2007). The mean age of children experiencing fixture loss (7.8 years SD 4) was significantly less than the mean age in those without fixture loss (9.6 years SD 3.5) ($P=0.05$). Two children were reported to have had failed osseointegration. The final study (n=138) reported that of the two BAHAs lost, one was in a child and one was in an adult (Tjellstrom et al 2007).

Expert clinical opinion suggests that children may be less likely to perform adequate hygiene and maintenance of their BAHA site, which may cause fixture loss. Only two included studies reported upon skin reactions in children after BAHA implantation (Davids et al 2007; Lloyd et al 2007 as reported above).

Davids et al (2007) (n=40) reported that three children required skin revisions which were related to poor hygiene and less than adequate upkeep of the surgical site.

Summary of safety for bone anchored hearing aid

Seven case series with a total of 619 patients were used to inform on the absolute safety of the BAHA for hearing loss.

Owing to the surgical techniques used, the devices implanted and the sites of implantation, several adverse events which were reported in MEI implantation were not encountered in BAHA implantation, and vice versa. Examples of these included skin and bony growth over the abutment (BAHA), and tinnitus and vertigo (MEI). However, other events may reasonably be expected to occur in either BAHA or MEI implantation.

Expert clinical opinion suggests that some safety issues may be likely to occur more frequently in children, such as damage to the device or difficulties with osseointegration. The inclusion of children in the BAHA studies may have artificially inflated the incidence of certain adverse events. Several studies included children yet did not report safety outcomes separately to those for adults.

The BAHA devices appeared to be more technologically consistent than the MEI, with no reported instances of BAHA device malfunction or failure compared with 0.9 per cent of all MEI devices implanted. Additionally, insufficient gain was more prevalent in MEI studies (1.6 per cent of all patients receiving MEI) than in BAHA studies (0.48 per cent of all patients receiving BAHA).

Once positioned, the MEI appeared to be more stable than the BAHA. Although 0.3 per cent of all MEIs migrated, loss of osseointegration or failed osseointegration was commonly encountered in the BAHA studies (4.52 per cent and 0.97 per cent respectively). The BAHA also appeared to be more susceptible than the MEI to damage or loss due to trauma. Device loss due to trauma was not encountered in the MEI studies yet 3.72 per cent of all implanted BAHAs were lost for this reason. Additionally, osseointegration was lost due to trauma in 1.62 per cent of all implanted BAHAs. Expert clinical opinion suggests that paediatric bone is softer than that of adults, and has a longer osseointegration time, and hence may be more susceptible to device loosening or damage.

Generally, BAHA patients reported more wound healing difficulty than MEI patients. This is likely to be due to the skin grafts employed in BAHA implantation, as well as the additional maintenance care required for the BAHA's abutment area.

Due to the absence of comparative evidence it is not possible to accurately compare the rates of adverse events between patients receiving MEI or CI. In summary, it appears as if MEI is at least as safe as BAHA.

Other safety considerations

Safety of MEI in MRI

Two studies reported upon a total of three patients who underwent MRI after VSB implantation (Schmuziger et al 2006; Todt et al 2004). In one case report two patients underwent MRI scanning with 1.5 T (Todt et al 2004). One patient experienced functional gain from the MEI, while the second patient did not due to auditory neuropathy. The patient with functional gain described a loud, banging sound during the scanning procedure but did not report any vertigo, tinnitus, or related symptoms. After the MRI there were no changes in functional gain of this patient's VSB. Neither patient experienced changes in the function of the external magnets at testing. MRI scanning did not visibly alter the fixation of the FMT clamp to the long process of the incus, and no fractures of the receiver's bony bed on the skull surface were found in either patient. However one patient's incus had some erosion on the surface of the long process where the MEI was attached.

A second case series reported upon one patient who underwent MRI (Schmuziger et al 2006). This patient's VSB was dislocated after MRI, and revision surgery was necessary to reattach the transducer to the incus.

Communication with the manufacturer of the VSB device (Med-EL) indicates that this MEI is not MRI safe at any Tesla level. It can be removed if necessary (personal communication, 2009).

Stability

Patients may elect to use the MEI rather than the BAHA due to perceived stability in the event of head trauma. The BAHA was refused in one patient on the grounds that he was a rowdy boy, which was considered to heighten the risk of BAHA damage (Tringali et al 2008). This perception may be supported to an extent as no losses of MEIs due to trauma were reported, compared with 3.72 per cent of all implanted BAHA devices. Additionally 1.62 per cent of all implanted BAHAs lost osseointegration due to trauma.

Summary of safety

No comparative evidence reporting on the safety of MEI compared with CI or BAHA was available. RCT evidence based on defined patient populations would better inform on any safety differences between MEI and the comparator procedures. In the absence of comparative safety data, information on the absolute safety of MEI, BAHA and CI implantation was included in this report. Even with the limitations in inclusion criteria for BAHA and CI data, much more evidence in terms of absolute patient numbers was available for CI. This reflects the fact that MEI is in its infancy compared with other more established alternatives.

Not all safety outcomes were uniformly reported across the identified studies. To address this, event rate has been reported in two manners throughout the report, both of which may be at risk of bias. The rate has been presented as a proportion of patients in the studies which specifically reported this outcome, which may be an over-inflated representation of the outcome, especially for rare events. The rate has also been presented as a proportion of the total patient number in all studies included for safety. This may be an under-representation of some outcomes, such as common outcomes which may not have been of interest in all studies (such as mild pain or infection).

Owing to the surgical techniques used, the devices implanted and the sites of implantation, several adverse events which were reported in BAHA or CI implantation were not encountered in MEI implantation. Several intracranial adverse events which were reported in CI patients were absent in MEI patients, including meningitis (which led to two deaths in children), dural damage and cerebrospinal fluid leak. The BAHA appeared to be more susceptible than the MEI to damage or loss due to trauma. Device loss due to trauma was not encountered in the MEI studies yet 3.72 per cent of all implanted BAHAs were lost for this reason, and osseointegration was lost due to trauma in 1.62 per cent of all implanted BAHAs. Expert clinical opinion suggests that paediatric bone is softer than that of adults, and has a longer osseointegration time, and hence may be more susceptible to device loosening or damage. Once positioned, the MEI appeared to be more stable than the BAHA. Although a small percentage of all MEIs migrated, loss of osseointegration or failed osseointegration was quite commonly encountered in the BAHA studies. Generally, BAHA patients reported more wound healing difficulty than MEI patients. This is likely to be due to the skin grafts employed in BAHA implantation, as well as the additional maintenance care required for the BAHA's abutment area.

Conversely, several adverse were reported more frequently in MEI implantation than in BAHA or CI implantation. The incidence of tympanic membrane perforation was higher in MEI patients (0.7 per cent) than in CI patients (0.06 per cent), and was not reported for BAHA patients. Haematomae occurred more frequently in MEI patients (1.2 per cent) than in CI patients (0.02 per cent). Extrusions also occurred more frequently in MEI than in CI patients, and were not reported to have occurred in BAHA patients. Insufficient gain was more prevalent in MEI studies (1.6 per cent of all patients receiving MEI) than in BAHA studies (0.48 per cent of all patients receiving BAHA). Insufficient gain was not reported in CI patients. The BAHA devices appeared to be the most technologically consistent of the three devices, with no reported instances of BAHA device malfunction or failure compared with 1.3 per cent of all CI devices and 0.9 per cent of all MEI devices implanted.

Residual hearing loss after implantation was an important adverse event which was uniquely reported in MEI patients. Expert clinical opinion advises that there is also a

significant risk of residual hearing loss in CI implantation, and that there is no risk of residual hearing loss in BAHA implantation. Residual hearing loss was reported upon by most MEI studies, with 13 studies reporting that patients suffered significant declines in mean residual hearing loss after MEI implantation. Unlike the CI literature, the MEI literature included many patients with mild or moderate HL. In these patients, any further deterioration in hearing may be of greater clinical importance compared with losses in patients with severe or profound HL. Patients with CHL did not report significantly worse residual hearing after implantation.

Expert clinical opinion endorsed by the Advisory Panel notes that certain adverse events are likely to be more commonly seen in children than in adults. Paediatric bone is softer than that of adults, and has a longer osseointegration time, and hence may be more susceptible to device loosening or damage. Additionally, children may be likely to sustain head trauma during rambunctious play. Children may also be less reliable at cleaning and maintaining their implant site. This may be especially important in the case of the BAHA.

Due to the differences in devices and the surgical procedures associated with them, the adverse events differ between MEI and its comparators. Overall, absolute evidence from case series studies suggests that MEI appears to be as safe as CI and BAHA.

Is it effective?

Comparative effectiveness data have been presented according to the five PICO populations identified in Table 4, Table 5 and Table 6 and listed below:

1. In patients with mild or moderate SNHL is the MEI more effective than the BAHA?
2. In patients with severe SNHL is the MEI more effective than the CI?
3. In patients with mild or moderate MHL is the MEI more effective than the BAHA?
4. In patients with severe MHL is the MEI more effective than the CI?
5. In patients with CHL is the MEI more effective than the BAHA?

Additionally, one comparative study reported effectiveness outcomes for MEI versus the CI in patients with SNHL of undefined severity (Verhaegen et al 2008). Due to the paucity of comparative studies identified, any effectiveness outcomes reported in this study have been included in this section.

An additional question has been included to inform on the effectiveness of MEI versus external HAs.

1. In patients with mild or moderate sensorineural hearing loss is the middle ear implant more effective than the bone anchored hearing aid?

No comparative studies which assessed the effectiveness of the MEI versus the BAHA in patients with mild or moderate SNHL were identified.

2. In patients with severe sensorineural hearing loss is the middle ear implant more effective than the cochlear implant?

No comparative studies which assessed the effectiveness of the MEI versus the CI in patients with severe SNHL were identified.

2a. In patients with sensorineural hearing loss of undefined severity is the middle ear implant as effective as the cochlear implant?

One comparative study (NHMRC level III-3) assessed the effectiveness of the CI versus the MEI in patients with SNHL of an undefined severity (Verhaegen et al 2008). A total of 10 patients used the Otologics MET and 123 patients used the CI, and patients were not reported to have been consecutively enrolled. All implants were performed unilaterally. MEI assessments were performed at least eight weeks postoperatively and CI assessments were conducted at one year follow-up to permit stabilisation of hearing; however, this retrospective study did not report upon losses to follow-up. The effectiveness outcomes were reported using projected data rather than actual measures.

Quality of life and satisfaction measures

This study did not report upon quality of life or satisfaction measures.

Technical outcomes

The study measured each patient's maximum phoneme score (MPS) and used these to form a best fitted nonlinear regression line, representing the best score possible. The assessors then obtained each patient's aided phoneme score in quiet at normal conversational level (65 dB sound pressure level). Comparisons were made for each hearing device's relationship to the MPS line. In patients whose mean SNHL exceeded 85 dB HL this study found that 90 per cent of patients had better speech recognition scores with a CI than with the Otologics MET. The study also suggested that in patients with external otitis and whose mean SNHL was less than 85 dB HL, the PS65 score with the MEI was projected to be 42 per cent or less, while the PS65 score with the CI was projected to be greater than 42 per cent.

Summary of the effectiveness of the middle ear implant vs the cochlear implant in patients with sensorineural hearing loss of undefined severity

One comparative study was included (NHMRC level III). Ten included patients received MEI implantation, compared with 123 patients who received CI implantation. No quality of life or patient satisfaction measures were used to compare the effectiveness of the CI and the MEI. Only two technical effectiveness outcomes were reported as projected, and not actual, measures. For projected **speech recognition scores** in relation to the best score possible, 90 per cent of patients with severe hearing loss were likely to record better speech recognition scores with the CI than with the MEI. In patients with external otitis and whose mean SNHL was less than 85 dB HL, the **PS65 score** with the MEI was projected to be 42 per cent or less, while the PS65 score with the CI was projected to be greater than 42 per cent.

On the basis of this single study: regarding projected speech recognition in patients with severe hearing loss, MEI appears to be less effective than CI. Regarding projected PS65 score in patients with mild, moderate or severe hearing loss, MEI appears to be less effective than CI.

3. In patients with mild or moderate mixed hearing loss is the middle ear implant more effective than the bone anchored hearing aid?

No comparative studies which assessed the effectiveness of the MEI versus the BAHA in patients with mild or moderate MHL were identified.

4. In patients with severe mixed hearing loss is the middle ear implant more effective than the cochlear implant?

No comparative studies which assessed the effectiveness of the MEI versus the CI in patients with severe MHL were identified.

5. In patients with conductive hearing loss is the middle ear implant more effective than the bone anchored hearing aid?

No comparative studies which assessed the effectiveness of the MEI versus the BAHA in patients with CHL were identified.

As only one comparative study was available to inform upon the relative effectiveness of the MEI compared with the BAHA and the CI, absolute effectiveness outcomes were collated for the MEI implantation alone. These outcomes were reported in level III and level IV studies. This information has been presented according to hearing loss indication and severity representative of the five populations: mild or moderate SNHL; severe SNHL; mild or moderate MHL; severe MHL; and CHL. Effectiveness outcomes which were reported in patients with SNHL or MHL of undefined severity have also been included and presented.

Importantly, few studies explicitly stated whether preoperative baseline measures were recorded with or without an external HA.

1. Is the middle ear implant effective in patients with mild or moderate sensorineural hearing loss?

A total of four studies, including two comparative studies and two case series, were used to assess the effectiveness of the MEI in patients with mild or moderate SNHL. It was not clearly stated whether baseline measures were measured with or without a HA.

Comparative studies

Two comparative studies (one NHMRC level III-2, one NHMRC level III-3) assessed the effectiveness of different types of MEI in 36 patients with mild or moderate SNHL (Snik and Cremers 2004a; Snik et al 2007). One study compared attachment types when implanting the VSB device (Snik and Cremers 2004a); while the second study compared the VSB and the Otologics MET in relation to baseline hearing (Snik et al 2007). Snik et al (2007) studied 23 patients and Snik and Cremers (2004a) studied 13 patients. Neither study reported whether or not these patients were consecutively enrolled. A total of three patients were lost to follow-up. Snik et al (2007) reported that one patient was excluded from analysis due to sudden symmetrical hearing deterioration after implantation, owing to hereditary diabetes. Snik and Cremers (2004a) reported that two patients were excluded from analysis: one due to chronic aeration problems which led to a chronic air-bone gap after surgery; and one due to pre-surgical hearing loss which exceeded the eligible range. While Snik et al (2007) stated that all patients had external otitis and were unable to successfully wear a conventional HA, it was not clearly stated whether or not baseline measures were unaided.

Quality of life and satisfaction measures

One study presented patient-reported outcomes in patients who received the VSB or the Otologics MET (Snik et al 2007). Quality of life was reported with the Glasgow Benefit Inventory (GBI), which is a standardised questionnaire utilised to examine the impact of benefit derived from an otological treatment. GBI scores 12 months after implantation were comparable for the VSB and the Otologics MET. MEI implantation led to significant improvements on the overall benefit (32.9 ± 15.4) ($P < 0.001$) and the general scores (41.5 ± 15.2) ($P < 0.001$). Improvements were also noted on the social subscale (17.6 ± 23.9) and the physical subscale (15.7 ± 37.5). After implantation patients could hear well without pain and/or itching. The authors suggested that the relatively high mean GBI scores

may be due to the difficulties encountered by the patients when wearing any conventional HA, due to their external otitis.

Technical outcomes

Abbreviated Profile of Hearing Aid Benefit (APHAB)

One comparative study reported APHAB outcomes in patients with SNHL (Snik et al 2007). On average patients showed significant improvement in the Ease of Communication subscale after implantation ($P < 0.001$). Other subscales also showed improvements (Table 32).

Table 32 Mean difference between pre- and post-implantation APHAB subscales

APHAB Subscale	Difference after implantation (%)	P-value
EC	19.6 (9.0-30.1)	<0.001
RV	12.7 (2.6-22.9)	0.02
BN	9.2 (1.3-17.2)	0.03
AV	-2.5 (-12.7-7.7)	ns

EC: ease of communication; RV: reverberation; BN: background noise; AV: aversiveness; ns: not significant

Individual patients with significant improvement or deterioration in the APHAB subscales are summarised in Table 33.

Table 33 Individual differences between pre- and post-implantation APHAB subscales

APHAB Subscale	Significant Improvement n	Significant Deterioration n
EC	10	0
RV	9	1
BN	6	0
AV	1	1
Joint subscales (EC, RV, BN)	6	1

EC: ease of communication; RV: reverberation; BN: background noise

There were no significant pre- to post-implantation differences between the VSB and Otologics MET for all four subscales of the APHAB.

Fitting and attachment

The effectiveness of attaching the MEI by crimping alone was compared with crimping plus SerenoCem fixation (Snik and Cremers 2004a). Measured aided thresholds were subtracted from the target aided thresholds. At 2 kHz the group with crimping plus SerenoCem fixation was 10 dB better than the group with crimp fixation alone ($P < 0.05$). No significant differences were reported at any other frequencies.

One study reported upon the adequacy of the audio processor fitting by comparing the mean functional gain of the MEI with the National Acoustic Laboratories (NAL) target gain (Snik et al 2007). The average difference between the measured gain and target gain was 2.3 ± 6.4 dB (-11.5 to 7.6 dB), indicating that the audio processor fitting was adequate (Snik et al 2007).

In summary, comparative evidence from two studies suggests that there are no significant differences between different types of MEI device.

Case series

Two case series reported effectiveness outcomes of the MEI in 14 patients with mild or moderate SNHL (Barbara et al 2009; Foyt and Carfrae 2006). The case series had small patient numbers (Barbara et al 2009 n=6; Foyt and Carfrae 2006 n=9). Both were prospective studies and enrolled patients consecutively. Barbara et al (2009) did not report the length of follow-up or any losses to follow-up, while Foyt and Carfrae (2006) followed patients for 24 months and reported that one patient was lost to follow-up.

Quality of life and satisfaction measures

Neither study reported upon quality of life or satisfaction measures.

Technical outcomes

Functional gain

Both studies reported upon mean functional gain provided by the MEI (Table 34), and both found that gain was provided.

Table 34 Functional gain in patients with mild or moderate SNHL

Study ID	N	Functional gain
Barbara 2009	3	Mean 15 dB (7-27) ^a
Foyt 2006	9	Mean 13.9 (6-32)

a: Estimated from figure, not stated in text

One study also reported upon mean aided thresholds when the MEI was turned 'on' and 'off' (Barbara et al 2009). One found that the mean gain provided in three patients when the MEI was turned 'on' as compared to 'off' was 55.7 dB (Barbara et al 2009).

Summary of effectiveness of middle ear implant in patients with mild or moderate sensorineural hearing loss

Four studies were available with a total of 50 patients. These included two comparative (level III-2 and level III-3) studies which reported on internal comparisons between different types of MEI and two case series (level IV). Outcome data were reported as before and after implantation. Quality of life and satisfaction measures were reported only in comparative studies. Outcomes were reported for 23 patients using the **GBI**. MEI implantation led to significant improvements on the overall benefit ($P<0.001$) and the general scores ($P<0.001$). However, the authors suggested that the relatively high mean GBI scores may be due to the difficulties encountered by the patients when wearing any conventional HA. It is possible that pre-fitting patients with a state-of-the-art, best-fit hearing aid may reduce this improvement.

Technical measures were reported for 23 patients by one comparative study. Patients showed a mean significant improvement in the **APHAB's** Ease of Communication subscale after implantation ($P<0.001$). Individual significant improvements were noted in the Ease of Communication scale for 10 patients, in the Reverberation scale for nine patients, in the Background Noise for six patients and in the Aversiveness for one patient. Significant individual improvements were noted in the joint subscales (Ease of Communication, Reverberation, Background Noise) for six patients. However three patients reported a significant deterioration in APHAB subscales (one Reverberation, one Aversiveness, one joint subscales).

Technical measures were also reported for 12 patients in two case series. The **mean functional gain** was above 10 dB, which was defined as a clinically significant change (P value not provided). One study also reported that the mean gain provided when the MEI was turned 'on' and 'off' in three patients was 55.7 dB.

In summary, MEI appears to be effective in improving hearing from baseline, pre-implantation levels in patients with mild or moderate SNHL. However caution is needed in interpreting these results as they are drawn from evidence of four studies of variable quality and include data from a total of only 50 patients.

2. Is the middle ear implant effective in patients with severe sensorineural hearing loss?

One comparative study (level III-3) assessed the effectiveness of the MEI in 13 patients with severe SNHL (Snik et al 2004). This study compared the VSB and the Otologics MET MEIs. VSB patients had been using their device for more than a year, while the Otologics MET patients were first-time users and measurements were taken at least four months after device fitting. Snik et al (2004) did not report whether or not patients were enrolled consecutively, and did not report on losses to follow-up. It was not clearly stated whether baseline measures were measured with or without a HA.

Quality of life and satisfaction measures

Snik et al (2004) did not report upon quality of life or satisfaction outcomes.

Technical outcomes

Functional gain

One study reported upon mean functional gain provided by the VSB and Otologics MET devices (Snik et al 2004). The gains provided by the devices were similar: VSB was 32.4 dB (63.8-75) and the Otologics MET 34 dB (70-82.5). The MET provided greater gain than the VSB in the frequencies up to 3000 Hz, while the VSB provided greater gain than the Otologics MET for frequencies higher than 3000 Hz.

This study also reported upon the adequacy of the audio processor fitting, by comparing the mean functional gain of the MEI with the National Acoustic Laboratories (NAL) target gain. The mean gain of the VSB exceeded the target gain by 29 dB (-4 to 11 dB), whereas the mean gain of the Otologics MET exceeded the target gains by 7 dB (-7 to 10 dB) (Snik et al 2004). No statistical analysis was performed on any outcome.

Case series

No case series reported upon patients who received the MEI for severe SNHL.

Summary of effectiveness of middle ear implant in patients with severe sensorineural hearing loss

Only one study, with a total of 13 patients, was available to assess the effectiveness of the MEI in patients with severe SNHL. This study was classified as an internal comparative study as it compared the effectiveness of the VSB and Otologics MET MEIs. As only one technical outcome was reported, this study has limited applicability.

No quality of life and patient satisfaction measures were reported upon. The **mean functional gain** provided by both the Otologics MET and the VSB devices exceeded 32 dB, which is considered to be clinically significant.

In summary, this single study suggests that MEI appears to be effective in improving hearing from baseline, pre-implantation levels in patients with severe SNHL. However, caution is needed in interpreting this result as it is drawn from a single, low-quality comparative study with only 13 patients.

2a. Is the middle ear implant effective in patients with sensorineural hearing loss of undefined severity?

Nine case series reported effectiveness outcomes in 262 patients receiving MEI for SNHL of undefined severity (Fisch et al 2001; Garin et al 2002; Mosnier et al 2008; Snik and Cremers 1999; Snik et al 2006; Sterkers et al 2003; Zenner 2000; Zenner et al 2003; Zenner et al 2004). Two studies assessed the same cohort of patients over the short- and long-term (Mosnier et al 2008; Sterkers et al 2003). Eight studies provided effectiveness outcomes before and after MEI implantation, and five studies provided effectiveness outcomes with MEI 'on' and 'off' (Table 35). Where possible these sets of studies have been reported separately. Most studies reported that patients had tried and failed an external HA; however, no study explicitly stated whether preoperative, baseline measurements were conducted with or without a HA.

Patient numbers ranged from seven to 125. Two case series declared sponsorship issues – one study was supported by the manufacturer (Fisch et al 2001) and the second used devices which were supplied by the manufacturer (Snik and Cremers 1999). Eight of the nine case series were prospective, although only two enrolled patients consecutively (Garin et al 2002; Sterkers et al 2003). Follow-up ranged from two months to eight years, although most studies followed patients for less than 12 months.

Table 35 Case series for MEI for sensorineural hearing loss

Study ID	Before/After MEI	MEI On/Off
Fisch 2001	✓	
Garin 2002		✓
Snik 1999	✓	✓
Snik 2006	✓	
Sterkers 2003	✓	✓
<i>Same cohort reported in Mosnier 2008</i>		
Zenner 2000	✓	
Zenner 2003	✓	✓
Zenner 2004	✓	✓

MEI: middle ear implant

Quality of life and satisfaction measures

A total of two level IV studies presented quality of life measures for 146 patients with SNHL of undefined severity (Snik et al 2006, Sterkers et al 2003). Both studies utilised the GBI. In addition Snik et al (2006) also presented data for the Short-Form Health Survey (SF-36) questionnaire and the Nijmegen Cochlear Implant Questionnaire (NCIQ). Meanwhile, Sterkers et al (2003) also employed a non-standardised questionnaire to measure perceived benefits from the implant.

GBI

GBI scores from these studies suggest that there was some substantial perceived benefit after implantation of the MEI. Sterkers et al (2003) reported that mean benefit scores demonstrated that the greatest benefit was noted for the general category in 89 per cent of SNHL patients (mean benefit score 20; estimated from

figure). There was no substantial benefit indicated for social support (55 per cent) and physical wellness (71 per cent). Notably, no statistical tests were presented to verify these results. Snik et al (2006) reported that SNHL patients perceived significant benefit after implantation as suggested by the mean overall GBI change of 33.9 (95% CI: 27.3 to 41.4; $P < 0.001$).

SF-36

Snik et al (2006) reported that significant differences were noted in the physical and mental subcategories of the SF-36 questionnaire when comparing post-implantation and baseline outcomes ($P = 0.05$ and $P = 0.01$, respectively) (Table 36).

Table 36 SF-36 and NCIQ scores post-MEI implantation (Vibrant Soundbridge, Otologics MET)

Questionnaire	Baseline	After implantation	Individual change (95% CI)	P-value
SF-36 physical	0.512±0.087	0.479±0.100	-0.033 (-0.063 to -0.002)	0.05
SF-36 mental	0.488±0.099	0.534±0.071	0.046 (0.012 to -0.079)	0.01
NCIQ communication	61.7±13.6	71.7±11.0	9.7 (3.8 to 13.5)	0.002
NCIQ psychological	60.2±13.9	71.3±13.1	10.5 (2.8 to 18.2)	0.01
NCIQ social	6302±15.9	76.0±12.4	13.6 (6.4 to 20.7)	0.001

Mental functioning was the only underlying category with significantly improved scores after MEI implantation. Physical score actually decreased after implantation; this may be explained by the increase in subdomain bodily pain ($P = 0.05$) consequent to surgery or the presence of the implant.

NCIQ

The communication-related physical, psychological and social subcategories of the NCIQ improved significantly after MEI implantation (Table 36; $P < 0.01$ for all subdomains) (Snik et al 2006).

Non-validated measures

The non-standardised survey utilised by Sterkers et al (2003) indicated that 83 per cent of SNHL patients were satisfied or very satisfied with the MEI (VSB). A moderate correlation was noted between the ratings for global satisfaction with the ratings for sound quality and comprehension in noise ($r = 0.64$). All other correlations were weak or non-existent. The survey noted that 50 per cent of respondents use the telephone with the MEI but no strong correlations on telephone use and other ratings were observed. A total of 76 per cent reported that they would repeat the procedure while 44 per cent indicated that they would consider binaural implantation (Sterkers et al 2003).

Technical outcomes

Functional gain

Two studies reported upon mean functional gain provided by the MEI (Table 37), and both found that approximately 26 dB of gain was provided. One further study reported upon gains for soft and moderate sounds (Snik and Cremers 1999). The gain provided by the MEI for soft sounds (averaged for the frequencies 500, 1500

and 4000 Hz) was 21 dB. In six of seven patients the gain of the MEI for moderate sounds was 17 dB.

Table 37 Functional gain in patients with SNHL of undefined severity

Study ID	N	Functional gain
Before/After		
Sterkers 2003	125	Mean 26.7 dB
<i>Same cohort reported in Mosnier 2008</i>		<i>Mean 26 dB (not significantly different from the 3-month outcomes)</i>
On/Off		
Garin 2002	9	Mean 25.8 dB ^a

a: Estimated from figure, not stated in text

One ‘before/after’ study also reported upon mean aided thresholds when the MEI was turned ‘on’ and ‘off’ and found that across 13 patients there was a median difference between MEI ‘on’ and ‘off’ of 13.2 dB (Zenner et al 2003).

One study reported upon loudness growth measurements taken before and after MEI implantation compared with target gain values (Snik and Cremers 1999). Results for low level sounds (40 dB SPL), sounds at a comfortable listening level (65 dB SPL) and loud sounds (90-95 dB SPL) were compared with target gain values calculated with the FIG6 method. Mean aided gain at 40 dB SPL was 21 dB, which on average was 8 dB (at 1.5 kHz) to 22 dB (at 0.5 kHz) lower than the FIG6 target value (Snik and Cremers 1999). Mean aided gain at 65 dB SPL was 17 dB, which was 3-11 dB lower than the FIG6 target value. Mean aided gain at 90 dB SPL was within 5 dB of the FIG6 target values. No statistics were provided (Snik and Cremers 1999).

Fitting

One study reported upon the adequacy of the audio processor fitting (Snik et al 2006). This study compared the mean functional gain of the MEI with the National Acoustic Laboratories (NAL) target gain. The mean±SD difference between the measured gain and the target gain was 2.4±6.4 dB (-11.5 to 7.6 dB), suggesting that the audio processor fitting was adequate (Snik et al 2006).

Speech recognition in quiet

Two studies reported upon speech recognition when the MEI was switched ‘on’ and ‘off’ (Mosnier et al 2008; Zenner et al 2003). The first study assessed speech recognition in quiet, and found that when the MEI was switched ‘off’ the average word recognition score at 60, 80 and 90 dB was 52 per cent (+25%, -11%). When the MEI was switched ‘on’ the word recognition score was significantly improved to 87 per cent (+6%, -15%) (*P* value not provided) (Zenner et al 2003).

In the second study 27 of 125 patients were assessed at three months and at five to eight years post surgery for speech comprehension with the MEI ‘on’ and ‘off’. No details were given regarding the selection of these patients (Mosnier et al 2008). Both the ‘on’ and ‘off’ speech comprehension scores significantly deteriorated from three months post surgery to five to eight years post surgery. The average decrease in speech comprehension score at five to eight years compared with three months post surgery was 19.4 per cent for VSB ‘off’ and 8.2 per cent for VSB ‘on’ (Mosnier et al 2008). Patients’ hearing also worsened

between these periods. From initial to final follow-up, the mean hearing present when the MEI was switched 'off' deteriorated from 56 ± 6.5 per cent to 37 ± 7.1 per cent ($P < 0.01$). Similarly, the mean hearing present when the MEI was switched 'on' deteriorated from 89 ± 4 per cent to 81 ± 5.3 per cent ($P < 0.05$). When MEI was switched 'on' the deterioration present was less pronounced than that at MEI 'off', signifying an effect from the MEI.

Speech discrimination in noise

Three studies reported upon speech discrimination in noise after MEI implantation (Garin et al 2002; Zenner 2000; Zenner et al 2003). One study provided 'on/off' measures, but did not clearly specify whether the MEI 'unaided' condition was preoperative or postoperative (Garin et al 2002). In this study at a signal-to-noise ratio of 0 dB (equivalent speech and noise signal intensities) MEI 'on' achieved higher scores than MEI 'off' (85 ± 20 and 55 ± 40 per cent respectively). A cohort of 15 normal listeners achieved 95 per cent. At signal-to-noise ratio of -5 dB (noise was increased by 5 dB), MEI 'on' achieved higher scores than MEI 'off' (60 ± 28 and 29 ± 31 per cent respectively). Normal listeners achieved 75 per cent (Garin et al 2002). At signal-to-noise ratio of -10 dB, MEI 'on' achieved higher scores than MEI 'off' (31 ± 25 and 7 ± 17 per cent respectively). Normal listeners achieved 45 per cent. Overall MEI 'on' improved hearing in noise compared with the MEI 'off', although no statistical results were provided. The MEI 'on' did not provide hearing equivalent to that of normal listeners (Garin et al 2002). This study also provided effectiveness outcomes using an unvalidated measure for in-noise assessment (Garin and Galle test). At S/N = -5 dB, the percentage of words correctly understood in background noise was VSB 'off' 8 per cent ± 13 and VSB 'on' 34 per cent ± 18 (no statistical analysis provided). Normal listeners ($n=15$) achieved 95 per cent. At S/N = -10 dB, the percentage of words correctly understood in background noise was VSB 'off' 66 per cent ± 22 and VSB 'on' 98 per cent ± 4 (no statistical analysis provided). Normal listeners achieved 100 per cent.

The other two studies reported 'before/after' measures (Zenner 2000; Zenner et al 2003). One reported that the sentence recognition threshold (a score of 50% correct) was in the range -2 to +1 dB signal-to-noise ratio (Zenner 2000). After MEI implantation the articulation index improved by 105 per cent and auditory localisation was correct 89.5 per cent of the time. The second study found that 11 patients (84.6 per cent) reached the sentence recognition threshold in the range -2 to +1 dB signal-to-noise ratio (Zenner et al 2003). When noise was directed towards the contralateral unaided, preoperative ear (thus allowing the implanted ear to focus on the speech signal), sentence recognition was 86 per cent (interquartile range +10%, -13%). This was significantly better than the sentence recognition of the unaided ear 77 per cent ± 11 (median value with interquartiles) (P value not provided) (Zenner et al 2003).

Speech discrimination in quiet

Three studies reported upon 'before/after' outcomes for speech discrimination in quiet (Snik and Cremers 1999; Zenner 2000; Zenner et al 2003). In the first study standard word lists consisting of monosyllables were used, with the speech gain being the shift in dB between the aided score and the unaided score at 65 dB. A mean speech gain of 20 dB (13-28) was observed across the seven patients (Snik and Cremers 1999). In the second study preoperatively 11/13 patients (84.6 per

cent) had a median loss of 20 per cent (interquartile range +5%, -5%) (Zenner et al 2003). With the MEI all patients attained 100 per cent word recognition. This study also reported upon sentence recognition. Twelve patients (92.3 per cent) achieved a score of 100 per cent after implantation, and the remaining patient achieved 98 per cent. The median value of sentence recognition in quiet at 65 dB SPL was 100 per cent (Zenner et al 2003). The third study reported that discrimination was significantly improved in 18 of 20 patients (90 per cent) after MEI implantation (statistics not provided) (Zenner 2000). Discrimination reached 100 per cent in 14 patients compared with four patients preoperatively. Additionally 100 per cent of standardised sentences were understood by 15 patients (75 per cent).

Summary of effectiveness of middle ear implant in patients with sensorineural hearing loss of undefined severity

All studies for this indication were case series (nine studies with a total of 262 patients). Statistical analyses were rarely provided to substantiate effectiveness outcomes.

Several quality of life and satisfaction measures were reported upon. Two studies reported upon validated quality of life measures in a total of 146 patients. One study (n=21) reported that patients perceived significant benefit in **GBI** score after MEI implantation ($P<0.001$). This study also reported significant improvements in the mental subcategory of the **SF-36** questionnaire when comparing baseline and post-implantation outcomes ($P=0.01$). The physical score decreased significantly after implantation ($P=0.05$), possibly due to the presence of the implant. This study also reported that the communication-related subcategories of the **NCIQ** improved significantly after MEI implantation ($P\leq 0.01$).

Several technical measures were also reported. **Mean functional gain** was reported for a total of 134 patients. MEI implantation provided at least 25 dB mean functional gain. Improvements of >10 dB are considered to be a clinically significant improvement. Speech recognition in quiet was reported by two case series. In all cases outcomes were improved in after MEI implantation or with MEI 'on'. No statistical reporting was provided. One study selectively reported upon 27 of 125 patients, and found that both MEI 'on' and MEI 'off' speech discrimination scores significantly worsened from three months post surgery to five to eight years postsurgery (MEI 'off' $P<0.01$; MEI 'on' $P<0.05$).

Speech discrimination in quiet was reported upon by three case series. One study (n=7) noted a mean speech gain of 20 dB (13-28) after MEI implantation. The second study found that the median value of sentence recognition in quiet at 65 dB SPL was 100 per cent. The third study reported that discrimination was significantly improved in 18 of 20 patients (90 per cent) after MEI implantation. However, no study provided statistical analysis.

In summary, MEI appears to improve hearing in patients with SNHL of undefined severity. However, caution is needed in interpreting these results as the data are of relatively low quality and outcome measures are variable between studies.

3. Is the middle ear implant effective in patients with mild or moderate mixed hearing loss?

No comparative studies assessed the effectiveness of the MEI in patients with mild or moderate MHL. Six case series reported effectiveness outcomes for a total of 47 procedures in 46 patients with moderate MHL (Cuda et al 2009; Dumon et al 2009; Foyt and Carfrae 2006; Lefebvre et al 2009; Suzuki et al 1989; Yanagihara et al 1997). In two case series the MEI was modified in some manner (Cuda et al 2009; Lefebvre et al 2009). In one case series the MEI's titanium attachment clip was cut off to permit implantation on the round window, which was necessary as middle ear anatomy varied due to the conductive component of the hearing loss (Cuda et al 2009). In the second case series a modified total ossicular replacement prosthesis (TORP) was clipped to the end of the MEI's transducer (Lefebvre et al 2009).

None of the six case series explicitly stated that preoperative baselines were obtained without the use of an external HA. Only one patient was reported to be unable to tolerate a traditional HA (Foyt and Carfrae 2006).

Patient numbers were very small and ranged from one to 13. One case series was authored by employees of the MEI manufacturer (Lefebvre et al 2009). All six of the case series were prospective, although only one study enrolled patients consecutively (Foyt and Carfrae 2006). Where reported, follow-up ranged from six months to 54 months (Cuda et al 2009; Dumon et al 2009; Foyt and Carfrae 2006; Lefebvre et al 2009; Yanagihara et al 1997).

Quality of life and satisfaction measures

None of the case series reported quality of life or satisfaction outcomes.

Technical outcomes

Functional gain

Four studies reported upon functional gain provided by the MEI (Table 38). A mean functional gain was conferred by the MEI in all studies and ranged from approximately 26 dB to 32 dB (Table 38).

Table 38 Mean functional gain of the MEI in patients with mild or moderate mixed hearing loss

Study ID	N	Frequencies used	Unaided, preoperative threshold (mean)	Aided threshold (mean)	Functional gain (mean)
Cuda 2009	8	500 Hz to 4000 Hz	62.8 dB HL	32.2 dB HL	30.6 dB
Dumon 2009	13	500 Hz to 4000 Hz	66 dB HL	34 dB HL	32 dB
Lefebvre 2009	6	250 Hz to 3000 Hz	63 dB HL ^a	37.5 dB HL	26.17 [SD 5.15] dB, decreased to 20.83 [SD 6.22] dB at 12 months
Yanagihara 1997	9	-	67.1 dB HL	36.5 dB HL	30.6 dB

a: Data approximated from figures

dB: decibels; HL: hearing level; SD: standard deviation; SPL: sound pressure level; - indicates not reported

One further study reported very briefly upon effectiveness outcomes (Suzuki et al 1989). Hearing was reported to have improved in all implanted cases, but no further data was supplied. This study reported no further effectiveness outcomes, aside from the fact that 7/9 patients (77.8 per cent) use their MEI all the time.

APHAB

One study reported APHAB outcomes after MEI implantation in six patients with MHL (Lefebvre et al 2009). APHAB scores were provided for five of six individual patients. After MEI implantation significant improvements were shown in the Ease of Communication (32.8 per cent), Reverberation (11 per cent) and Background Noise (13.6 per cent) scales. A mean worsening of approximately 17.6 per cent was found on the Aversiveness scale (data approximated from figures). This study was unclear as to whether the MEI-aided condition was compared to an unaided or to a HA pre-surgical condition.

Speech reception threshold

One study reported upon speech reception threshold (SRT) in quiet (Dumon et al 2009). This study calculated SRT for both 50 per cent and 100 per cent intelligibility and reported improvements in SRT in quiet after activation of the MEI (Table 39).

Table 39 SRT in quiet in patients with mild or moderate mixed hearing loss

Study ID	Preoperative	MEI off	MEI on	Difference
Dumon 2009	77 dB ^a	75 dB ^a	52 dB ^a	Post-op: 2 dB ^a Total: 25 dB ^a
	89 dB ^b	83 dB ^b	59 dB ^b	Post-op: 6 dB ^b Total: 24 dB ^b

^a SRT intelligibility of 50%

^b SRT intelligibility of 100%

dB: decibels; HL: hearing loss; MEI: middle ear implant; SPL: sound pressure level; - indicates not reported

Speech perception at conversational levels was reported upon by two studies (Cuda et al 2009; Lefebvre et al 2009). Both studies indicated an improvement in speech perception after MEI implantation (Table 40).

Table 40 Speech perception at conversational level

Study ID	Preoperative	Postoperative	Difference
Cuda 2009 ^a	-	88.3% [SD 14.6] (range 65-100%)	-
Lefebvre 2009	-	36.25% [SD 46.07]	63.33% [SD 32.04] (range 10-90)

^a Measured at 60 dB

SD: standard deviation; - indicates not reported

Summary of effectiveness of middle ear implant in patients with mild or moderate mixed hearing loss

No comparative studies were available to inform on the effectiveness of MEI in patients with mild or moderate MHL. Six case series which assessed a total of 47 procedures in 46 patients were utilised for effectiveness outcomes. These NHMRC level IV studies had very small patient numbers, and each failed to provide statistical analysis to substantiate effectiveness outcomes. Two of the case series modified the MEI devices due to varied middle ear anatomy.

No quality of life or patient satisfaction measures were provided. Four technical effectiveness outcomes were reported upon. Four case series found that a mean **functional gain** was provided by the MEI, and ranged from approximately 26 dB to approximately 32 dB. Improvements of >10 dB are considered to be clinically significant. **APHAB** outcomes were reported for five of six included patients in one study, although no statistical analysis was provided. Significant improvements were reported to have occurred after MEI implantation in the Ease of Communication, Reverberation and Background Noise scales. **Speech reception threshold** outcomes were reported for a total of 13 patients. Improvements were noted after activation of the MEI for both 50 per cent (25 dB) and 100 per cent (24 dB) intelligibility, although no statistical analysis was provided. **Speech perception at conversational level** was reported separately in 14 patients. Improvements were reported after MEI implantation. Speech perception outcomes were reported by three studies.

In summary, in these case series, MEI implantation or activation generally led to improvements in patients with mild or moderate MHL. However caution is needed in interpreting these results as they are drawn from a small number of low quality case series including only 46 patients and no statistical analyses were reported.

4. Is the middle ear implant effective in patients with severe mixed hearing loss?

Two case series reported effectiveness outcomes in 47 patients who received MEI for severe MHL (Colletti et al 2006; Streitberger et al 2009). Both case series reported ‘before/after’ effectiveness outcomes, and one also reported additional ‘on/off’ outcomes (Colletti et al 2006). One case series reported that the MEI was modified by cutting off its titanium clip before positioning the device on the round window (Streitberger et al 2009). This placement was due to varied middle ear anatomy.

One case series reported upon seven patients (Colletti et al 2006) and the second reported upon 40 patients (Streitberger et al 2009). Both case series were prospective, although neither was reported to have enrolled patients consecutively. Follow-up ranged from six to nine months. Neither case series explicitly stated that preoperative baselines were measured without the use of an external HA.

Quality of life and satisfaction measures

None of the case series reported quality of life or satisfaction outcomes.

Technical outcomes

Functional gain

Both studies reported upon functional gain provided by the MEI. A mean functional gain was conferred by the MEI in both studies (Table 41).

Table 41 Mean functional gain of the MEI in patients with mixed hearing loss

Study ID	N	Frequencies used	Preoperative threshold (mean)	Aided threshold (mean)	Functional gain (mean)
Colletti 2006	7	250Hz to 4000 Hz	72.9 dB HL	23.6 dB HL	49.3 dB
Streitberger 2009	40	250 Hz to 4000 Hz	82.38 dB SPL [SD 2.33]	50.63 dB SPL [SD 5.81] 47.89 dB SPL [SD 13.76] at 6-9 month follow-up	31.75 dB at activation 34.5 dB at 6-9 month follow-up

dB: decibels; HL: hearing level; SD: standard deviation; SPL: sound pressure level; - indicates not reported

One case series also compared the effectiveness of the MEI when set to either ‘on’ or ‘off’ (Colletti et al 2006). The mean MEI ‘off’ threshold across 500-4000 Hz was 79.5 dB HL, which improved to 23.6 dB HL after the MEI was turned ‘on’ (data approximated from figures, no statistical comparison provided) (Colletti et al 2006). This improvement brought patients into the mild hearing loss category (20-39 dB HL, see Table 1). However the placement of the MEI caused a worsening in AC thresholds from approximately 72.9 dB HL to approximately 79.5 dB HL in the seven patients. This effect was attributed to inadequate coupling of the bone vibrator, presumably due to oedema, at the time of postoperative measurements.

Both studies compared aided thresholds at short-term follow-up and longer-term follow-up (Colletti et al 2006; Streitberger et al 2009). None of these studies found a significant difference between aided thresholds at short term (nine months in

Colletti et al 2006; three months in Streitberger et al 2009) and longer term (12 months in Colletti et al 2006; six to nine months in Streitberger et al 2009), suggesting that the placement and efficiency of the MEI was stable in these 47 patients.

Speech reception threshold

Both case series reported upon SRT in quiet. One study calculated SRT for only 50 per cent intelligibility (Colletti et al 2006) and the second study did not report the intelligibility levels of SRT calculations (Streitberger et al 2009) and the evaluators conservatively assumed that these were 50 per cent. Both studies reported improvements in SRT in quiet after activation of the MEI (Table 42). In one cohort the SRT improved further between activation (62.82 dB SPL; 32.6 dB gain) and long-term follow-up (53.33 dB SPL; 40.95 dB gain) (Streitberger et al 2009). Additionally, one study reported that while only one patient was able to achieve 100 per cent intelligibility preoperatively, six of seven patients achieved 100 per cent postoperatively (Colletti et al 2006).

Table 42 SRT in quiet in patients with mixed hearing loss

Study ID	Preoperative	MEI off	MEI on	Difference
Colletti 2006	85 dB HL (range 70-100) ^a	-	50 dB HL (range 30-70) ^a	<i>P</i> <0.001
Streitberger 2009	-	94.28 dB SPL	53.33 dB SPL	40.95 dB gain

^a SRT intelligibility of 50%

dB: decibels; HL: hearing loss; MEI: middle ear implant; SPL: sound pressure level; - indicates not reported

Speech perception at conversational levels was reported upon by one study, which indicated an improvement in speech perception after MEI implantation (Streitberger et al 2009) (Table 43). The SRT improved further between activation (91.15 per cent) and long-term follow-up (95.75 per cent) (Streitberger et al 2009).

Table 43 Speech perception at conversational level

Study ID	Preoperative	Postoperative	Difference
Streitberger 2009	47.75% [SD 30.51]	95.75% [SD 7.81]	48%

SD: standard deviation; - indicates not reported

Summary of effectiveness of middle ear implant in patients with severe mixed hearing loss

No comparative studies were available to inform on the effectiveness of MEI in patients with mild or moderate MHL. Two case series (NHMRC level IV) which assessed a total of 47 patients were utilised for effectiveness outcomes. One case series modified the MEI devices due to varied middle ear anatomy.

No quality of life or patient satisfaction measures were reported upon, and only three technical outcomes were reported on. Mean functional gain afforded by the MEI ranged from 49.3 dB to 34.5 dB. In seven patients **speech reception threshold in quiet** improved significantly from preoperative to MEI 'on' ($P < 0.001$). In 40 patients a 40.95 dB gain was noted between MEI 'off' and MEI 'on', although no statistical analysis was provided. One study reporting upon **speech perception at conversational levels** in 40 patients found a 48 per cent improvement from mean preoperative level to mean postoperative level, although no statistical analysis was provided.

In summary, in these case series, MEI implantation or activation generally led to improvements in patients with severe MHL. However caution is needed in interpreting these results as they were drawn from a small number of low quality case series including only 47 patients and with limited reporting of statistical analyses.

4a. Is the middle ear implant effective in patients with mixed hearing loss of an undefined severity?

No comparative studies reported upon the effectiveness of the MEI in patients with MHL of an undefined severity. One case series reported effectiveness outcomes in 19 patients who received MEI for MHL which ranged in severity from moderate to severe (Colletti et al 2009). This study was methodologically designed to be a comparative study but the comparator (total ossicular replacement prosthesis) was not a comparator of interest for this report. For the purposes of this report the single arm that assessed MEI in this study has been included as level IV evidence. The MEI was modified by cutting off the titanium attachment clip. This permitted implantation on the round window which was necessary as middle ear anatomy varied due to the conductive component of the hearing loss.

Although this case series was prospective, the 19 patients were not reported to have been enrolled consecutively. Mean follow-up was 36 months and Colletti et al (2009) did not report upon losses to follow-up. It was not explicitly stated whether or not preoperative baseline measures were recorded with or without an external HA.

Quality of life and satisfaction measures

Colletti et al (2009) did not report upon quality of life or satisfaction outcomes.

Technical outcomes

Functional gain

Colletti et al (2009) found that a mean functional gain of 58.31 dB [SD 38.6] was conferred by the MEI. Gains higher than 10 dB were obtained in 14/19 (73.7 per

cent) patients.

Speech perception at conversational level

Speech perception at conversational levels significantly improved after MEI implantation (Table 44).

Table 44 Speech perception at conversational level

Study ID	Preoperative	Postoperative	Difference
Colletti 2009 ^a	6.8%; [SD 2.5]	86.2%; [SD 36.5]	<i>P</i> =0.0004

^a Measured at 65 dB

SD: standard deviation; - indicates not reported

Summary of effectiveness of middle ear implant in patients with mixed hearing loss of undefined severity

No comparative studies were available to inform on the effectiveness of MEI in patients with MHL of undefined severity. One case series (NHMRC level IV) which assessed a total of 19 patients was utilised for effectiveness outcomes. This case series modified the MEI devices due to varied middle ear anatomy.

No quality of life or patient satisfaction measures were reported, and only two technical measures were reported. The **mean functional gain** provided by the MEI was 58.31 dB [SD 38.6]. The **speech perception at conversational levels** was significantly improved from preoperative to after MEI implantation (*P*=0.0004).

In summary, generally MEI implantation led to improvements in patients with MHL of undefined severity. However caution is needed in interpreting these results as they are drawn from a single case series involving only 19 patients.

5. Is the middle ear implant effective in patients with conductive hearing loss?

No comparative studies assessed the effectiveness of the MEI in patients with CHL. Two case series reported effectiveness outcomes in a total of 12 patients who received MEI for CHL (Frenzel et al 2009; Siegert et al 2007) (Table 15). These case series assessed 'before/after' effectiveness outcomes in patients with either unilateral osseous atresia (n=7) or congenital auricular atresia (n=5, four of which had unilateral and one of which had bilateral malformations). In one case series all seven patients had moderate CHL (Frenzel et al 2009) while in the second patients were reported to have moderate to severe CHL (Siegert et al 2007). In one case series the titanium clip of the MEI was removed and the circular base was placed into the round window niche (Frenzel et al 2009). These seven patients all received VSB implantation integrated in a total auricular reconstruction. In the second study the coupling device was modified and a titanium prosthesis designed especially for the study was used for sound transmission (Siegert et al 2007).

Both case series were prospective, although only one reported that patients were enrolled consecutively (Frenzel et al 2009). Mean follow-up ranged from three to eight months and neither case series reported upon losses to follow-up. Neither case series explicitly stated whether preoperative baseline measures were recorded with or without an external HA. In one case series the MEIs were supplied without charge by the manufacturer, and one author was an employee of the manufacturer (Siegert et al 2007).

Quality of life and satisfaction measures

Neither of the case series reported quality of life or satisfaction outcomes.

Technical outcomes

Functional gain

Both studies reported upon mean functional gain across four frequencies provided by the MEI, which was measured at 45.5 dB (Frenzel et al 2009) and 36 dB HL (Siegert et al 2007).

One study reported that the mean aided threshold was 23.8 dB HL [SD 6.2] across four frequencies and 23.5 dB HL [SD 5.8] across eight frequencies (Frenzel et al 2009). Both of these thresholds were 13.3 dB worse than the BC threshold; however, this gain allowed the seven patients to be re-classified from the higher end of the moderate category (preoperatively 69.2 dB HL) to the lower end of the mild hearing loss category (23.8 dB HL) (Frenzel et al 2009).

Speech reception threshold

In one study the mean speech reception threshold (50% speech discrimination) improved from 59 dB in the unaided condition to 21 dB with the MEI on, representing a 38 dB functional gain for speech (Frenzel et al 2009). In the second study the average speech threshold showed a gain after implantation of 32 dB HL (Siegert et al 2007).

Speech discrimination

Both studies reported upon speech discrimination at the average conversational level. In one study speech discrimination improved by 70 per cent (no further data provided) (Siegert et al 2007), and in the other study improved from 76 per cent preoperatively to 99 per cent with the MEI activated, representing a 75.7 per cent improvement (Frenzel et al 2009). One study provided further speech discrimination results (Frenzel et al 2009). At 50 dB speech discrimination with the MEI on was 64 per cent [SD 18.4], compared with 0 per cent preoperatively. At 80 dB speech discrimination with the MEI on was 100 per cent [SD 0], compared with 94 per cent preoperatively (data estimated from figures).

One study reported upon mean speech discrimination in noise (Frenzel et al 2009). The mean speech discrimination score in noise with the MEI on was 75 per cent at 60 dB and 97 per cent at 80 dB.

Summary of effectiveness of middle ear implant in patients with conductive hearing loss

No comparative studies assessed the effectiveness of the MEI in patients with CHL. Two case series reported effectiveness outcomes in a total of 12 patients who suffered from either unilateral osseous atresia or congenital auricular atresia. The implanted MEIs were modified to permit placement due to anatomic variation.

No quality of life or patient satisfaction measures were reported. Several technical outcomes were reported. The **mean functional gain** in the 12 patients exceeded 36 dB HL. A change of 10 dB HL or greater is considered to be clinically significant. After MEI implantation in seven patients, the **mean aided thresholds** were worse than the BC threshold. However, the gain provided by the MEI allowed the patients to be re-classified from the higher end of the moderate category to the lower end of the mild hearing loss category. Mean **speech reception threshold** improved by at least 32 dB HL after MEI implantation, although no statistical analyses were provided. **Speech discrimination in quiet** was improved by 70 per cent in one case series and by 75.7 per cent in the second, although no statistical analyses were provided.

In summary, although these 12 patients appeared to benefit from MEI implantation, this evidence is limited by the small number of patients studied and lack of statistical analysis. Additionally, these patients all suffered either unilateral osseous atresia or congenital auricular atresia, and it is unclear whether the benefits seen in these patients would extend to patients with other types of CHL.

Effectiveness of the middle ear implant versus the external hearing aid

A total of 20 comparative studies with a total of 763 patients were identified which assessed the effectiveness of the MEI compared with the HA for SNHL (Table 17; Table 20) and MHL (Table 18). Two studies reported upon the same cohort of patients with MHL (Caye-Thomassen et al 2002; Tos et al 1994). One study was a regulatory document prepared for the US Food and Drug Administration (FDA) (Symphonix Devices, Incorporated 2000). As this study was authored by an MEI manufacturer and has not been published in a peer-reviewed journal, outcomes have been reported separately from the remaining comparative studies.

Four studies reported that patients used optimally fitted, best fit or state-of-the-art HA for comparison with the MEI (Chen et al 2004; Todt et al 2002; Uziel et al 2003; Verhaegen et al 2008). Where reported, the remaining studies used the patient's own conventional HA. One study stated that the HA used were not the best possible digital HA due to the high cost of these devices (Thill et al 2002).

Effectiveness of the middle ear implant versus the external hearing aid: sensorineural hearing loss

A total of 14 comparative studies were identified which assessed the effectiveness of the MEI compared with the HA for SNHL (Table 17). These studies included a total of 664 patients.

Several studies appeared to have been supported in some manner by MEI device manufacturers (Chen et al 2004; Fraysse et al 2001; Hough et al 2001; Jenkins et al 2007; Matthews 2002; Snik and Cremers 2001; Thill et al 2002). Five studies enrolled patients consecutively (Fraysse et al 2001; Hough et al 2001; Luetje et al 2002; Matthews 2002; Uziel et al 2003) and the remaining studies did not report upon enrolment. The sample sizes ranged from five to 282, although approximately half of the studies recruited less than 20 patients each (Chen et al 2004; Hough et al 2001; Snik and Cremers 2001; Thill et al 2002; Todt et al 2002; Uziel et al 2003). Where reported, the length of follow-up ranged from two to 18 months. While all studies provided inclusion criteria, four studies failed to provide exclusion criteria (Roland et al 2001; Thill et al 2002; Todt et al 2002; Uziel et al 2003).

Quality of life and satisfaction measures

Six comparative studies reported results on quality of life and/or satisfaction after MEI implantation in patients with SNHL. Most studies utilised general subjective statements to reflect patient satisfaction (Jenkins et al 2007; Roland et al 2001; Snik and Cremers 2001; Todt et al 2005). Two studies utilised the Hearing Device Satisfaction Score (HDSS)¹ to assess patients hearing difficulties in various listening situations (Thill et al 2002; Uziel et al 2003). No statistical tests were presented for quality of life or satisfaction measures after MEI implantation.

¹ Developed by Symphonix Devices.

HDSS

Thill et al (2002) reported that there was an average improvement of satisfaction for all subcategories of the HDSS scale (canal occlusion, sound quality, phoning, usefulness, quality of life and Lersen effect) (data not provided). All patients were wearing their VBS every day and all day long, a substantial improvement to their hearing aids (Thill et al 2002). Similarly, Uziel et al (2003) stated that most patients (5/6) experienced significant improvement in satisfaction ratings for most subcategories (sound quality, feedback, quality of life, ease of use) ($P=0.038$ to 0.043), except for mould issues and telephone use.

General and unvalidated

Four SNHL studies that presented general patient satisfaction statements reported positive outcomes post implantation (Jenkins et al 2007; Roland et al 2001; Snik and Cremers 2001; Todt et al 2005). One study noted that 85 per cent (17/20) of patients utilised the VSB every day (Jenkins et al 2007) and most used it for longer than 11 hours per day. Another study reported that 80 per cent (4/5) of patients used the VSB all day (Snik and Cremers 2001).

The results infer that patient satisfaction for the VSB were generally positive across these studies. Todt et al (2005) stated that most patients were highly satisfied (but wanted higher technical flexibility of the audio processor). The proportion of patients who would consider binaural MEI implantation was reported to be 80 per cent (Todt et al 2005).

For the SOUNDTEC MEI, one study demonstrated that patient satisfaction was approximately 32.6 per cent higher compared to optimally fit traditional hearing aids (actual data not reported). In addition, 95.6 per cent of patients noted overall preference for the SOUNDTEC system over the optimally fit traditional hearing aid (Roland et al 2001).

Technical outcomes

Functional gain

Nine studies reported upon the mean functional gain provided by the MEI compared with the HA (Table 45). One study also compared the functional gain provided by two different digital audio processors (D type and Signia type) with that provided by an HA (Todt et al 2005). The gain provided by the D type at 500 Hz, 1, 2 and 4 kHz was 22.8 [6.5] dB and the gain provided by the Signia type was 29.8 [2.9] dB. The differences between the types were not statistically significant. As the D type processor was commonly employed in the included studies, the functional gain provided by this audio processor was detailed in Table 45.

Table 45 Mean functional gain provided by the middle ear implant versus the hearing aid in patients with sensorineural hearing loss

Study ID	HA gain	MEI gain	Details
Chen 2004	20 dB	17 dB	MEI produced less gain at frequencies 3000 Hz and higher compared to the HA (at 3000 Hz HA was 18.5 and MEI was 7)
Fraysse 2001	17 dB [SD 7-13 dB]	25 dB [SD 12-15 dB]	MEI provided clinically significant greater gain compared with the HA (<i>P</i> -value not provided)
Hough 2001	-	-	MEI provided overall 52% improvement (8.3 dB ± 3.9) in functional gain compared to the HA
Jenkins 2007	-	-	MEI performance significantly less than the patient's own HA (<i>P</i> <0.05 for all frequencies but 4000 and 6000 Hz)
Luetje 2002	17.8 dB	31.2 dB	MEI provided significantly more gain than HA (mean change was 14.1 dB, <i>P</i> <0.001)
Matthews 2002	14.6 dB ^a	22.4 dB ^a	MEI provided mean 7.8 dB improvement ^a
Roland 2001	-	-	Average MEI improvement over HA across 500-4000 Hz was 9.95 dB gain. At 6000Hz MEI had 21.1dB more gain compared to optimally for traditional hearing aids
Todt 2002	15.2 dB	24.3 dB	-
Todt 2005	18.0 dB [SD 3.4 dB]	22.8 dB ^b [SD 6.5 dB]	-

a: Estimated from figure

b: D type audio processor

dB decibels; HA: hearing aid; MEI: middle ear implant SD: standard deviation; - indicates not reported

One study noted that the lower functional gains noted in the HA may be due to patients' inability to comfortably tolerate higher gain settings, due to feedback and distortion that may occur when amplification is increased (Hough et al 2001).

Two studies also assessed functional gain at individual frequencies (Fraysse et al 2001; Hough et al 2001). In the first study, in comparison to the HA the MEI with the D processor provided significantly greater gain for 7/9 measured frequencies (excluding 250 and 4000 Hz) (Fraysse et al 2001). The maximum gain provided at each frequency for the MEI was 20 dB to 25 dB better than the hearing aid at 500 to 2000 Hz and at 8000 Hz. Maximum gains at 3000 to 6000 Hz varied by 5 to 15 dB in favour of the MEI. The second study assessed functional gain of the MEI and the HA at 2000, 3000 and 4000 Hz (Hough et al 2001). The functional gain provided by the MEI at these frequencies was an average of 42 per cent higher than that obtained with the optimally fit HA (9.6 dB±7.4 dB).

APHAB

Four studies reported effectiveness outcomes of the MEI compared with the HA using the APHAB sub-scales (Chen et al 2004; Jenkins et al 2004; Snik et al 2007; Todt et al 2002) (Table 46). Two of these studies did not clearly state whether or not comparisons were made to an HA, although this appeared to be the case (Jenkins et al 2004; Snik et al 2007). One additional study provided an average measure across the EC, BN and RV subscales and found that the MEI provided a significant mean 7.2 point improvement over the HA (Matthews 2002).

Table 46 APHAB improvements of the middle ear implant compared with the hearing aid in patients with sensorineural hearing loss

Study ID	Improvement after MEI implantation	P-value
Background Noise (BN)		
Jenkins 2004	45 point improvement ^a	-
Snik 2007	9.2% improvement ^b	P=0.03
Todt 2002	37 point improvement	P<0.05
Reverberation (RV)		
Jenkins 2004	44 point improvement ^a	-
Snik 2007	12.7% improvement ^b	P=0.02
Todt 2002	32 point improvement	P<0.05
Ease of Communication (EC)		
Jenkins 2004	55 point improvement ^a	-
Snik 2007	19.6% improvement ^b	P<0.001
Todt 2002	27 point improvement	P<0.05
Aversiveness (AV)		
Chen 2004	Approximate improvement over HA of 21%	ns
Jenkins 2004	26 point improvement ^a	-
Snik 2007	2.5% improvement ^b	ns
Todt 2002	35 point improvement	P<0.05

a: This study did not clearly state whether score was improvement over HA, or merely the score achieved with MEI

b: This study did not clearly state whether baseline was with or without HA

HA: hearing aid; MEI: middle ear implant; ns: not significant; - indicates not reported

Six further studies reported narrative effectiveness outcomes for the MEI compared with the HA using the APHAB (Chen et al 2004; Jenkins et al 2004; Jenkins et al 2007; Roland et al 2001; Thill et al 2002; Uziel et al 2003). Generally the MEI was preferred over the HA (Chen et al 2004; Jenkins et al 2004; Jenkins et al 2007; Thill et al 2002; Uziel et al 2003). One study found that patients reported significantly fewer difficulties in understanding speech with the MEI than they did with their preoperative HA (statistics not provided) (Thill et al 2002). A second study found that patients with severe HL reported greater benefit ($P<0.001$) of MEI on the EC, RV and BN subscales than the HA, but also experienced more aversiveness of sounds (Jenkins et al 2004). One study found no significant differences between the MEI and HA for the EC, RV and BN scales (Roland et al 2001).

Hough Ear Institute Profile

Three studies reported effectiveness outcomes using the Hough Ear Institute Profile (Hough et al 2001; Matthews 2002; Roland et al 2001). All patients had either moderate or severe SNHL. One study (n=10) reported that when using the MEI feedback was eliminated, the occlusive effect was reduced (data not provided) and the sound quality was increased by 27.3 per cent (± 26.5 SD) (Hough et al 2001). It was unclear whether these improvements were compared with the unaided condition or with the HA. The overall subject satisfaction with the MEI improved 16.7 per cent over the HA condition.

The second study (n=103, 94 subjects responded) reported that the MEI was rated by 99 per cent of patients as having the least amount of feedback, but it was unclear whether this was in comparison to the unaided condition or to the HA (Matthews 2002). In terms of sound quality 89 per cent of subjects preferred the

MEI over their HA. Occlusion was reported by 54 per cent of patients with HA and by 23 per cent of patients with the MEI. Of 94 subjects responding, 89 per cent preferred the MEI (presumably to their HA) in terms of overall satisfaction.

The third study (n=23) found that although average daily use of the MEI or the HA did not vary for most patients, the MEI provided higher fidelity of sound and decreased feedback compared with the HA (no data provided) (Roland et al 2001). Sixteen patients reported feedback with the HA, and 14 of these patients noted that feedback was completely alleviated with the MEI. Twelve patients reported occlusion with the HA, and nine of these patients noted that occlusion was absent with the MEI. Overall satisfaction was approximately 32.6 per cent higher for the MEI than for the optimally fit HA. A total of 95.6 per cent of subjects noted overall preference for the MEI over the optimally fit HA (Roland et al 2001).

PHAP

One study reported effectiveness outcomes using the Profile of Hearing Aid Performance (PHAP) (Luetje et al 2002). The number of patients reporting improvement in scores was significantly more for the MEI than the pre-surgical HA in all seven subscales of the PHAP ($P=0.001$). The numbers of individuals reporting improvement of the MEI over the HA are detailed below:

- o Familiar talkers: n=9 (18 per cent)
- o Ease of communications: n=15 (30 per cent)
- o Reverberation: n=24 (48 per cent)
- o Reduced cues: n=18 (36 per cent)
- o Background noise: n=28 (56 per cent)
- o Aversiveness: n=21 (42 per cent)
- o Distortion of sounds: n=17 (34 per cent)

Speech discrimination

Six studies reported upon the effectiveness of the MEI compared with the HA in terms of speech discrimination in quiet (Chen et al 2004; Hough et al 2001, Matthews 2002; Roland et al 2001; Snik and Cremers 2001; Todt et al 2002) (Table 47). Seven studies reported upon the effectiveness of the MEI compared with the HA in terms of speech discrimination in noise (Frayssé 2001; Matthews 2002; Roland 2001; Todt 2002; Todt 2005; Uziel 2003; Zenner 2003) (Table 48).

Table 47 Speech discrimination in quiet scores for the middle ear implant compared with the hearing aid in sensorineural hearing loss

Study ID	Presentation level	Speech disc. HA	Speech disc. MEI	Difference
Chen 2004	50 dB	-	-	HA was >20% words better than the MEI at all follow-up times
Hough 2001	-	-	-	MEI provided average 3.8% increase compared with the optimally fit HA
Jenkins 2004	-	-	-	Speech recognition scores with the MEI were equivalent to those with the digital hearing aid, and both were significantly better ($P<0.001$) than those with the patients' 'walk-in' hearing aid
Matthews 2002	63 dB SPL	-	-	MEI provided 5.3% increase compared to HA (stated to be significant, although statistical significance not provided)
Roland 2001	-	-	-	No significant difference between MEI and HA
Snik 2001	65 dB	77.2% ^a	67.4%	4 of 5 patients had better scores with HA than MEI (3 patients $P=0.05$, one patient $P<0.01$)
Todt 2002	65 dB	63% [8.0%]	89% [2.9%]	MEI provided average 26% improvement compared to HA
Todt 2005	65 dB	73% [8.0%]	75% [10.4%]	-
Verhaegen 2009	65 dB	-	-	Scores with the VSB and Otologics MET were not better than those with a state-of-the-art BTE

a: Calculated from data provided

BTE: behind the ear; dB: decibels; HA: hearing aid; MEI: middle ear implant; MET: Otologics Middle Ear Transducer; SPL: sound pressure level; Speech Disc.: speech discrimination; VSB: Vibrant Soundbridge; - indicates not reported

One study reported that in patients with SNHL without external otitis (thus allowing the use of a HA), the HA should be the first choice up to a SNHL of 95 dB HL (Verhaegen et al 2008).

Table 48 Speech discrimination in noise scores for the middle ear implant compared with the hearing aid in sensorineural hearing loss

Study ID	Presentation level	Speech disc.	Speech disc.	Difference
		HA	MEI	
Fraysse 2001	-	-	-	At the 50% discrimination level, the aided condition with each device reveals significant speech gain over the preoperative unaided condition. Speech gain was recorded as 13 dB with the HA ($P=0.033$) and 12 dB with the Vibrant D ($P=0.017$).
Matthews 2002	63 dB SPL	-	-	No significant difference
Roland 2001	-	-	-	No significant difference
Todt 2002	65 dB	62% [8.2%]	74% [9.0%]	No significant difference
Todt 2005	65 dB	-	-	HA was 23% better than the MEI
Uziel 2003	60 dB SPL	-	-	Then SNR of which 50% correct word score was achievable was significantly lower when using the VSB compared to the SIGNIA HA ($P=0.028$)
Zenner 2003 ^a	60-90 dB SPL	-	-	MEI provided $\geq 10\%$ improvement over the HA ^b

a: MEI n=13, HA n=5

b: Estimated from figure

dB: decibels; HA: hearing aid; MEI: middle ear implant; SNR: signal to noise ratio; SPL: sound pressure level; - indicates not reported

Hearing in Noise Test

One study assessed patients using the Hearing in Noise Test HINT^c (Chen et al 2004). Only one patient was assessed. When compared to the HA, the subject's ability to understand speech in quiet when using the MEI was improved by 88 per cent and in noise by 62 per cent.

Revised Speech Perception In Noise

Two studies reported outcomes using the Speech Perception in Noise (SPIN) test (Hough et al 2001; Luetje et al 2002). In one study, sentences were presented in a +8 signal-to-noise ratio to 10 patients (Hough et al 2001). An average of 17 per cent improvement in low predictability (LP) sentence scores (1.3 words correct with ± 3.3 SD) was reported when the MEI was compared with those of the optimally fit HA (Hough et al 2001). The second study employed the Revised test (R-SPIN) in 50 patients who received the MEI with a D audio processor (Luetje et al 2002). After MEI implantation patients demonstrated a mean increase of six per cent in aided speech intelligibility in the presence of background noise. The mean change in LP word scores was not significant compared with HA scores. Individually, after MEI implantation 12 (24 per cent) showed a significant improvement, 31 (62 per cent) showed no significant change, and 7 (14 per cent) patients showed a decrease in LP word scores compared to their HA. The mean group LP score improved over the HA by a factor of 4.

Speech reception threshold

One study reported upon speech reception threshold after MEI implantation (Chen et al 2004). The MEI had a <5 dB improvement over the HA at four months post-implantation, and a <5 dB worsening at one and two months post-

implantation. The MEI had a >5 dB HL worsening at 10 months post-implantation. When measured at 65 dB, the MEI was not significantly better than the patient's best-fit HA.

Other audiological measures

One study reported upon the articulation index (Hough et al 2001a). This study found that MEI implantation provided a clinically significant 13.1 per cent average improvement (± 8.7 dB) over the HA value. Although no statistical significance was provided, this improvement allowed increased availability in the 1000, 2000 and 3000 Hz frequencies which are important for speech understanding.

One study reported upon warble tone thresholds (Uziel et al 2003). This study found that warble tone thresholds with the HA and MEI were comparable across the test frequency range ($P=0.14 - 0.91$).

One study reported upon the use of Monaural Word scores (Jenkins et al 2007). In this study there was a significant difference in Monaural Word scores, where the hearing aid condition was better ($P<0.001$).

Food and Drug Administration regulatory data: sensorineural hearing loss

In addition to the 664 patients assessed in the 14 comparative studies, a regulatory document prepared for the US Food and Drug Administration (FDA) was identified (Symphonix Devices, Incorporated 2000). This study reported upon the effectiveness of the VSB MEI in comparison with the patient's pre-surgical HA in a total of 54 patients with SNHL (see Table 49). The VSB was implanted with either the Vibrant P or the Vibrant D audio processor. As the Vibrant D represents a technological advance from the Vibrant P audio processor, only effectiveness data for the Vibrant D audio processor were extracted and included.

This study was produced by an MEI device manufacturer and was not published in a peer-reviewed journal. The study did not report upon study design (retrospective or prospective) or upon the method of patient enrolment. Both inclusion and exclusion criteria were provided. Patients were followed up for five months post-surgery plus an additional six weeks to allow acclimatisation to the audio processor. One patient was lost to follow-up as their MEI did not activate.

Table 49 FDA regulatory data for middle ear implant for sensorineural hearing loss

Study ID	N	HL aetiology	Surgical history	Mean age	Gender M/F	Mean preoperative PTA threshold	Previous HA use
Symphonix Devices, Incorporated 2000	54	Unknown: 44/54 Heredity: 5/54 Noise exposure: 2/54 Presbycusis: 1/54 Barotrauma: 1/54 Trauma: 1/54	-	Age 28-44: 11 patients Age 45-64: 23 patients Age 65+: 20 patients	26/28	-	Yes

HA: hearing aid; HL: hearing loss; PTA: pure-tone average; - indicates not reported

Quality of life and satisfaction measures

This document utilised the Hearing Device Satisfaction Score (HDSS)² to assess patients hearing difficulties in various listening situations. No statistical tests were presented for quality of life or satisfaction measures after MEI implantation.

HDSS

At five months, a total of 86 per cent (42/49) of SNHL patients were satisfied with the clearness of sound and tone with the VSB compared to 31 per cent (15/49) who were satisfied with the clearness of sound and tone of their own hearing aids (Symphonix Devices, Incorporated 2000). Improvement in overall sound quality satisfaction with the VSB vs hearing aids was noted in 94 per cent (44/47) of patients. Meanwhile, 89 per cent (43/49) experienced improvement of their satisfaction rating for sound quality of their own voice with the VSB. The overall fit and comfort of the VSB was satisfactory in 98 per cent (48/49) of patients. In the subgroup of 11 patients who were dissatisfied with the fit and comfort of their conventional hearing aids, 100 per cent were satisfied with the VSB. In addition, 97 per cent (31/32) of patients who previously experienced acoustic feedback with their hearing aid reported substantial improvement (no acoustic feedback) with the VSB. The HDSS results indicated that maintenance was not a substantial concern in 98 per cent (45/46) of patients and all of the 14 patients who were previously dissatisfied with cleaning and maintenance of their hearing aids were satisfied with the VSB (Symphonix Devices, Incorporated 2000).

General and unvalidated

The FDA regulatory data (Symphonix Devices, Incorporated 2000) also utilised the unvalidated Soundbridge Hearing Aid Comparison Questionnaire (SHACQ)

² Developed by Symphonix Devices.

and found that speech perception in a controlled environment was similar between the VSB and the patient's own hearing aid. The SHACQ also indicated that the VSB was preferred over conventional hearing aids in several speech environments: 86 per cent (33/43) preferred VSB for speech outdoors, 95 per cent (41/43) preferred VSB in quiet environments, 88 per cent (35/40) preferred VSB for speech in restaurant, 86 per cent (38/44) preferred VSB for speech on television and 88 per cent (45/40) preferred VSB for speech on radio (Symphonix Devices, Incorporated 2000).

Technical outcomes

Functional gain

All patients demonstrated a higher gain with the MEI compared to the presurgical HA. Patients showed statistically significant improvement at the frequencies 500, 1000, 2000, 4000 and 6000 Hz (Table 50).

Table 50 Number of patients experiencing functional gain with the VSB compared with pre-surgery external HA

Frequency	VSB D audio processor	
	n (%)	P-value
500 Hz	46/50 (92)	<0.001
1000	49/50 (98)	<0.001
2000	50/50 (100)	<0.001
4000	47/50 (94)	<0.001
6000	43/50 (86)	<0.001
8000	13/13 (100)	-

HA: hearing aid; VSB: Vibrant Soundbridge; - indicates not reported

PHAP

Effectiveness outcomes for this cohort were also reported using the Profile of Hearing Aid Performance (PHAP) (see Table 51). When assessed as a group, the authors observed a mean significant improvement with the VSB compared to pre-surgery HA on all seven subscales of the PHAP (statistical data not reported). When assessed individually, the authors reported significant improvements compared with pre-surgical HA. However, no statistical data to support this claim was presented.

Table 51 Individual PHAP scores for patients after VSB implantation

PHAP Scale	Patients with significant improvement
Familiar talkers	9/50 patients (18%)
Ease of communication	15/50 patients (30%)
Reverberation	24/50 patients (48%)
Reduced cues	18/50 patients (36%)
Background noise	28/50 patients (56%)
Aversiveness of sounds	21/50 patients (42%)
Distortion of sounds	17/50 patients (34%)

Effectiveness of the middle ear implant versus the external hearing aid: mixed hearing loss

Two comparative studies assessed the effectiveness of the MEI compared with the HA for MHL (Caye-Thomassen et al 2002; Tos et al 1994). These studies examined the same cohort of nine patients; one study assessed short-term outcomes (Tos et al 1994) and the other assessed long-term outcomes (Caye-Thomassen et al 2002) of the Heide system MEI. In all patients the MEI was modified to facilitate placement, which was difficult due to the conductive portion of the hearing loss. The hydroxylapatite shaft of the MEI was removed to avoid protrusion under the tympanic membrane.

Neither study reported upon study design (retrospective or prospective) or upon the method of patient enrolment. Neither inclusion nor exclusion criteria were provided. Three patients were lost to follow-up, and at mean 9.5 years six patients were available for follow-up (Caye-Thomassen et al 2002).

Quality of life and satisfaction measures

Neither of the studies reported upon quality of life or satisfaction measures.

Technical outcomes

Functional gain

The mean functional gain of the MEI was 31 dB and the mean MEI gain compared to the HA was 17.7 dB (no statistical data provided). However at mean 9.5 years follow-up, no patients used the MEI for various reasons including fitting problems (four patients), loss of the driver (one patient) and prosthesis dislocation (one patient). The mean time of MEI use was 24 months (3-60 months) (Caye-Thomassen et al 2002).

Effectiveness of the middle ear implant versus the external hearing aid: conductive hearing loss

No comparative studies assessing the effectiveness of the MEI compared with the HA for CHL could be identified.

Effectiveness summary for middle ear implant vs external hearing aid

Sensorineural hearing loss

Fourteen comparative studies reported upon the effectiveness of the MEI versus the HA in a total of 664 patients. Only four of these studies clearly stated that they used an optimal, best-fit, or state-of-the-art HA.

Quality of life and patient satisfaction measures: generally improvements were noted in all scores with MEI over baseline preoperative EHA. For the **HDSS** two studies found that patients reported an improvement in satisfaction with MEI over the HA. Significant improvements were noted in five patients ($P<0.05$).

Technical measures: Four of ten studies reported statistically significant improvements in **APHAB** with MEI compared with HA, while one study found no statistically significant differences between the MEI and HA. Nine studies reported upon **mean functional gain** after MEI implantation compared with the HA. One study found that MEI was significantly better than HA ($P<0.001$), while one study found that generally HA was significantly better than MEI ($P<0.05$). Of the remaining seven studies that reported upon this outcome six found that MEI was better than HA, although generally no clinically significant difference (≥ 10 dB) was seen. Three studies with a total of 127 patients reported outcomes using the **Hough Ear Institute Profile**. Generally subject satisfaction was higher with the MEI than with the HA, although no statistical analyses were performed. One study with 53 patients reported outcomes using **PHAP**. After MEI implantation a greater proportion of patients reported improvements in all seven PHAP subscales compared to their pre-surgery HA results ($P=0.001$). Nine studies reported upon **speech discrimination in quiet**. Three studies reported that the MEI was better than the HA, with improvements ranging from 5.3 per cent to 26 per cent. Two studies reported that the HA was better than the MEI, and reported significant improvements in four patients (three patients $P=0.05$; one patient $P<0.01$). The remaining studies did not report any significant differences between the MEI and HA. Six studies reported upon **speech discrimination in noise**. One study found that in noise, 50 per cent speech comprehension was achieved at significantly lower (more difficult) signal-to-noise ratios with the MEI than the HA ($P=0.028$). The remaining studies generally found that there was no significant difference between the MEI and HA. Outcomes for the **Hearing In Noise Test** were reported upon in one patient. The patient reported improvements with MEI versus HA, although no statistical analysis was provided. Two studies reported upon patients using the **Revised Speech Perception In Noise** test. Neither study reported a significant improvement after MEI implantation compared with HA. One study reported outcomes using the **Speech Reception Threshold**. When measured at 65 dB the MEI was not significantly better than the patient's best-fit HA.

In summary, the evidence assessing the effectiveness of the MEI compared with the HA provided varied outcomes. Generally the MEI appears to be at least as effective as the HA in patients with SNHL.

One additional comparative cohort reported effectiveness outcomes for the MEI compared with the HA (Symphonix Devices, Incorporated 2000).

Quality of life and patient satisfaction outcomes: this document used the **HDSS** to assess patients. Improvements in HDSS score were noted after MEI implantation compared with the HA, although no statistical analysis was provided.

Technical measures: all patients demonstrated a higher **functional gain** with the MEI compared to the presurgical HA. Patients showed statistically significant improvement at the frequencies 500, 1000, 2000, 4000 and 6000 Hz ($P < 0.001$). Significant mean and individual improvements were reported after MEI implantation compared with pre-surgical HA, although no statistical analyses were provided.

This reporting was supplied by an MEI device manufacturer, and was not published in a peer-reviewed journal. In summary this cohort of 54 patients with SNHL generally reported improvements after MEI implantation compared with the pre-surgical HA.

Mixed hearing loss

Two comparative studies reported upon the effectiveness of the MEI versus the HA. These studies both assessed the same cohort and provided short- and long-term outcomes in a total of nine patients. Neither of these studies clearly stated that they used an optimal, best-fit, or state-of-the-art HA.

Quality of life and patient satisfaction measures: neither study reported upon these outcomes.

Technical measures: the **mean functional gain** of the MEI was 31 dB. The mean MEI gain compared to the HA was 17.7 dB. A gain of ≥ 10 dB is considered clinically significant. Despite this gain at mean 9.5 years follow-up none of the patients used the MEI, and the mean length of use was 24 months (3-60 months).

In summary, the MEI demonstrated a mean functional gain compared with the HA in patients with MHL. However due to various fitting and extrusion issues, use of the MEI was discontinued by all nine patients.

Other considerations

Three studies reported that a total of 48 patients elected to have the MEI rather than the BAHA due to reasons such as cosmetic issues, discomfort by pressure, and poor speech understanding when bone conduction was above 40 dB (Frenzel et al 2009; Streitberger et al 2009; Tringali et al 2009). Additionally, seven patients with unilateral microtia and osseous atresia elected to use the MEI rather than surgical atresia repair in conjunction with BAHA, although the reason for this was not provided (Frenzel et al 2009).

Summary of effectiveness outcomes

The effectiveness conclusions drawn have been limited by the paucity of comparative studies. The evidence was unable to reliably inform upon the effectiveness of the MEI compared with the CI or the BAHA. Only one comparative study was available to assess the effectiveness of the MEI versus the comparators of interest (CI and BAHA).

Effectiveness of the middle ear implant vs the cochlear implant in patients with sensorineural hearing loss of undefined severity

One comparative study was assessed (NHMRC level III). Regarding projected speech recognition in patients with severe hearing loss, MEI appears to be less effective than CI. Regarding projected PS65 score in patients with mild, moderate or severe hearing loss, MEI appears to be less effective than CI.

As only one comparative study was available to inform upon the relative effectiveness of the MEI compared with the BAHA and the CI, absolute effectiveness outcomes were collated for the MEI implantation alone from 29 level IV studies. Of these 29 studies, seven were retrospective while the remaining were prospective studies. Sample sizes ranged from one to 125 patients; however, the majority of studies (22 out of 29) had less than 20 patients. Generally, improvements were seen when the MEI was implanted or activated.

Effectiveness of the middle ear implant in patients with mild or moderate sensorineural hearing loss

Four studies were available with a total of 50 patients. These included two comparative (level III) studies which reported on internal comparisons between different types of MEI and two case series (level IV). In summary, MEI appears to be effective in improving hearing from baseline, pre-implantation levels in patients with mild or moderate SNHL.

Effectiveness of the middle ear implant in patients with severe sensorineural hearing loss

One case series with a total of 13 patients was available for this indication. In summary, MEI appears to be effective in improving hearing from baseline, pre-implantation levels in patients with severe SNHL. Importantly, only a small number of patients were assessed and no statistical analyses were reported.

Effectiveness of the middle ear implant in patients with sensorineural hearing loss of undefined severity

Nine case series with a total of 262 patients were available for this indication, and statistical analyses were rarely provided to substantiate effectiveness outcomes. In summary, MEI appears to improve hearing in patients with SNHL of undefined severity. However, the data are of relatively low quality and outcome measures are variable between studies.

Effectiveness of the middle ear implant in patients with mild or moderate mixed hearing loss

Six case series with a total of 47 procedures in 46 patients were available for this indication. Two of the case series modified the MEI devices due to varied middle ear anatomy. In summary, generally MEI implantation or activation led to improvements in patients with mild or moderate MHL. Importantly, only a small number of patients were assessed and no statistical analyses were reported.

Effectiveness of the middle ear implant in patients with severe mixed hearing loss

Two case series which assessed a total of 47 patients were available for this indication. One case series modified the MEI devices due to varied middle ear anatomy. In summary, generally MEI implantation or activation led to improvements in patients with severe MHL. Importantly, only a small number of patients were assessed and few statistical analyses were reported.

Effectiveness of the middle ear implant in patients with mixed hearing loss of undefined severity

One case series with a total of 19 patients was available for this indication. This case series modified the MEI devices due to varied middle ear anatomy. In summary, generally MEI implantation led to improvements in patients with MHL of undefined severity. Importantly, only a small number of patients were assessed and few statistical analyses were reported.

Effectiveness of the middle ear implant in patients with conductive hearing loss

Two case series with a total of 12 patients who suffered from either unilateral ossseous atresia or congenital auricular atresia were available for this indication. The implanted MEIs were modified to permit placement due to anatomic variation. In summary, 12 patients appeared to benefit from MEI implantation. However this evidence is limited by the small number of patients studied and lack of statistical analysis. Additionally, these patients all suffered either unilateral ossseous atresia or congenital auricular atresia, and it is unclear whether the benefits seen in these patients would extend to patients with other types of CHL.

This report has been limited by the paucity of high-level evidence upon which to draw conclusions on the effectiveness of the MEI. Only one comparative study assessed the MEI versus the CI, and no comparative studies assessed the MEI versus the BAHA. Three additional included comparative studies used comparators which were not of relevance to this report. The remaining studies included to assess effectiveness were all case series, and subject to bias.

Effectiveness of the middle ear implant vs the external hearing aid

Fourteen comparative studies reported upon the effectiveness of the MEI versus the HA in a total of 664 patients. Only four of these studies clearly stated that they used an optimal, best-fit, or state-of-the-art HA. The evidence provided varied outcomes. However, generally the MEI appears to be at least as effective as the HA in patients with SNHL and MHL. No studies informed upon the effectiveness of the MEI versus the HA in patients with CHL.

The included studies displayed considerable variability regarding patient enrolment, study design, and length of follow-up. Several studies assessed the MEI in patients who had a range of hearing severities, such as mild to severe, which made meaningful reporting difficult for these various severities.

The included studies presented a variety of MEI devices. Most studies assessed the VSB MEI; however, the Otologics MET, Envoy Esteem, Rion device, SOUNDTEC DDHS, and TICA MEIs were also assessed. Additionally, some studies described instances in which the MEI attachment method or the devices themselves had been modified to permit implantation. Hence, differences in components and attachment occurred between the six identified different MEI devices and also between patients receiving the same MEI.

The majority of the available studies assessed the MEI in patients with SNHL. This is reflective of the anticipated Australian practice suggested by clinical experts.

The reporting of effectiveness outcomes was compromised by the lack of uniform outcome measurements. While the primary technical outcome measure (functional gain) was identified a priori, not all studies reported upon this outcome. Patient-related outcomes were not reported in all studies. Where these were reported, different outcome measures such as the GBI and the SF-36 were used.

Effectiveness outcomes were further compromised by the fact that some studies reported that baseline measurements were taken with a digital, best fit, or state-of-the-art HA, while others used the patient's own HA. Further, in some before/after MEI studies it was not clearly stated whether baseline measures were measured with or without a HA. It appears that presently there is considerable variability in HA management prior to the consideration of MEI implantation.

Expert opinion

Expert clinical opinion advises that of the three implanted hearing devices in question, the BAHA implantation involves the least invasive surgical procedure. The MEI implantation is considered to be more invasive than the BAHA, while the MEI and CI implantation are comparable in terms of surgical technique and complexity. Additionally, the CI is unlikely to be implanted in patients with mild or moderate hearing loss, as the implantation may cause further declines in hearing.

Expert clinical opinion advises that there is a significant risk of residual hearing loss in CI and MEI implantation, and that there is no risk of residual hearing loss in BAHA implantation.

Certain adverse events are likely to be more commonly seen in children. Paediatric bone is softer than that of adults, and has a longer osseointegration time. Hence, BAHAs implanted in children may be more susceptible to device loosening or damage. Loosening may also result from head trauma during rambunctious play. Children may also be less reliable at cleaning and maintaining their implant site, which may contribute to fixture loss.

Expert clinical opinion advises that the MEI is capable of providing better spatial hearing outcomes than those afforded by the BAHA. Additionally, the BAHA is reported to be less effective in treating SNHL.

It is likely that there is presently a sizeable, unaddressed pool of patients who may be eligible for MEI. This pool may exist for several reasons including patient comorbidities, inequity of service distribution, costs, cultural factors and waiting lists. It is likely that patients who are not presently accessing implantable devices will represent the largest uptake for leakage of MEI. This patient population is likely to be presently persisting with their hearing loss or with a poor hearing aid rather than using a CI or BAHA. Introduction of the MEI to the Australian public health system will create a new indication for these patients, who may take this treatment option. Expert clinical opinion suggests that there may not be any cost savings associated with availability of MEI, only growth.

The Envoy Esteem device is currently undergoing clinical trials in the USK, USA and India, and Australian patients are travelling overseas to participate in these trials.

What are the economic considerations?

Economic evaluation of new health care technologies is important when determining whether the new initiative offers additional benefits and at what cost. Economic evaluations are able to determine whether the new initiative is dominated by (or dominates) the existing technology, such that the costs are higher (lower) and the effectiveness is less (greater). Economic evaluation is particularly important when the new initiative offers health benefits at additional costs. Within a constrained health care budget, determining the additional cost that would be paid for a given health gain is important when ascertaining whether such incremental costs represent value for money.

The usual process for an economic evaluation is first to determine the incremental effectiveness, which is the additional benefits associated with the new technology relative to current practice. Secondly, to determine the incremental costs, this is the difference in costs between the new initiative and current practice. Finally the incremental cost-effectiveness ratio (ICER) can be calculated using the following ratio:

$$ICER = \frac{Cost_{New} - Cost_{Comparator}}{Effectiveness_{New} - Effectiveness_{Comparator}}$$

The ICER can then be compared to a threshold, or range of thresholds, to determine whether the health system should invest in the new technology.

If the technology is just as effective as the existing technology, then a cost-minimisation approach is warranted.

Objective

The objective of this section is to conduct an economic evaluation of MEI. The Advisory Panel decided that CI and BAHA would be the most appropriate comparators for the cost analysis.

Search Strategies

As described in the 'approach to assessment', a search strategy was developed to systematically identify studies in which MEI were used. Databases of peer-reviewed literature including Medline, PubMed, CINAHL and Cochrane have been searched. The bibliographies of all retrieved publications were hand searched for any relevant references missing in the database search. Web-based searches included the Internet engines 'Google' and 'Google scholar'.

In addition to the search terms described in the 'approach to assessment' section, Cost\$ or Econ\$ were added. This was to identify any published cost-effectiveness analysis. The inclusion and exclusion criteria remained the same.

Background – evidence of cost-effectiveness

One recent study was identified in the literature search pertaining to the cost-effectiveness of MEI. Using a retrospective design, Snik et al (2006) investigated the cost-effectiveness of middle ear implants in patients with moderate to severe SNHL and severe chronic external otitis. Of those patients who received an MEI, 13 were implanted with a Vibrant® Soundbridge® device and eight were implanted with an Otologics MET device. The outcome measure used in the study was quality adjusted life years (QALYs) derived from the SF-36 health survey. All patients were required to complete the questionnaire before implantation and post implantation.

Costs were limited to direct medical costs only. The authors estimated that on average, MEI implantation cost €14,354 (2006 prices = A\$24,076³). The corresponding cost-utility ratio reported was €16,085 (A\$27,686) per QALY gained. The authors suggest that this value is cost-effective when compared to CI (range of €12,107 (A\$20,839) to €22,283 (A\$38,354)).

A limitation of the Snik et al (2006) study is that only MEI patients were included, therefore the cost-effectiveness ratio represents the cost per QALY gained when compared to pre-treatment quality of life value. Preferably the authors should have determined the incremental cost-effectiveness relative to an alternative treatment, such as CI or BAHA. Consequently it is not possible to determine the relative cost-effectiveness of MEI based on this study.

A second report from the Comité d'Evaluation et de Diffusion des Innovations Technologiques in France also reviewed the economic considerations of MEI. The estimated total costs of the procedure, including the device, implantation, and pre and post-surgery tests, was €10,000 (2002: A\$17,591).⁴ The cost-effectiveness was not evaluated nor was a comparison made with other implantation devices or technologies.

Rationale for the cost-effectiveness analysis

The Advisory Panel decided that CI and BAHA would be the comparators for the cost analysis.

As previously discussed, no significant difference in the primary outcome was demonstrated between the MEI, CI or BAHA. Consequently, until more data are published supporting the superior effectiveness of one of the treatments for hearing loss, a cost-effectiveness analysis is not warranted. Therefore the aim of the present economic evaluation was to review the costs of MEI compared to BAHA and CI for the treatment of patients with SNHL, MHL and CHL when these interventions are provided under Australian conditions, and to provide an indication of the extent of uncertainty.

When comparing MEI with BAHA and CI it is important to note that in many cases BAHA and CI are not direct comparators to each other. This is summarised in Table 52. For SNHL the BAHA is a comparator when the condition is mild or moderate, whereas CI is the comparator when the condition is severe. Likewise

³ Exchange rate as of June 30, 2006: 1 Euro = \$1.72 Australian

⁴ Exchange rate as of June 30, 2002: 1 Euro = \$1.76 Australian

for MHL BAHA is a comparator when the condition is mild to moderate, whereas CI is the comparator when the condition is severe. For CHL BAHA is the only comparator, irrespective of hearing loss severity.

Table 52 Device applicability relative to type and severity of hearing loss

	Sensorineural hearing loss			Conductive hearing loss		Mixed hearing loss		
	MEI	BAHA	CI	MEI	BAHA	MEI	BAHA	CI
Mild	✓	✓		✓	✓	✓	✓	
Moderate	✓	✓		✓	✓	✓	✓	
Severe	✓		✓	✓	✓	✓		✓

Ranges include: Mild (20-39 dB), Moderate (40-69 dB) and Severe (70-94 dB)
 MEI: middle ear implant, BAHA: bone anchored hearing aid, CI: cochlear implant
 Profound hearing loss (95+ dB) is not included in this analysis

Assumptions

- The MEI is only considered applicable if a traditional HA is not suitable.
- Only hearing loss in the range from mild to severe is considered in this analysis. Individuals with profound hearing loss would normally only be considered for a CI and are therefore excluded.
- A limited societal perspective is used in the cost analysis, which includes patient co-payments.
- The replacement rate of MEI is uncertain; therefore, only costs incurred in the first year are included.

Estimate of costs

The estimated costs of MEI, BAHA and CI were taken from a number of sources. These included the Medicare Benefits Schedule (MBS), Australian Refined Diagnostic Related Group (AR-DRG) (D01Z version 5.1 round 11 – Private and Public), manufacturers’ implants and the median charged Medicare fee.

Resource use and MBS item numbers were determined by the Advisory Panel.

Average costs per procedure

MBS items

The MBS item fees represent the Government contribution to each procedure and were obtained from the MBS (see Table 53). The benefit amount and not the actual Medicare schedule fee were used in the model, as the patient usually receives a reimbursement of 75 per cent of the schedule fee for inpatient services and 85 per cent for outpatient services. Using the full fee would double count some of the copayment contribution.

Average copayments

Average copayments were sourced from the Department of Health and Ageing. The copayment component is calculated as the MBS fee charged minus the MBS benefit paid plus any additional specialist fees. It is possible that the copayment is not the entire patient contribution and it may also include some insurance

contribution (up to 25 per cent of the MBS fee for inpatient services). To avoid double counting, the 25 per cent insurance contribution is not included as a separate cost. The copayments are calculated as averages of all procedures claimed under the item number. Consequently there may be a degree of heterogeneity; therefore, the accuracy of the copayment is dependent on the other procedures that are also claimed under the same item number.

Table 53 MBS item numbers, fees and copayments

MBS item	Item #	MBS fee	MBS schedule*	Copayment
Level B GP consultation**	23	\$34.30	\$34.30	\$20.61
Initial specialist consultation**	104	\$80.85	\$68.75	\$59.57
Audiology service**	10952	\$58.85	\$50.05	\$32.19
Neuromuscular electrodiagnosis**	11015	\$141.65	\$120.45	\$65.76
Brain stem evoked audiometry**	11300	\$181.90	\$154.65	\$83.52
Brief pre-anaesthesia consultation**	17610	\$40.60	\$34.55	\$40.39
Anaesthesia initiation (ear)	20120	\$93.50	\$79.50	\$194.59
Anaesthesia initiation (cranial bone)	20225	\$224.40	\$190.75	\$566.85
Osseo-integration - implantation	41603	\$476.20	\$407.10	\$629.36
Osseo-integration - fixation	41604	\$176.25	\$149.85	\$247.95
Cochlear implant	41617	\$1,791.15	\$1,343.40	\$1,645.95
Assist at operation	51303	\$358.23	\$268.68	\$179.25
CT scan**	56016	\$290.00	\$246.50	\$113.22

* The MBS schedule is 75% of the MBS fee for inpatient services and 85% for outpatient services

** These MBS items are undertaken in the outpatient setting and therefore will contribute to the extended safety net

Mental Assessment

The mental health assessment cost was estimated using the Manual of Resource Items and Their Associated Cost from Pharmaceutical Benefits Advisory Committee guidelines.⁵ The cost of a clinical psychologist / clinical counsellor appointment (\$122.50 for an initial consultation) was obtained from the Department of Veteran Affairs (DVA) fee schedule for allied health practitioners.

Implant Costs

The costs of the CI and BAHA can be divided into the implant cost and processor cost. Both were sourced directly from the manufacturer, Cochlear Australia & New Zealand.⁶ The cost of the MEI was provided by Life Systems Medical Pty Ltd.⁷ The following costs, including the implant and processor, were obtained: \$25,070 (CI), \$8,830 (BAHA) and \$14,400 (MEI).

Hospital Stay

The average per diem cost for hospitalisation was derived from the AR-DRG information for DRG D01Z (version 5.1 round 11 – Private and Public) for CI. The Advisory Panel indicated that a one-night hospital stay would be necessary

⁵ Pharmaceutical Benefits Advisory Committee:

<http://www.health.gov.au/internet/main/publishing.nsf/Content/health-pbs-general-pubs-pharmpac-gusubpac.htm>

⁶ Cochlear Australia & New Zealand: <http://www.cochlear.com/au/>

⁷ Vibrant® Soundbridge®: Life Systems Medical Pty Ltd., Australia

for all MEIs and 90 per cent of CIs. BAHA would be administered as an inpatient procedure but not require a hospital stay.

Battery costs

Battery life for each of the devices depends on the individual usage. It was assumed the CI battery would last four days, BAHA seven days and MEI seven days. The costs of batteries were sourced from two online distributors of hearing aid batteries. The cost for a pack of 12 batteries is \$9.16⁸, and 60 batteries is \$45.00.⁹ Therefore the unit cost of each battery is \$0.76 and \$0.75, respectively.

Re-implantation costs

The Advisory Panel provided estimates of the failure rates for each device. The failure rates used in the model were: 1 per cent CI, 2.5 per cent MEI and 5 per cent BAHA. These are tested in the sensitivity analysis. The re-implantation costs are estimated to be the same as the initial procedure. This may be an overestimation of the total cost of re-implantation as some items and tests may not be repeated. On the other hand the estimate does not include the removal of the failed device.

⁸ Microbattery.com: <http://shopping.microbattery.com>

⁹ The Audio Store Hearing Clinic: www.theaudiostore.com.au

Table 54 Calculation of average costs for MEI

	Units	Unit cost	Total
Consumables			
Implant ¹⁰	1.0	\$9,920	\$9,920
Processor	1.0	\$4,480	\$4,480
Needle electrodes ¹¹	1.0	\$250	\$250
Costs associated with procedure			
<i>Pre operational</i>			
ENT specialist (MBS 104)	2.0	\$69	\$138
MBS 104 copayment	2.0	\$60	\$119
Brain stem evoked audiometry (MBS 11300)	1.0	\$155	\$155
MBS 11300 copayment	1.0	\$84	\$84
Facial stem monitoring (MBS 11015)	1.0	\$120	\$120
MBS 11015 copayment	1.0	\$66	\$66
Anaesthesia (MBS 20120)	1.0	\$80	\$80
MBS 20120 copayment	1.0	\$195	\$195
Anaesthesia prep (MBS 17610)	1.0	\$35	\$35
MBS 17610 copayment	1.0	\$40	\$40
Surgery consultation (MBS 23)	1.0	\$34	\$34
MBS 23 copayment	1.0	\$21	\$21
Counselling and mental assessment	1.0	\$123	\$123
<i>Operational</i>			
CT Scan (MBS 56016)	1.0	\$247	\$247
MBS 56016 copayment	1.0	\$113	\$113
MRI *	1.0	\$450	\$450
Implant procedure (MBS 41617)	1.0	\$1,343	\$1,343
MBS 41617 copayment	1.0	\$1,646	\$1,646
Assistance (MBS 51303)	1.0	\$269	\$269
MBS 51303 copayment	1.0	\$179	\$179
Anaesthesia (MBS 20225)	1.0	\$191	\$191
MBS 20225 copayment	1.0	\$567	\$567
Hospital stay	1.0	\$541	\$541
<i>Post operational</i>			
Brain stem evoked audiometry (MBS 11300)	1.0	\$155	\$155
MBS 11300 copayment	1.0	\$84	\$84
Anaesthesia (MBS 20120)	1.0	\$80	\$80
MBS 20120 copayment	1.0	\$195	\$195
Battery Cost	52.0	\$0.76	\$40
ENT specialist (MBS 104)	4.0	\$69	\$275
MBS 104 copayment	4.0	\$60	\$238
Audiologist (MBS 10952)	10.0	\$50	\$501
MBS 10952 copayment	10.0	\$32	\$322
Total consumables			\$14,690
Total MBS fees			\$4,733
Total patient out-of-pocket			\$3,868
Total cost per procedure			\$23,291
Re-implantation	0.025	\$23,291	\$582
Total cost of MEI implant			\$23,873

ENT: ear, nose, throat; MBS: Medicare Benefits Schedule; CT: computed tomography; MRI: magnetic resonance imaging

* No single MRI item covers MEI, therefore an average of all MRI fees has been used, excluding any co-payments

¹⁰ Vibrant® Soundbridge®

¹¹ Expert opinion from advisory panel

Table 55 Calculation of average costs for BAHA

	Units	Unit cost	Total
Consumables			
Processor ¹²	1.0	\$6,900	\$6,900
Needle electrodes	1.0	\$250	\$250
Abutment Snap Coupling	1.0	\$1,930	\$1,930
Costs associated with procedure			
<i>Pre operational</i>			
ENT specialist (MBS 104)	2.0	\$69	\$138
MBS 104 copayment	2.0	\$60	\$119
Brain stem evoked audiometry (MBS 11300)	0.0	\$155	\$0
MBS 11300 copayment	0.0	\$84	\$0
Facial stem monitoring (MBS 11015)	1.0	\$120	\$120
MBS 11015 copayment	1.0	\$66	\$66
Anaesthesia (MBS 20120)	0.0	\$80	\$0
MBS 20120 copayment	0.0	\$195	\$0
Anaesthesia prep (MBS 17610)	1.0	\$35	\$35
MBS 17610 copayment	1.0	\$40	\$40
Surgery consultation (MBS 23)	1.0	\$34	\$34
MBS 23 copayment	1.0	\$21	\$21
Counselling and mental assessment	1.0	\$123	\$123
<i>Operational</i>			
CT Scan (MBS 56016)	1.0	\$247	\$247
MBS 56016 copayment	1.0	\$113	\$113
MRI *	1.0	\$450	\$450
Assistance (MBS 51303)	1.0	\$269	\$269
MBS 51303 copayment	1.0	\$179	\$179
Anaesthesia (MBS 20225)	1.0	\$191	\$191
MBS 20225 copayment	1.0	\$567	\$567
Osseointegration procedure (MBS 41603)	1.0	\$407	\$407
MBS 41603 copayment	1.0	\$629	\$629
Osseointegration procedure (MBS 41604)	1.0	\$150	\$150
MBS 41604 copayment	1.0	\$248	\$248
Hospital stay	1.0	\$541	\$541
<i>Post operational</i>			
Brain stem evoked audiometry (MBS 11300)	0.0	\$155	\$0
MBS 11300 copayment	0.0	\$84	\$0
Battery Cost	52.0	\$0.76	\$40
ENT specialist (MBS 104)	4.0	\$69	\$275
MBS 104 copayment	4.0	\$60	\$238
Audiologist (MBS 10952)	2.0	\$50	\$100
MBS 10952 copayment	2.0	\$32	\$64
Total consumables			\$9,120
Total MBS fees			\$3,078
Total patient out-of-pocket			\$2,285
Total cost per procedure			\$14,483
Re-implantation	0.05	\$14,483	\$724
Total cost of BAHA			\$15,207

ENT: ear, nose, throat; MBS: Medicare Benefits Schedule; CT: computed tomography; MRI: magnetic resonance imaging

* No single MRI item covers MEI, therefore an average of all MRI fees has been used, excluding any co-payments

¹² Cochlear Australia & New Zealand: <http://www.cochlear.com/au/>

Table 56 Calculation of average costs for CI

	Units	Unit Cost	Total
Consumables			
Implant ¹³	1.0	\$13,570	\$13,570
Processor	1.0	\$11,500	\$11,500
Needle electrodes	1.0	\$250	\$250
Costs associated with procedure			
<i>Pre operational</i>			
ENT specialist (MBS 104)	2.0	\$69	\$138
MBS 104 copayment	2.0	\$60	\$119
Brain stem evoked audiometry (MBS 11300)	1.0	\$155	\$155
MBS 11300 copayment	1.0	\$84	\$84
Facial stem monitoring (MBS 11015)	1.0	\$120	\$120
MBS 11015 copayment	1.0	\$66	\$66
Anaesthesia (MBS 20120)	1.0	\$80	\$80
MBS 20120 copayment	1.0	\$195	\$195
Anaesthesia prep (MBS 17610)	1.0	\$35	\$35
MBS 17610 copayment	1.0	\$40	\$40
Surgery consultation (MBS 23)	1.0	\$34	\$34
MBS 23 copayment	1.0	\$21	\$21
Counselling and mental assessment	1.0	\$123	\$123
<i>Operational</i>			
CT Scan (MBS 56016)	1.0	\$247	\$247
MBS 56016 copayment	1.0	\$113	\$113
MRI *	1.0	\$450	\$450
Implant procedure (MBS 41617)	1.0	\$1,343	\$1,343
MBS 41617 copayment	1.0	\$1,646	\$1,646
Assistance (MBS 51303)	1.0	\$269	\$269
MBS 51303 copayment	1.0	\$179	\$179
Anaesthesia (MBS 20225)	1.0	\$191	\$191
MBS 20225 copayment	1.0	\$567	\$567
Hospital stay	0.9	\$541	\$487
<i>Post operational</i>			
Brain stem evoked audiometry (MBS 11300)	1.0	\$155	\$155
MBS 11300 copayment	1.0	\$84	\$84
Anaesthesia (MBS 20120)	1.0	\$80	\$80
MBS 20120 copayment	1.0	\$195	\$195
Battery Cost	122.0	\$0.76	\$93
ENT specialist (MBS 104)	4.0	\$69	\$275
MBS 104 copayment	4.0	\$60	\$238
Audiologist (MBS 10952)	12.0	\$50	\$601
MBS 10952 copayment	12.0	\$32	\$386
Total consumables			\$25,413
Total MBS fees			\$4,779
Total patient out-of-pocket			\$3,932
Total cost per procedure			\$34,124
Re-implantation	0.01	\$34,124	\$341
Total cost of CI implant			\$34,466

ENT: ear, nose, throat; MBS: Medicare Benefits Schedule; CT: computed tomography; MRI : magnetic resonance imaging

* No single MRI item covers MEI, therefore an average of all MRI fees has been used, excluding any co-payments

¹³ Cochlear Australia & New Zealand: <http://www.cochlear.com/au/>

Average costs of each procedure

The total estimated first year cost of an MEI, BAHA and CI is \$23,873, \$15,207 and \$34,466, respectively (see Table 57). The incremental cost of using an MEI as opposed to a BAHA is \$8,666. The incremental cost saving of using an MEI as opposed to a CI is \$10,593. See Table 54, Table 55 and Table 56 for a complete breakdown of the costs.

The main difference between the cost of the MEI, CI and BAHA procedures is the cost of the implants and processors. The MBS and patient out-of-pocket costs are also lower for BAHA; however, this is offset somewhat by the higher re-implantation rate.

Table 57 Average costs per procedure

	MEI	BAHA	CI
Total consumables	\$14,690	\$9,120	\$25,413
Total MBS fees	\$4,733	\$3,078	\$4,779
Total patient out-of-pocket	\$3,868	\$2,285	\$3,932
Total cost per procedure	\$23,291	\$14,483	\$34,124
Re-implantation	\$582	\$724	\$341
Total cost of device	\$23,873	\$15,207	\$34,466
<i>Incremental cost (MEI vs BAHA/CI)</i>		\$8,666	-\$10,593

BAHA: bone anchored hearing aid; CI: cochlear implant; MBS: Medicare Benefits Schedule; MEI: middle ear implant

Implication to the extended safety net

MBS items 23, 104, 10952 and 56016 are all performed in the outpatient setting. Therefore any out-of-pocket cost associated with these items will contribute towards the Extended Medicare Safety Net (EMSN). The total out-of-pocket cost for these items is \$225.59, which is below the \$1126 threshold (\$562.90 for concession card holders). Consequently, out-of-pocket contributions for MEI, CI or BAHA procedures are unlikely to impact upon the EMSN.

Sensitivity analysis

In the sensitivity analysis a worst case scenario approach was adopted. In the worst case the number of ear, nose and throat (ENT) visits would increase from two to three visits, battery life would increase to two batteries per week instead of one, the number of audiologist visits would double, the nights in hospital was estimated using DRG average length of stay and the failure rates would change to 5 per cent for MEI, 10 per cent for BAHA and 5 per cent for CI.

Table 58 Average total costs for MEI, BAHA and CI

	Base Case	Worst Case
MEI	\$23,873	\$26,942
BAHA	\$15,207	\$16,028
CI	\$34,466	\$38,491

BAHA: bone anchored hearing aid; CI: cochlear implant; MEI: middle ear implant

Table 58 demonstrates that the costs are insensitive to these changes. The main contributor to the overall costs of each procedure is the implant and processor costs. For example, in the case of the CI, approximately 74 per cent of the total cost is due to the implant and processor. Therefore, adjusting the other parameters has little impact on the overall cost estimate in the first year.

Other cost considerations

Only the costs incurred in the first year were included in the analysis. This is due to the uncertainty in the future costs. The expected life of a CI is 20 to 30 years. In the application, the life-expectancy of the MEI is estimated to be 24 years; however, the validity of the value is unknown at this point. Other considerations are the replacement of the sound processor for both the CI and MEI. In the application it is suggested that this should occur every six years.

Financial implications

The number of potential candidates for an MEI can be estimated in a number of ways. For the primary analysis the number of procedures currently performed in Australia was estimated using 2006-07 MBS codes for BAHA and CI. In the sensitivity analysis the method proposed in the application was repeated using the prevalence of hearing loss in the Australian population.

In 2006-07 the number of CIs performed in Australia was as follows: MBS 41617=397, MBS 41603=106 and MBS 41604=101. One problem with using these data is that CI is used for severe and profound hearing loss. However MEI is not suitable for profound hearing loss, therefore the expected number of individuals treated for profound hearing loss needs to be subtracted from these values. In the absence of Australian data, the estimated prevalence of severely and profound hearing loss in the UK was used to estimate the proportion of profound hearing loss¹⁴. Based on these data it was estimated that 17.6 per cent of CI are for profound hearing loss. Overall it is estimated that 327 individuals are suitable for an MEI (ie treatment of severe hearing loss).

It was assumed that all individuals receiving BAHA would be suitable for MEI (106 patients).

Based on these data, the total cost of BAHA would be \$1,611,957 (106 patients) and the total cost of CI would be \$11,270,250 (327 patients), resulting in a total cost of \$12,882,207. If MEI was used instead of BAHA and CI the total cost would be \$10,336,916. Hence the cost savings of performing MEI as a direct replacement for BAHA and CI would be \$2,545,291.

These figures are based on 2006-07 data, therefore future projections are uncertain.

¹⁴ The Royal National Institute for Deaf People:
http://www.rnid.org.uk/information_resources/aboutdeafness/statistics/statistics.htm

Table 59 Incremental costs per procedure using MBS data

	MEI	BAHA	CI
Total cost per patient	\$23,873	\$15,207	\$34,466
Number of patients	433	106	327
<i>Breakdown of financial implications:</i>			
Consumables	\$6,519,653	\$1,015,022	\$8,393,193
MBS items	\$2,100,738	\$342,593	\$1,578,451
Patient out-of-pocket	\$1,716,524	\$254,342	\$1,298,605
Total financial implications	A=\$10,336,916	B=\$1,611,957	C=\$11,270,250
<i>Incremental costs:</i>			
Consumables	-\$2,888,562		
MBS items	\$179,694		
Patient out-of-pocket	\$163,577		
Total cost savings A-(B+C)	-\$2,545,291		

BAHA: bone anchored hearing aid; CI: cochlear implant; MBS: Medicare Benefits Schedule; MEI: middle ear implant

As can be seen in Table 59 the bulk of the cost savings are due to reduced consumable costs. There would be a slight increase in the costs borne by the patient and the government.

One possible limitation to using MBS codes for CI and BAHA is the possibility of underestimating the total number of people suitable for MEI. This is because the MBS codes for CI numbers do not include severe patients with conductive hearing loss. Also, there remains a question as to whether BAHA is appropriate for sensorineural patients, or if there is an unaddressed pool of candidates with mild or moderate sensorineural hearing loss that would benefit from MEI instead of a BAHA. Since sensorineural is a significant portion of all hearing loss, this could result in an underestimate of the number of candidates for MEI.

The proportion of CIs undertaken on profoundly deaf individuals was uncertain; therefore, a second analysis was undertaken. Based on expert opinion, the number of CIs performed each year for profound hearing loss was estimated to be 60 per cent. Using these data the estimated number of eligible patients for MEI would be 265 (106 BAHA and 159 CI).

Table 60 Incremental costs per procedure using MBS data (lower number of CI)

	MEI	BAHA	CI
Total cost per patient	\$23,873	\$15,207	\$34,466
Number of patients	265	106	159
<i>Breakdown of financial implications:</i>			
Consumables	\$3,990,088	\$1,015,022	\$4,081,094
MBS Items	\$1,285,671	\$342,593	\$767,504
Patient out-of-pocket	\$1,050,529	\$254,342	\$631,432
Total financial implications	A=\$6,326,288	B=\$1,611,957	C=\$5,480,030
<i>Incremental costs:</i>			
Consumables	-\$1,106,028		
MBS Items	\$175,574		
Patient out-of-pocket	\$164,755		
Total cost savings A-(B+C)	-\$765,699		

BAHA: bone anchored hearing aid; CI: cochlear implant; MBS: Medicare Benefits Schedule; MEI: middle ear implant

As can be seen in Table 60, when MEI replaces a lower number of CI the cost savings is reduced to \$765,699. As before, the majority of cost savings is associated with a reduction in consumables.

Sensitivity analysis of financial implications

In the application it was estimated that 144 patients would be suitable for an MEI each year. Using the same methodology as the Applicant, but with 2009 ABS data, the number of suitable MEI patients was re-calculated as follows. Firstly, the prevalence of hearing loss was obtained from Listen Hear! Report (Access Economics, 2006). Secondly, the total number of individuals with sensorineural hearing loss was estimated to be 90 per cent of all hearing loss. Thirdly, it was estimated that 0.8 per cent of sensorineural hearing loss patients would be suitable for an MEI (Jenker et al 2002). Finally, it was estimated that 0.5 per cent had external otitis, therefore a traditional hearing aid would not be suitable.

Using this methodology, 149 candidates would require an MEI each year. Without MEI, 36 would require a BAHA and 113 would require a CI (based on MBS ratios). Based on these data, the total cost of BAHA would be \$554,692 (36 patients) and the total cost of CI would be \$3,878,215 (113 patients). This gives a total cost of \$4,432,907. If MEI was used instead of BAHA and CI the total cost would be \$3,557,045. Hence the cost savings of performing MEI as a direct replacement for BAHA and CI would be \$875,862.

Table 61 Incremental costs per procedure using the method proposed by the Applicant

	MEI	BAHA	CI
Total cost per patient	\$23,873	\$15,207	\$34,466
Number of patients	149	36	113
<i>Breakdown of financial implications:</i>			
Consumables	\$2,243,483	\$349,280	\$2,888,189
MBS items	\$722,887	\$117,890	\$543,162
Patient out-of-pocket	\$590,675	\$87,522	\$446,864
Total financial implications	A=\$3,557,045,	B=\$554,692	C=\$3,878,215
<i>Incremental costs:</i>			
Consumables	-\$993,986		
MBS items	\$61,835		
Patient out-of-pocket	\$56,289		
Total cost savings A-(B+C)	-\$875,862		

BAHA: bone anchored hearing aid; CI: cochlear implant; MBS: Medicare Benefits Schedule; MEI: middle ear implant

Further considerations

The analysis thus far has demonstrated that if MEI is used as a direct replacement for CI there will be a cost saving, but if MEI replaces BAHA there will be an increase in cost. Since, in general, more CIs are performed there is an overall cost saving.

However, an issue arises if a pool of individuals exists who would elect to have an MEI and would previously not have had a CI or BAHA. This could include people who are not satisfied with a traditional hearing aid. Estimating this pool of individuals is difficult due to lack of data. Using the Applicant's estimate, the number of suitable MEI candidates with moderate or severe hearing loss is 9613. However, as this is the overall number in Australia, and not the number of people

who would receive the procedure in a given year, using this estimate per annum is an over-estimate.

An incremental analysis is presented in Table 62. This analysis is provided as an illustration only. The possible new candidates for MEI are estimated as follows: 1) only individuals with moderate or severe hearing loss are included, since individuals with mild hearing loss are unlikely to elect to have MEI; and 2) individuals with otitis media are removed, because these individuals have been included in the initial analysis.¹⁵ Of the remaining individuals it is estimated that between one per cent and five per cent may choose an MEI if available.

Table 62 Additional cost per annum for MEIs elected from an unaddressed pool that would not have been treated with either a BAHA or CI

Estimated percentage electing for an MEI	Possible new candidates*	Additional cost per annum**
1%	96	\$2,291,787
2%	192	\$4,583,575
3%	288	\$6,875,362
4%	385	\$9,191,022
5%	481	\$11,482,809

*Estimates exclude patients with external otitis

**Does not include cost of hearing aids avoided

MEI: middle ear implant

Based on these estimates, if one per cent of the estimated pool of individuals with moderate or severe hearing loss elected to have MEI, the additional cost would be \$2,291,787. These estimates are based on prevalence data of hearing loss in Australia and include a large portion of older Australians for whom an MEI would not be viable.

It is worth noting that if people elect to have an MEI in place of a hearing aid, there would be a cost saving from each hearing aid avoided that would reduce these overall cost estimates. For example, if a hearing aid costs \$5000 per patient, the additional cost would be reduced to $(\$2,291,787 - \$480,000) = \$1,811,787$. However this may not be appropriate, as all patients may already have a hearing aid and the cost becomes a sunk cost.

¹⁵ It is estimated that 17.6% of individuals classified with severe hearing loss, actually have profound hearing loss. This number was subtracted from the total estimates. (based on UK data: http://www.rnid.org.uk/information_resources/aboutdeafness/statistics/statistics.htm)

Discussion

Limitations of the evidence

This report has been limited by the paucity of high-level evidence upon which to draw conclusions on the relative safety and effectiveness of the MEI. Only one comparative study assessed the MEI versus the CI, and no comparative studies assessed the MEI versus the BAHA. Three additional included comparative studies used comparators which were not of relevance to this report. The remaining studies included to assess effectiveness outcomes for the MEI were all case series, and subject to bias. The lack of high level evidence is likely related to the relative youth of the MEI procedure, and also to ethical issues regarding randomising patients to receive different types of surgical implantation.

The included studies displayed considerable variability regarding patient enrolment, study design and length of follow-up. Several studies assessed the MEI in patients who had a range of hearing severities, such as mild to severe, which made meaningful reporting difficult for these various severities.

The included studies presented a variety of MEI devices. While most studies assessed the VSB MEI, the Otologics MET, Envoy Esteem, Rion device, SOUNDTEC DDHS, and TICA MEIs were also assessed. Additionally, some studies described instances in which the MEI attachment method or the devices themselves had been modified to permit implantation. Hence, differences in components and attachment occurred between the six identified different MEI devices and also between patients receiving the same MEI.

Safety

No comparative evidence reporting on the safety of MEI compared with CI or BAHA was available. RCT evidence based on defined patient populations would better inform on any safety differences between MEI and the comparator procedures. In the absence of comparative safety data, information on the absolute safety of MEI, BAHA and CI implantation were included in this report. Even with the limitations in inclusion criteria for BAHA and CI data, much more evidence in terms of absolute patient numbers was available for CI. This reflects the fact that MEI is in its infancy compared with other more established alternatives.

Not all safety outcomes were uniformly reported across the identified studies. To address this, event rate has been reported in two manners throughout the report, both of which may be at risk of bias. The rate has been presented as a proportion of patients in the studies which specifically reported this outcome, which may be an over-inflated representation of the outcome, especially for rare events. The rate has also been presented as a proportion of the total patient number in all studies included for safety. This may be an under-representation of some outcomes, such as common outcomes which may not have been of interest in all studies (such as mild pain or infection).

Owing to the surgical techniques used, the devices implanted and the sites of implantation, several adverse events which were reported in BAHA or CI implantation were not encountered in MEI implantation. Several intracranial adverse events which were reported in CI patients were absent in MEI patients, including meningitis (which led to two deaths in children), dural damage and cerebrospinal fluid leak. The BAHA appeared to be more susceptible than the MEI to damage or loss due to trauma. Device loss due to trauma was not encountered in the MEI studies yet 3.72 per cent of all implanted BAHAs were lost for this reason, and osseointegration was lost due to trauma in 1.62 per cent of all implanted BAHAs. Once positioned, the MEI appeared to be more stable than the BAHA. Although a small percentage of all MEIs migrated, loss of osseointegration or failed osseointegration was quite commonly encountered in the BAHA studies. Generally, BAHA patients reported more wound healing difficulty than MEI patients. This is likely to be due to the skin grafts employed in BAHA implantation, as well as the additional maintenance care required for the BAHA's abutment area.

Conversely, several adverse were reported more frequently in MEI implantation than in BAHA or CI implantation. The incidence of tympanic membrane perforation was higher in MEI patients (0.7 per cent) than in CI patients (0.06 per cent), and did not occur in BAHA patients. Haematomae occurred more frequently in MEI patients (1.2 per cent) than in CI patients (0.02 per cent). Extrusions also occurred more frequently in MEI than in CI patients, and were not reported to have occurred in BAHA patients. Insufficient gain was more prevalent in MEI studies (1.6 per cent of all patients receiving MEI) than in BAHA studies (0.48 per cent of all patients receiving BAHA). Insufficient gain was not reported in CI patients. The BAHA devices appeared to be the most technologically consistent of the three devices, with no reported instances of BAHA device malfunction or failure compared with 1.3 per cent of all CI devices and 0.9 per cent of all MEI devices implanted.

Residual hearing loss after implantation was an important adverse event which was uniquely reported in MEI patients. Residual hearing loss was reported upon by most MEI studies, with thirteen studies reporting that patients suffered significant declines in mean residual hearing loss after MEI implantation. Unlike the CI literature, the MEI literature included many patients with mild or moderate HL. In these patients, any further deterioration in hearing may be of greater clinical importance compared with losses in patients with severe or profound HL. Patients with CHL did not report significantly worse residual hearing after implantation.

Expert clinical opinion endorsed by the Advisory Panel notes that certain adverse events are likely to be more commonly seen in children than in adults. Paediatric bone is softer than that of adults, and has a longer osseointegration time, and hence may be more susceptible to device loosening or damage. Additionally, children may be likely to sustain head trauma during rambunctious play. Children may also be less reliable at cleaning and maintaining their implant site. This may be especially important in the case of the BAHA.

Communication with the manufacturer of the VSB device (Med-EL) indicates that this MEI is not MRI safe at any Tesla level, and can be removed if necessary.

Due to the differences in devices and the surgical procedures associated with them, the adverse events differ between MEI and its comparators. Overall, absolute evidence from case series studies suggests that MEI appears to be as safe as CI and BAHA.

Effectiveness

Generally, MEI implantation and/or activation led to improvements in patients with SNHL, MHL and CHL. However, these conclusions are limited by the paucity of high-level evidence. Only one comparative study assessed the MEI versus the CI, and no comparative studies assessed the MEI versus the BAHA. Three additional included comparative studies used comparators which were not of relevance to this report. The remaining studies included to assess effectiveness were all case series, and subject to bias.

The included studies displayed considerable variability regarding patient enrolment, study design and length of follow-up. Several studies assessed the MEI in patients who had a range of hearing severities, such as mild to severe, which made meaningful reporting difficult for these various severities.

The included studies presented a variety of MEI devices. While most studies assessed the VSB MEI, the Otologics MET, Envoy Esteem, Rion device, SOUNDTEC DDHS, and TICA MEIs were also assessed. Additionally, some studies described instances in which the MEI attachment method or the devices themselves had been modified to permit implantation. Hence, differences in components and attachment occurred between the six identified different MEI devices and also between patients receiving the same MEI.

The majority of the available studies assessed the MEI in patients with SNHL. This is reflective of the anticipated Australian practice suggested by clinical experts.

The reporting of effectiveness outcomes was compromised by the lack of uniform outcome measurements. While the primary technical outcome measure (functional gain) was identified a priori, not all studies reported upon this outcome. Patient-related outcomes were not reported in all studies. Where these were reported, different outcome measures such as the GBI and the SF-36 were used.

Effectiveness outcomes were further compromised by the fact that some studies reported that baseline measurements were taken with a digital, best fit, or state-of-the-art HA, while others used the patient's own HA. Further, in some before/after MEI studies it was not clearly stated whether baseline measures were measured with or without a HA. It appears that presently there is considerable variability in HA management prior to the consideration of MEI implantation.

Cost-effectiveness

The objective of the economic evaluation was to compare the cost-effectiveness of MEI relative to BAHA and CI. In the absence of conclusive effectiveness data, a cost analysis was conducted to compare the different costs associated with each of the three procedures.

The estimated costs of MEI, BAHA and CI were taken from a number of sources. These included the Medicare Benefits Schedule (MBS), Australian Refined Diagnostic Related Group (AR-DRG) cost, manufacturer's implants and the median charged MBS fee.

Based on a number of estimates and assumptions:

- The total estimated first year cost of an MEI, BAHA and CI is \$23,873, \$15,207 and \$34,466, respectively. The incremental **cost** of using an MEI as opposed to a BAHA is \$8,666. The incremental **cost saving** of using an MEI as opposed to a CI is \$10,593.
- Based on 2006-07 MBS data, the total cost of BAHA would be \$1,611,957 (106 patients) and the total cost of CI would be \$11,270,250 (327 patients). This gives a total cost of \$12,882,207. If MEI was used instead of BAHA and CI the total cost would be \$10,336,916. Hence the cost savings of performing MEI as a direct replacement for BAHA and CI would be over \$2.5 million.
- Expert opinion endorsed by the Advisory Panel indicated that MEI would not just replace current CI and BAHA use, but would become another option in meeting the pool of unmet need of those with hearing loss. Expert opinion was that these individuals, currently persisting with hearing loss or a less than optimal hearing aid, may consider MEI implantation while they are not considering or accessing BAHA or CI. The previously mentioned variability in HA management prior to consideration of MEI, and limited data on the pool of 'unmet need', makes this number difficult to quantify. Sensitivity analysis suggests that if one per cent of the estimated pool of individuals with moderate or severe hearing loss elected to have MEI, the additional cost would be \$2,291,787. These estimates are based on prevalence data of hearing loss in Australia and include a large portion of older Australians for whom an MEI would not be viable.

Conclusions

Safety

No comparative evidence reporting on the safety of MEI compared with CI or BAHA was available. RCT evidence based on defined patient populations would better inform on any safety differences between MEI and the comparator procedures. In the absence of comparative safety data, information on the absolute safety of MEI, BAHA and CI implantation were included in this report. Even with the limitations in inclusion criteria for BAHA and CI data, much more evidence in terms of absolute patient numbers was available for CI. This reflects the fact that MEI is in its infancy compared with other more established alternatives.

The safety data revealed a wide variability in outcomes owing to the surgical techniques used, the devices implanted and the sites of implantation. Further, there was variability in outcome reporting between studies which considered the same device.

Residual hearing loss after implantation was uniquely reported in MEI patients. Residual hearing loss was reported upon by most MEI studies, with 13 studies reporting that patients suffered significant declines in mean residual hearing loss after MEI implantation. Unlike the CI literature, the MEI literature included many patients with mild or moderate HL. In these patients, any further deterioration in hearing may be of greater clinical importance compared with losses in patients with severe or profound HL. Patients with CHL did not report significantly worse residual hearing after implantation.

Expert clinical opinion endorsed by the Advisory Panel notes that certain adverse events are likely to be more commonly seen in children than in adults. Paediatric bone is softer than that of adults, and has a longer osseointegration time, and hence may be more susceptible to device loosening or damage. Additionally, children may be likely to sustain head trauma during rambunctious play. Children may also be less reliable at cleaning and maintaining their implant site. This may be especially important in the case of the BAHA.

Communication with the manufacturer of the VSB device (Med-EL) indicates that this MEI is not MRI safe at any Tesla level, and can be removed if necessary.

Due to the differences in devices and the surgical procedures associated with them, the adverse events differ between MEI and its comparators. Overall, absolute evidence from case series studies suggests that MEI appears to be as safe as CI and BAHA.

Effectiveness

This report has been limited by the paucity of high-level evidence upon which to draw conclusions on the effectiveness of the MEI. Only one comparative study assessed the MEI versus the CI, and no comparative studies assessed the MEI versus the BAHA. Three additional included comparative studies used

comparators which were not of relevance to this report. The remaining studies included to assess effectiveness were all case series, and subject to bias. These studies displayed considerable variability regarding patient enrolment, study design and length of follow-up. Several studies assessed the MEI in patients who had a range of hearing severities, such as mild to severe, which made meaningful reporting difficult for these various severities.

The main outcome of interest was functional gain. Where reported, the gain provided by the MEI was usually of clinical significance (≥ 10 dB). Other effectiveness outcomes were varied and not uniformly reported across the studies. Where reported, quality of life and patient satisfaction outcomes showed improvements after MEI implantation or activation. Where reported, technical outcomes generally showed improvements after MEI implantation or activation but statistical analyses were generally not supplied.

Effectiveness of the MEI vs the CI in patients with SNHL of undefined severity

One comparative study was assessed (NHMRC level III). Regarding projected speech recognition in patients with severe hearing loss, MEI appears to be less effective than CI. Regarding projected PS65 score in patients with mild, moderate or severe hearing loss, MEI appears to be less effective than CI.

As only one comparative study was available to inform upon the relative effectiveness of the MEI compared with the BAHA and the CI, absolute effectiveness outcomes were collated for the MEI implantation alone from 29 level IV studies. Of these 29 studies, seven were retrospective while the remaining were prospective studies. The majority of the available studies assessed the MEI in patients with SNHL. This is reflective of the anticipated Australian practice suggested by clinical experts. Sample sizes ranged from one to 125 patients; however, the majority of studies (22 out of 29) had less than 20 patients. In some studies it was not clearly stated whether baseline measures were measured with or without a HA.

Effectiveness of the MEI in patients with mild or moderate SNHL

Four studies were available with a total of 50 patients. These included two comparative studies reporting on internal comparisons between different types of MEI and two case series. In summary, MEI appears to be effective in improving hearing from baseline, pre-implantation levels in patients with mild or moderate SNHL.

Effectiveness of the MEI in patients with severe SNHL

One case series with a total of 13 patients was available for this indication. In summary, MEI appears to be effective in improving hearing from baseline, pre-implantation levels in patients with severe SNHL. Importantly, only a small number of patients were assessed and no statistical analyses were reported.

Effectiveness of the MEI in patients with SNHL of undefined severity

Nine case series with a total of 262 patients were available for this indication, and statistical analyses were rarely provided to substantiate effectiveness outcomes. In summary, MEI appears to improve hearing in patients with SNHL of undefined

severity. However, the data are of relatively low quality and outcome measures are variable between studies.

Effectiveness of the MEI in patients with mild or moderate MHL

Six case series with a total of 47 procedures in 46 patients were available for this indication. Two of the case series modified the MEI devices due to varied middle ear anatomy. In summary, generally MEI implantation or activation led to improvements in patients with mild or moderate MHL. Importantly, only a small number of patients were assessed and no statistical analyses were reported.

Effectiveness of the MEI in patients with severe MHL

Two case series which assessed a total of 47 patients were available for this indication. One case series modified the MEI devices due to varied middle ear anatomy. In summary, generally MEI implantation or activation led to improvements in patients with severe MHL. Importantly, only a small number of patients were assessed and few statistical analyses were reported.

Effectiveness of the MEI in patients with MHL of undefined severity

One case series with a total of 19 patients was available for this indication. This case series modified the MEI devices due to varied middle ear anatomy. In summary, generally MEI implantation led to improvements in patients with MHL of undefined severity. Importantly, only a small number of patients were assessed and few statistical analyses were reported.

Effectiveness of the MEI in patients with CHL

Two case series with a total of 12 patients who suffered from either unilateral osseous atresia or congenital auricular atresia were available for this indication. The implanted MEIs were modified to permit placement due to anatomic variation. In summary, 12 patients appeared to benefit from MEI implantation; however, this evidence is limited by the small number of patients studied and lack of statistical analysis. Additionally, these patients all suffered either unilateral osseous atresia or congenital auricular atresia, and it is unclear whether the benefits seen in these patients would extend to patients with other types of CHL.

The low level evidence suggests that in patients with mild, moderate or severe SNHL; SNHL of undefined severity; mild, moderate or severe MHL; MHL of undefined severity; or CHL; the MEI appears to be effective when implanted or switched on.

This report also briefly assessed the effectiveness of the MEI versus the external HA. Effectiveness outcomes were compromised by the fact that some studies reported that baseline measurements were taken with a digital, best fit, or state-of-the-art HA, while others used the patient's own HA. It appears that presently there is considerable variability in HA management prior to the consideration of MEI implantation. Generally the MEI appears to be as effective as the HA in patients with SNHL and MHL.

Cost-effectiveness

The objective of the economic evaluation was to compare the cost-effectiveness of MEI relative to BAHA and CI. In the absence of conclusive effectiveness data, a cost analysis was conducted to compare the different costs associated with each of the three procedures.

The estimated costs of MEI, BAHA and CI were taken from a number of sources. These included the Medicare Benefits Schedule (MBS), Australian Refined Diagnostic Related Group (AR-DRG) cost, manufacturer's implants and the median charged MBS fee.

Based on a number of estimates and assumptions:

- The total estimated first year cost of an MEI, BAHA and CI is \$23,873, \$15,207, and \$34,466, respectively. The incremental cost of using an MEI as opposed to a BAHA is \$8,666. The incremental cost saving of using an MEI as opposed to a CI is \$10,593.
- Based on 2006-07 MBS data, the total cost of BAHA would be \$1,611,957 (106 patients) and the total cost of CI would be \$11,270,250 (327 patients). This gives a total cost of \$12,882,207. If MEI was used instead of BAHA and CI the total cost would be \$10,336,916. Hence the cost savings of performing MEI as a direct replacement for BAHA and CI would be over \$2.5 million.
- Expert opinion endorsed by the Advisory Panel indicated that MEI would not just replace current CI and BAHA use, but would become another option in meeting the pool of unmet need of those with hearing loss. Expert opinion was that these individuals, currently persisting with hearing loss or a less than optimal hearing aid, may consider MEI implantation while they are not considering or accessing BAHA or CI. The previously mentioned variability in HA management prior to consideration of MEI, and limited data on the pool of 'unmet need', makes this number difficult to quantify. Sensitivity analysis suggests that if one per cent of the estimated pool of individuals with moderate or severe hearing loss elected to have MEI, the additional cost would be \$2,291,787. These estimates are based on prevalence data of hearing loss in Australia and include a large portion of older Australians for whom an MEI would not be viable.

Appendix A MSAC terms of reference and membership

MSAC's terms of reference are to:

- advise the Minister for Health and Ageing on the strength of evidence pertaining to new and emerging medical technologies and procedures in relation to their safety, effectiveness and cost-effectiveness and under what circumstances public funding should be supported;
- advise the Minister for Health and Ageing on which new medical technologies and procedures should be funded on an interim basis to allow data to be assembled to determine their safety, effectiveness and cost-effectiveness;
- advise the Minister for Health and Ageing on references related either to new and/or existing medical technologies and procedures; and
- undertake health technology assessment work referred by the Australian Health Ministers' Advisory Council (AHMAC) and report its findings to AHMAC.

The membership of MSAC comprises a mix of clinical expertise covering pathology, nuclear medicine, surgery, specialist medicine and general practice, plus clinical epidemiology and clinical trials, health economics, consumers, and health administration and planning:

Member	Expertise or Affiliation
Professor Robyn Ward (Chair)	Medical Oncology
Associate Professor Frederick Khafagi (Deputy Chair)	Nuclear Medicine
Professor Jim Butler (Economics Sub-committee Chair)	Health Economics
Associate Professor John Atherton	Cardiology
Professor Justin Beilby	General Practice/Research
Associate Professor Michael Bilous	Anatomical Pathology
Professor Jim Bishop AO	Chief Medical Officer (<i>ex officio member</i>)
Professor Peter Cameron	Trauma and Emergency Medicine
Associate Professor Kirsty Douglas	General Practice/Research
Dr Kwun Fong	Thoracic Medicine
Professor Richard Fox	Medical Oncology
Professor John Horvath	Renal Medicine/Health Workforce
Ms Elizabeth Koff	Health Administration
Professor Helen Lapsley	Health Economics
Professor Peter McCluskey	Ophthalmology
Mr Russell McGowan	Consumer Health Representative
Dr Allan McKenzie	Radiology
Dr Graeme Suthers	Genetics/Pathology
Mr David Swan	AHMAC Representative
Professor Ken Thomson	Radiology
Dr Christine Tippet	Obstetrics/Gynaecology
Associate Professor David Winlaw	Paediatric Cardiothoracic Surgery
Dr Caroline Wright	Colorectal Cancer/Surgery
Dr Shiong Tan	Health Promotion/Population Health (resigned 24/02/2010)

Appendix B Advisory panel and evaluators

Advisory panel for MSAC Application 1137: Middle ear implant for sensorineural, conductive and mixed hearing losses

Dr Shiong Tan	Chair, member of MSAC (resigned 24/02/2010)
A/Professor Kirsty Douglas <i>(Deputy Chair)</i>	Member of MSAC, member of Economics Sub-Committee
A/Professor Melville Da Cruz	Royal Australasian College of Surgeons nominee
Dr John Malouf	ENT specialist
A/Professor Christopher Perry	ENT specialist
Mr Jason Ridgway	Audiologist
Ms Alexandra Rivers	Consumers' Health Forum of Australia nominee
Ms Hema Indrasamy	Project manager

Economics Sub-Committee Advice to Advisory Panel

Name	Organisation
Professor Jim Butler	MSAC member, Chair of Economics Sub-Committee

Evaluators

Name	Organisation
Mrs Caryn Perera	ASERNIP-S
Dr Prema Thavaneswaran	ASERNIP-S
Mr Irving Lee	ASERNIP-S
Dr Alun Cameron	ASERNIP-S
Ms Jody Church	CHERE
Dr Stephen Goodall	CHERE

Included comparative studies:

CI vs MEI

SNHL

Verhaegen VJO, Mylanus EAM, et al, 2008. 'Audiological application criteria for implantable hearing aid devices: a clinical experience at the Nijmegen ORL clinic', *The Laryngoscope*, 118, 1645-1649.

MEI vs MEI

SNHL

Snik AFM, van Duijnhoven, et al, 2007. 'Evaluation of the subjective effect of middle ear implantation in hearing-impaired patients with severe external otitis', *Journal of the American Academy of Audiology*, 18, 496-503.

Snik A, Noten J, Cremers C, 2004. 'Gain and maximum output of two electromagnetic middle ear implants: are real ear measurements helpful?', *Journal of the American Academy of Audiology*, 15, 249-257.

Snik A and Cremers C, 2004a. 'Audiometric evaluation of an attempt to optimize the fixation of the transducer of a middle-ear implant to the ossicular chain with bone cement', *Clinical Otolaryngology and Allied Sciences*, 29, 5-9.

Undefined hearing loss

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MEI vs HA

SNHL

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Additional FDA cohort:

Symphonix Devices, Incorporated. 'Summary of safety and effectiveness' available at: http://www.accessdata.fda.gov/cdrh_docs/pdf/P990052b.pdf

MHL

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CHL

Nil

UNDEFINED HEARING LOSS

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Schmuziger N, Schimmann F, et al, 2006. 'Long-term assessment after implantation of the Vibrant Soundbridge device', *Otology and Neurotology*, 27, 183-188.

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SNHL case series

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Snik AFM and Cremers CWRJ, 1999. 'First audiometric results with the Vibrant Soundbridge, a semi-implantable hearing device for sensorineural hearing loss', *Audiology*, 38, 335-338.

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- Colletti V, Soli SD, et al, 2006. 'Treatment of mixed hearing losses via implantation of a vibratory transducer on the round window', *International Journal of Audiology*, 45, 600-608.
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CHL case series

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- Tringali S, Pergola N, et al, 2008. 'Fully implantable hearing device as a new treatment of conductive hearing loss in Franceschetti syndrome', *International Journal of Pediatric Otorhinolaryngology*, 72, 513-517.

Undefined case series

Nil

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- Bibas A, Phillips S, et al, 2006. 'Chronic suppurative otitis media following paediatric cochlear implantation', *Cochlear Implants International*, 7, 167-178.
- Biernath KR, Reefhuis J, et al, 2006. 'Bacterial meningitis among children with cochlear implants beyond 24 months after implantation', *Pediatrics*, 117, 284-289.
- Brown KD, Connell SS, et al, 2009. 'Incidence and indications for revision cochlear implant surgery in adults and children', *The Laryngoscope*, 119, 152-157.

- Cote M, Ferron P, et al, 2007. 'Cochlear reimplantation: causes of failure, outcomes, and audiologic performance', *The Laryngoscope*, 117, 1225-1235.
- Cullen RD, Fayad JN, et al, 2008. 'Revision cochlear implant surgery in children', *Otology and Neurotology*, 29, 214-220.
- Dodson KM, Maiburger PG, Sismanis A, 2007. 'Intracranial complications of cochlear implantation', *Otology and Neurotology*, 28, 459-462.
- Hopfenspirger MT, Levine SC, Rimell FL, 2007. 'Infectious complications in pediatric cochlear implants', *The Laryngoscope*, 117, 1825-1829.
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Verhaegen VJO, Mylanus EAM, et al, 2008. 'Audiological application criteria for implantable hearing aid devices: a clinical experience at the Nijmegen ORL clinic', *The Laryngoscope*, 118, 1645-1649.

Viccaro M, Mancini P, et al, 2007. 'Positional vertigo and cochlear implantation', *Otology and Neurotology*, 28, 764-767.

Wootten CT, Backous DD, Haynes DS, 2006. 'Management of cerebrospinal fluid leakage from cochleostomy during cochlear implant surgery', *The Laryngoscope*, 116, 2055-2059.

Included BAHA studies:

Badran K, Arya AK, et al, 2009. 'Long-term complications of bone-anchored hearing aids: a 14-year experience', *The Journal of Laryngology and Otology*, 123, 170-176.

Davids T, Gordon KA, et al, 2007. 'Bone-anchored hearing aids in infants and children younger than 5 years', *Archives of Otolaryngology Head and Neck Surgery*, 133, 51-55.

Gillett D, Fairley JW, et al, 2006. 'Bone-anchored hearing aids: results of the first eight years of a programme in a district general hospital, assessed by the Glasgow benefit inventory', *The Journal of Laryngology and Otology*, 120, 537-542.

Lloyd S, Almeyda J, et al, 2007. 'Updated surgical experience with bone-anchored hearing aids in children', *The Journal of Laryngology and Otology*, 121, 826-831.

Tjellstrom A, Granstrom G, Odersjo M, 2007. 'Survival rate of self-tapping implants of bone-anchored hearing aids', *The Journal of Laryngology and Otology*, 121, 101-104.

Yuen H-W, Bodmer D, et al, 2009. 'Management of single-sided deafness with the bone-anchored hearing aid', *Otolaryngology – Head and Neck Surgery*, 141, 16-23.

Appendix D Further data tables

Table 63 Validity characteristics of comparative studies included in the report

Study ID	HL severity	Study design		Sample size Enrolment	Follow-up Losses to follow-up	Inclusion criteria	Exclusion criteria	Comments
		Retrospective	Prospective					
Cochlear implant compared with middle ear implant								
<i>Sensorineural hearing loss</i>								
Verhaegen 2008	-	✓		202	MEI and HA: at least 2 months CI: 12 months	✓	✓	-
				-	-			
Middle ear implant compared with hearing aid								
<i>FDA regulatory document</i>								
Symphonix Devices Incorporated 2000 (FDA regulatory document)	Moderate to severe	-		54	5 months post-surgery plus an additional 6 weeks to acclimatise to the Vibrant D audio processor.	✓	✓	This report was produced by the device manufacturer and the FDA. One patient's device did not activate. This patient was not evaluated. For safety outcomes, 5 subjects from the feasibility study and 22 subjects from the supplemental safety cohort were also assessed, in addition to the 54 patients in the clinical study.
				-	1			

Sensorineural hearing loss

Chen 2004	Mild to severe	–	7	12 months	✓	✓	Three authors were clinical investigators for St Croix Medical. Two authors were employees and stockholders of St Croix Medical. All speech materials were on pre-recorded discs supplied by St Croix Medical, the study sponsor.
			–	–			
Fraysse 2001	Mild to severe	–	25	At least 6 months postsurgery; APHAB 3 months postsurgery	✓	✓	The study was supported by Symphonix Devices Inc.
			consecutive	–			
Hough 2001	Moderate to moderately severe	–	10	–	✓	✓	Dr Hough is the founder and a major stockholder and Drs Dyer and Wood and Pamela Matthews are also stockholders of SOUNDTEC, Inc. This study was supported in part through funding provided by SOUNDTEC, Inc.
			consecutive	–			
Jenkins 2004	Moderate, moderately severe or severe	–	282	12 months	✓	✓	–
			–	–			
Jenkins 2007	Moderate	–	20	3 months	✓	✓	Financial disclosure Otologics, LLC
			–	–			
Luetje 2002	Severe	–	53	5 months	✓	✓	Only 50 of the 53 patients were fitted with the D audio processor.
			consecutive	–			
Matthews 2002	Severe	–	103	5 months	✓	✓	The author's contact email address was for SOUNDTEC and he/she was probably an employee of the company.
			consecutive	8			Of the 103 patients in the study, 95 had completed testing at the time of publication, 8 patients were lost to follow-up.
Roland 2001	Severe	–	23	5 months	✓	–	–
			–	–			

Snik 2007	Moderate	-	23	-	✓	-	Data on one patient were excluded, because he had hereditary diabetes that led to sudden symmetrical hearing deterioration a few months after implantation, and his final hearing thresholds were poorer than those permitted for middle ear implantation.
			-	1			
Snik 2004	Severe	-	13	VSB patients had been using their device for more than a year. The Otologics MET patients were first-time users, and measurements were taken at least 4 months after device fitting	✓	-	-
Snik 2004a	Moderate	-	13	Crimping: 42 months (24-72 months) Cement: 24 months (8-42 months)	✓	-	Two patients were excluded: one developed chronic aeration problems and as a consequence a chronic air-bone gap after surgery; the other patient's pre-surgery hearing thresholds in the high frequency range were far outside the application range (exceeding 100 dB HL).
			consecutive	2			
Snik 2001	Moderate to severe	-	15	At least 2 months	✓	✓	The audio processors were provided by Symphonix Devices Inc. One patient excluded with high-frequency deafness (hearing threshold at 1-4 kHz that exceeded 100 dB HL)
			-	1			
Thill 2002	Moderate	-	13	3 months	✓	-	Siemens provided most of the implants for this study.
			-	-			
Todt 2005	Mild to severe	-	23	-	✓	-	The work was supported by a grant from the Sonnenfeld Foundation.

Todt 2002	Mild to severe	-	5	1.5 years	✓	-	The Sonnenfeld Foundation supported the study.
Uziel 2003	Mild to moderate	-	6	At least 3 months experience with the sound processor	-	-	There were no losses to follow-up.
			consecutive	0			
			-	1			
<i>Mixed hearing loss</i>							
Caye-Thomasen 2002	Severe	-	9	9.5 years (range 8.8-10 years)	-	-	Only 6 patients were available at follow-up. Three patients were lost to follow-up.
			-	3			
Tos 1994	Severe	-	9	3 months	-	-	Smith and Nephew provided help and support to the study.
			-	3			Only 6 patients were evaluated. Three patients were lost to follow-up.
<i>Undefined hearing loss</i>							
Kodera 1994	Moderate	-	6	-	-	-	-
			-	-			
Schmuziger 2006	Moderate	-	24	42 months [SD 8 months] (range 26-55 months)	-	-	4 patients were lost to follow-up (1 died from a disease which was not related to the implantation; 2 refused to participate in the study; 1 could not be reached).
			-	4			
Stieve 2009	-	-	34	At least 12 months	-	-	-
			-	-			
Truy 2008	Moderate	-	6	3 months	✓	-	-
			-	-			

dB: decibels; HA: hearing aid; MEI: middle ear implant; MET: middle ear transducer; SD: standard deviation; VSB: Vibrant Soundbridge; - indicates not reported

Table 64 Critical appraisal of case series for middle ear implant in patients with sensorineural hearing loss

Study ID	HL severity	Study design		Sample size	Follow-up duration	Inclusion criteria described	Exclusion criteria described	Comments
		Retro	Prosp					
Barbara 2009	Moderate		✓	6	-	✓	-	-
				Consecutive	-			
Fisch 2001	Mild to severe		✓	47	3 months	✓	✓	This study was supported by the manufacturer
				-	-			
Foyt 2006	Moderate		✓	9	24 months	-	-	-
				Consecutive	1			
Garin 2002	Moderate to severe	✓		9	15.6 months	✓	-	-
				-	-			
Snik 2006	-		✓	21	6 to 24 months	-	-	-
				-	4			
Snik 2000	Moderate		✓	6	8 to 19 months	✓	-	-
				-	0			
Snik 1999	Moderate to severe		✓	7	2 months	✓	-	Devices supplied by manufacturer
				-	-			
Sterkers 2003	Mild to severe		✓	125	3 months	✓	-	Contralateral hearing aid utilised
				Consecutive	30			
				<i>Same cohort reported in Mosnier 2008</i>				
Todt 2005	-	✓		2	-	-	-	Partly sponsored by Sonnenfield Foundation
				-	0			
Vincent 2004	Moderate		✓	39	16 months	✓	-	-
				-	-			
Zenner 2000	Moderate to severe		✓	20	6 months	✓	-	-
				Consecutive	1			
Zenner 2003	Moderate to severe		✓	13	Minimum 6 months	✓	✓	-
				-	-			

Zenner 2004	Moderate to severe	✓	20	6 months	✓	✓	One patient was lost to follow-up (patient decided to leave the study prematurely)
			-	1			

- indicates not reported

Table 65 Critical appraisal of case series for middle ear implant in patients with mixed hearing loss

Study ID	HL severity	Study design		Sample size Enrolment	Follow-up duration Losses	Inclusion	Exclusion	Comments
		Retro	Prosp					
Colletti 2009	Moderate to severe	✓		19	36 months	-	-	Eardrops used for 4 weeks post implant
				-	-			
Colletti 2006	Severe	✓		7	9 months	-	-	-
				-	-			
Cuda 2009	Moderate	✓		8	12 months	-	-	-
				-	0			
Dumon 2009	Moderate	✓		13	6 months	✓	-	-
				-	0			
Dumon 2007	Severe	✓		1	-	-	-	-
				-	0			
Foyt 2006	Moderate	✓		1	MI: 24 months; TS:44.4 months	-	-	-
				Consecutive	1			
Lefebvre 2009	Moderate	✓		6	12 months	✓	✓	2 authors are employees of manufacturer
				-	0			

Streitberger 2009	Severe	✓	40	6 to 9 months	✓	-	-	
			-	0				
Suzuki 1989	Moderate	✓	9	-	-	-	-	Contralateral hearing aid in 1 patient
			-	0				
Suzuki 1994	-	✓	30	52 months	-	-	-	Received some form of assistance from an employee of manufacturer
<i>Same cohort reported in Suzuki 1995</i>			-	-				
Tono 2000	Moderate to severe	✓	3	24 to 48 months	-	-	-	
			-	0				
Tringali 2009	Severe	✓	1	15 months	-	-	-	One author was employee of manufacturer
			-	0				
Venail 2007	Moderate to severe	✓	4	-	-	-	-	
			-	0				
Yanagihara 1997	Moderate	✓	9	54 months	-	-	-	
<i>Same cohort reported in Yanagihara 2001</i>			-	1				

MI: minimally invasive; TS: traditional surgery; - indicates not reported

Table 66 Critical appraisal of case series for middle ear implant in conductive hearing loss

Study ID	HL severity	Study design		Sample size	Follow-up duration	Inclusion	Exclusion	Comments
		Retro	Prosp	Enrolment	Losses			
Frenzel 2009	Moderate		✓	7	8 months	✓	✓	-
				Consecutive	-			
Siegert 2007	Moderate to severe		✓	5	3 months	-	-	The implantable hearing devices were produced and supplied for this study without any charge by Otologics. One author is an employee of the manufacturer.
				-	-			
Tringali 2008	Severe	✓		1	15 months	-	-	-
				-	0			

- indicates not reported

Table 67 Patient characteristics for sensorineural hearing loss

Study ID	N	HL aetiology	Surgical history	Mean age (range)	Gender M/F	Mean preoperative PTA threshold	Previous HA use
LEVEL III							
Chen 2004	7	Noise induced n=2, hereditary n=1, ototoxicity n=1, antibiotics n=1, unknown n=2	-	64.4 (42-88)	5/2	-	Yes
Fraysse 2001	25	-	-	49.3 (20-73)	8/17	Mild n=2; moderate n=12; moderate-severe n=6; severe n=5	21/25 patients used a HA preoperatively
Hough 2001	10	Congenital n=1, noise-induced n=1; unknown n=8	-	65.3	5/5	54 dB HL	Yes
Jenkins 2004	282	-	-	-	-	51 dB HL ^a	Yes
Jenkins 2007	20	-	-	62.8 (31.6-82)	10/10	53.7 dB HL ^a	Yes
Luetje 2002	53	Heredity n=4; noise-induced n=2; presbycusis n=1; barotraumas n=1; trauma n=1; unknown n=44	-	58.7 (28-86)	26/27	-	Yes
Matthews 2002	103	-	-	65.1	68/35	-	Yes
Roland 2001	23	-	-	67.1	13/10	-	Yes
Snik 2004	13	-	-	VSB 54 (39-65) MET 41.8 (20-56)	-	-	-
Snik 2004a	13	-	-	Crimping mean 46 (35-53), crimping plus SerenoCem 56 (47-64)	1/10	57 dB HL	-
Snik 2001	15	-	-	Not reported (33-67)	-	57 dB HL	Yes
Snik	23	-	-	53 (18-79)	11/12	VSB 49 dB HL	Yes

2007							MET 64 dB HL	
Thill 2002	13	-	-	57 (36-72)	5/8	-	-	Yes
Todt 2002	5	-	-	Not reported (54-69)	-	-	55 dB HL	Yes
Todt 2005	23	-	-	Not reported (41-80)	-	-	Mild to severe SNHL	Yes
Uziel 2003	6	Noise-induced n=2, ototoxicity n=1; unknown n=3	-	56 (32-67)	4/2	-	54.83 dB HL	Yes
LEVEL IV								
Barbara 2009	6	-	-	-	-	-	58.9 dB HL	-
Cremers 2008	1	Unknown	Prior VSB implanted, migrated into hypotympanum	63 at original surgery	0/1	-	55 dB HL ^a	Yes
Fisch 2001	47	Unknown 40 (85%) Known 7 (15%)	-	48.4 (19-80)	23/24	-	Mild n=1 Moderate n=24 Moderate to severe n=18 Severe n=4	Yes ^b
Foyt 2006	8	-	-	Not reported (21-84)	3/6	-	54.4 dB HL	Yes
Garin 2008	9	Symmetric idiopathic bilateral SNHL	-	63 (37-72)	4/5	-	Moderate to severe SNHL	Yes. All patients suffered from chronic eczema of the external auditory canal which led to repetitive bouts of otitis externa
Snik 1999	7	-	-	49.4 (33-67)	2/5	-	56 dB HL	Yes. 5/7 stopped due to severe external otitis
Snik 2000	6	-	No previous ear surgery	49 (33-66)	1/5	-	55 dB HL	No. All patients had severe bilateral chronic otitis externa, which made the use of ear moulds impossible or troublesome
Snik 2006	21	-	-	52.4 (18-79)	9/12	-	-	Yes

Sterkers 2003	125 ^c	-	-	56 (24-81) ^c	45/50 ^c	Mild, moderate, moderate to severe, severe SNHL	11/95 (11.5%) used HA before surgery
<i>Same cohort reported in Mosnier 2008</i>							
Todt 2004	2	1 noise-induced, 1 unknown	-	-	2/0	-	Yes
Vincent 2004	39	-	-	-	-	54.6 dB HL	-
Zenner 2000	20	-	-	-	-	-	Yes
Zenner 2003	13	-	-	All adult (no further details)	-	Moderate to severe SNHL	5 patients has used HAs and encountered problems, 8 patients could not use HA due to their professions
Zenner 2004	20	-	-	-	-	-	Yes

a: Approximated and calculated from figure

b: For medical reasons, eight (17%) patients had been unable to use conventional amplification in the external ear before implantation. The remaining patients reported being dissatisfied with their hearing aids because of sound quality and/or discomfort and wanted to try a surgical solution for their hearing loss

c: Data only available for 95 patients

dB: decibels; HA: hearing aid; HL: hearing loss; MET: Otologics Middle Ear Transducer; PTA: pure-tone average; SNHL: sensorineural hearing loss; - indicates not reported

Table 68 Patient characteristics for mixed hearing loss

Study ID	N	HL aetiology	Surgical history	Mean age (range)	Gender M/F	Mean preoperative PTA thresholds	Previous HA use
LEVEL III							
Tos 1994 <i>Same cohort reported in Caye-Thomasen 2002</i>	9	Malleus fixation n=2; absent stapes n=4	Previous conservative radical cavity n=2 Previous tympanoplasty n=1	60 (47-78)	3/3	-	-
LEVEL IV							
Colletti 2009	7	Chronic otitis media n=4; middle ear malformation/microtia/atresia/stenosis n=1; tinnitus/vertigo n=1	1 previous surgery n=2 2 previous surgeries n=4 3 previous surgeries n=1 Surgeries included otoplasty, ossiculoplasty, tympanoplasty, MPL, 1 previous unsuccessful VSB implant on the incus	56.7 (28-74)	3/4	72.9 dB HL	-
Colletti 2006	19	Bilateral chronic otitis media without cholesteatoma	-	-	9/10	-	-
Cuda 2009	8	Otosclerosis n=3, Cholesteatoma n=2, Tympanosclerosis n=2, Congenital aural atresia n=1	Previous stapes surgeries n=3 Tympanoplasty n=4 Atresia auris n=1	49.4 (28-59)	1/7	62.8 dB HL	-
Dumon 2007	1	Primary otosclerosis	-	42	1/0	-	-
Dumon 2009	13	Otosclerosis n=5, Sequelae of chronic otitis n=7, Congenital aural atresia n=1	One otosclerosis patient had a stapedotomy piston implanted 37 years previously	56 (17-73)	7/6	-	-
Foyt 2006	1	Ear canal stenosis and severe recurrent dermatitis	-	Not reported (21-84)	-	52 dB HL	No: a HA could not be fitted
Lefebvre 2009	6	-	-	Adults (>18 years)	-	-	-
Streitberger 2009	40	Ossicular chain abnormal in all 40	All ears had previous surgeries (range 1-5 operations, median 3 operations). All had	59.5 (35-81)	-	-	-

		patients Stapes footplate abnormal in 20 patients	tympanomastoidectomies (23 canal-wall up and 17 canal-wall down)				
Suzuki 1989	9 (10 ears)	Chronic otitis media= 6 ears Middle ear cholesteatoma= 3 ears Microtia and atresia= 1 ear	One patient had a previous tympanoplasty	55.8 (33-68)	5/4	-	-
Suzuki 1994 <i>Same cohort reported in Suzuki 1995</i>	30	-	One patient had preparatory operations (tympanoplasty in 1, not reported in other)	58 (37-69)	6/13	-	-
Tono 2000	3	Cholesteatoma and otitis media with effusion n=1, Bilateral otitis media and tympanosclerosis n=1 Adhesive otitis media n=1	Tympanoplasty n=1, mastoidectomy n=3	55 (51-57)	2/1	-	One patient yes, not reported for 2 patients
Tringali 2009	1	Bilateral hearing loss secondary to cholesteatoma	-	48	0/1	Mean 80 dB HL	Unclear. Patient did not want a standard HA for chronic irritation of the external ear canal
Venail 2008	4	OM with labyrinthitis n=1 Otosclerosis n=3	Stapedotomy and Teflon piston n=2 Stapedotomy and McGee piston n=1	59.5 (49-72)	2/2	-	Yes
Yanagihara 1997 <i>Same cohort reported in Yanagihara 2001</i>	9	-	3 patients had received MEI in the phase I study, but underwent reimplantation in the subsequent phase II study	52 (42-67)	-	67.1 dB HL	-

dB: decibels; HA: hearing aid; HL hearing loss; MEI: middle ear implant; PTA: pure-tone average; - indicates not reported

Table 69 Patient characteristics for conductive hearing loss

Study ID	N	HL aetiology	Surgical history	Mean age (range)	Gender M/F	Mean preoperative PTA thresholds	Previous HA use
LEVEL IV							
Frenzel 2009	7	Unilateral microtia and osseous atresia	-	15 (10-26)	5/2	69.2 dB HL	Not reported (traditional hearing aids, worn externally in the ear canal, do not fit well in reconstructed ear canals)
Siegert 2007	5	Congenital auricular atresia n=5 (4 patients had unilateral and 1 patient had bilateral malformations)	-	31.4 (18-40)	4/1	-	-
Tringali 2008	1	Francheschetti syndrome (Treacher Collins). Bilateral conductive hearing loss secondary to ossicular malformations and external ear agenesis	-	14	1/0	70 dB HL	Not reported (in Francheschetti syndrome with bilateral ear canal agenesis, conventional acoustic hearing aids cannot be used)

dB: decibels; HA: hearing aid; HL: hearing loss; PTA: pure-tone average; - indicates not reported

Table 70 Patient characteristics for undefined hearing loss

Study ID	N	HL aetiology	Surgical history	Mean age (range)	Gender M/F	Mean preoperative PTA thresholds	Previous HA use
LEVEL III							
Kodera 1994	6	-	-	-	-	57 dB HL	-
Schmuziger 2006	24 ^a	-	-	59 (37-75)	16/4	-	-
Stieve 2009	34	-	-	-	-	-	-
Truy 2008	6	-	-	Not reported (42-59)	2/4	-	Yes

a: Four losses to follow-up
 HA: hearing aid; HL: hearing loss; PTA: pure-tone average; - indicates not reported

Table 71 Technical characteristics for sensorineural hearing loss

Study ID	MEI	Point of attachment	Attachment method	Surgical technique					Anaesthesia
				Access	Atticotomy	Mastoidectomy	Tympanotomy	Other details	
LEVEL III									
Chen 2004	Envoy	Lateral body of the incus and the tip of the capitulum of the stapes	Glass ionomeric cement	PAI	-	✓	-	Incus resection	GA
Fraysse 2001	VSB with D audio processor	Long process of the incus	FMT attachment clip	-	-	✓	✓	Enlarged endaural incision/simple retroauricular incision/enlarged retroauricular incision	GA
Hough 2001	SOUNDTEC	Stapedial head	Incodostapedial joint opened, attachment ring placed	TC	-	-	-	Rosen canal excision, tympanomeatal flap elevated to visualise incudostapedial joint.	LA
Jenkins 2004	MET	Incus	1 mm hole made in incus, healing leads to flexible fibrous union	PAI	✓	-	-	-	-
Jenkins 2007	MET	Incus	0.75 mm hole made in incus	-	✓	-	-	-	GA
Luetje 2002	VSB with D audio processor	Incus	FMT attached to incus (no further details provided)	-	-	-	-	The surgical approach is very similar to that used for cochlear implantation	-

Matthews 2002	SOUNDTEC	Head of the stapes	Incudostapedial joint opened, attachment ring placed, incudostapedial joint closed	TC	-	-	-	-	-	
Roland 2001	SOUNDTEC	Incudostapedial joint	-	-	-	-	-	-	LA	
Snik 2004	VSB n=8; MET n=5	-	-	-	-	-	-	-	-	
Snik 2004a	VSB with 304D audio processor	-	6 attachment clip crimped, 7 patients attachment clip crimped and bone cement (Serenocem)	-	-	-	-	Each surgeon who participated in the trial used their own preferred style of incision	-	
Snik 2001	VSB	-	-	-	-	-	-	-	-	
Snik 2007	VSB n=14; MET n=9	-	-	-	-	-	-	-	-	
Thill 2002	VSB	Incus	FMT attachment clip	-	-	✓	✓	-	GA	
Todt 2002	VSB with D audio processor	Incus	Not reported (one patient had additional bone cement)	-	-	-	-	Corresponds to cochlear implantations	-	
Todt 2005	VSB with Signia audio processor or D audio processor	-	-	-	-	-	-	Similar to cochlear implantation but slightly modified (no further details)	-	
Uziel 2003	VSB	-	-	-	-	-	-	-	-	
LEVEL IV										
Barbara 2009	Esteem 2	Sensor attached to body of incus, driver attached to head of stapes	Bioglass cement	PAI	-	✓	✓	-	GA	
Cremers 2008	VSB	On top of the anterior crus, positioned	FMT's grip was removed and SerenoCem used to affix	-	-	-	-	-	-	

		between the stapes and tympanic membrane								
Fisch 2001	VSB	Incus, located inferior to and in contact with the lenticular process	FMT attachment clip	-	-	✓	✓	Each surgeon who participated in the trial used their own preferred style of incision	-	
Foyt 2006	VSB	Incus	FMT attachment clip	PAI n=2 Smaller incision without traditional skin flap for receiver n=6	-	-	-	2 patients had traditional postauricular large flap incision with hair shave, receiver was sutured in place 6 patients had progressively smaller skin incision without the traditional skin flap for the receiver, no hair shave, no suture fixation of receiver	GA	
Garin 2002	VSB, 4 with 8 channel Siemens chip, 5 with 3 channel Widex clip	-	-	-	-	-	-	-	-	
Snik 1999	VSB	-	-	-	-	-	-	-	-	
Snik 2000	VSB	-	-	-	-	-	-	-	-	
Snik 2006	VSB n=13; MET n=8	-	-	-	-	-	-	-	-	
Sterkers 2003	VSB	-	-	-	-	-	-	-	-	

<i>Same cohort reported in Mosnier 2008</i>										
Todt 2004	VSB, patient 1 D type audio processor, patient 2 not reported	-	-	-	-	-	-	-	-	-
Vincent 2004	VSB	-	-	-	-	-	-	-	-	-
Zenner 2000	TICA LZ 3001	-	-	-	-	-	-	-	-	-
Zenner 2003	TICA	Incus body	-	-	-	-	-	Reversible malleus neck dissection	-	-
Zenner 2004	TICA	-	-	-	-	-	-	-	-	-

FMT: floating mass transducer; GA: general anaesthesia; LA: local anaesthesia; MET: Otologics Middle Ear Transducer; PAI: postauricular incision; TC: transcanal approach; TICA: Totally Implantable Cochlea Amplifier; VSB: Vibrant Soundbridge; - indicates not reported

Table 72 Technical characteristics for mixed hearing loss

Study ID	MEI	Point of attachment	Attachment	Surgical technique				Anaesthesia
				Access	Mastoidectomy	Tympanotomy	Other details	
LEVEL III								
Tos 1994 <i>Same cohort reported in Caye-Thomasen 2002</i>	Heide system	Between stapes and tympanic membrane n=2 Stapes footplate n=4	-	-	-	-	Tympanoplasty. Patients with fixed malleus: disruption of the ossicular chain was performed with extrusion of the incus, resection of the malleus head and interposition of a magnetic PORP between the stapes and the ear drum	-
LEVEL IV								
Colletti 2006	VSB	Round window	-	RAI	✓	✓	-	6 GA, 1 not reported
Colletti 2009	VSB	Round window	Fascia placed to encapsulate the FMT	-	✓	-	Tympano-ossiculoplasty	-
Cuda 2009	VSB	Round window	Fascia placed to encapsulate the FMT	TCA n=5 TMA n=3	-	-	Round window niche osteoplasty	GA
Dumon 2007	VSB together with a stapedotomy piston	Incus	FMT attachment clip The stapedotomy piston's loop was fitted in the long process of the incus, over the clip of the FMT, and tightened	Combined RAA and ACA	-	-	Vibrant Soundbridge with a stapedotomy piston	-
Dumon 2009	VSB	Chronic otitis patients: in 5 cases on the ossicular chain, in 2 patients on the round window membrane Otosclerosis patients: long process of the incus	Long process of incus: FMT attachment clip crimped Round window membrane: fragment of dorsal vein of hand applied around the FMT to ensure adhesion between the round window membrane and the FMT	Combined RAA and ACA n=5 TMFRA n=1 RTMFRA n=4 ACA n=3	-	-	-	-

		Congenital aural atresia: on the long process of the incus, in contact with the incudo-stapedial joint							
Foyt 2006	VSB	Incus	FMT attachment clip	Minimal skin incision	-	-	No traditional skin flap for the receiver. No hair shave was used	GA	
Lefebvre 2009	MET	Round window membrane	Fascia graft	PAI	-	✓	-	-	
Streitberger 2009	VSB	Round window niche n=32 Stapes footplate n=5 Stapes superstructure n=2 Cochlear fenestration n=1	FMT stabilised by cartilage and covered with fascia or periostium to prevent displacement and extrusion	-	-	-	Adapted on the basis of anatomical findings from previous surgeries	-	
Suzuki 1989	Rion device	-	-	-	-	-	-	-	
Suzuki 1994	Rion device	-	-	-	-	-	-	-	
<i>Same cohort reported in Suzuki 1995</i>									
Tono 2000	Rion device	Stapes head n=1 Stapes superstructure n=1 Stapes footplate n=1	-	-	-	-	The MEI was connected to a ceramic tube on the stapes head n=1; connected to a ceramic tube on the stapes superstructure n=1; connected to a ceramic columnella standing on the footplate	-	
Tringali 2009	Carina device with MET transducer	Round window	-	FRA	✓	-	-	-	
Venail 2007	VSB n=2;	-	-	RAA n=1	-	-	-	-	

	MET n=2			TCA n=2 - n=1				
Yanagihara 1997 <i>Same cohort reported in Yanagihara 2001</i>	Rion device	Stapes	-	-	-	-	Type 1 operation: intact canal wall technique, thus preserving the posterior ear canal and the ear drum Type 2 operation: device implantation into the ear missing the bony external auditory canal (most common)	LA with light sedation

ACA: auditory canal approach; FMT: floating mass transducer; FRA: facial recess approach; GA: general anaesthesia; LA: local anaesthesia; MEI: middle ear implant; MET: Otologics Middle Ear Transducer; TMA: transmastoid approach; TCA: transcanal approach; RAA: retroauricular approach; TMFRA: Trans-mastoid facial recess approach; RTMFRA: Retroauricular transmastoid facial recess approach; VSB: Vibrant Soundbridge; - indicates not reported

Table 73 Technical characteristics for conductive hearing loss

Study ID	MEI implanted	Point of attachment	Attachment type	Surgical technique	Anaesthesia
LEVEL IV					
Frenzel 2009	VSB	Incus n=1 Round window n=2 Stapes n=3 Footplate n=1	Crimping (incus and footplate) Fascia straps and cartilage chips (round window) Crimped and fascia strips (stapes)	Implantation was performed as part of reconstructive surgery. The incus and malleus were fused into a malformed complex	-
Siegert 2007	MET	Stapes head	Prosthesis in pressure-free contact with stapes	Malleus-incus complex removed completely after severing the incudostapedial joint	-
Tringali 2008	Carina device with MET V transducer	Posterior part of the oval window	-	Facial recess approach, posterior stapedotomy	-

MEI: middle ear implant; MET: Otologics Middle Ear Transducer; - indicates not reported

Table 74 Technical characteristics for undefined hearing loss

Study ID	MEI implanted	Point of attachment	Attachment type	Surgical technique	Anaesthesia
LEVEL III					
Kodera 1994	Rion device	-	-	-	-
Schmuziger 2006	VSB	-	-	-	-
Stieve 2009	MET n=19; VSB n=15	MET: mastoid and incus VSB: incus	-	-	-
Truy 2008	VSB	-	-	-	-

MEI: middle ear implant; MET: Otologics Middle Ear Transducer; VSB: Vibrant Soundbridge; - indicates not reported

Appendix E Excluded studies

Abstract/conference proceeding

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Cadaver study

- Abass HA, Kane M, 1997. 'Mechanical, acoustic and electromagnetic evaluation of the semi-implantable middle ear hearing device (SIMEHD)', *ENT: Ear, Nose and Throat Journal*, 76, 321-327.
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Appendix F Clinical trials and health technology assessments

Clinical trials

Recruiting

Title: Evaluation of middle ear implants in the therapeutic strategy of auditory rehabilitation in case of failure of conventional hearing aid

Institution: Assistance Publique – Hôpitaux de Paris

Contact: Oliver Sterkers

Start date: March 2007

Expected completion date: March 2011

Identifier: NCT00451503

Appendix G Current MBS listings for hearing loss procedures

Table 75 Surgical approaches to hearing loss

MBS item number	Therapeutic procedure
10952	<p>AUDIOLOGY</p> <p>Audiology health service provided to a person by an eligible audiologist if:</p> <p>(a) the service is provided to a person who has a chronic condition and complex care needs being managed by a medical practitioner (including a general practitioner, but not a specialist or consultant physician) under an EPC plan; and</p> <p>(b) the service is recommended in the person's EPC plan as part of the management of the person's chronic condition and complex care needs; and</p> <p>(c) the person is referred to the eligible audiologist by the medical practitioner using a referral form that has been issued by the Department or a referral form that substantially complies with the form issued by the Department; and</p> <p>(d) the person is not an admitted patient of a hospital; and</p> <p>(e) the service is provided to the person individually and in person; and</p> <p>(f) the service is of at least 20 minutes duration; and</p> <p>(g) after the service, the eligible audiologist gives a written report to the referring medical practitioner mentioned in paragraph (c):</p> <p style="padding-left: 20px;">(i) if the service is the only service under the referral - in relation to that service; or</p> <p style="padding-left: 20px;">(ii) if the service is the first or the last service under the referral - in relation to that service; or</p> <p style="padding-left: 20px;">(iii) if neither subparagraph (i) nor (ii) applies but the service involves matters that the referring medical practitioner would reasonably expect to be informed of - in relation to those matters; and</p> <p>(h) for a service for which a private health insurance benefit is payable - the person who incurred the medical expenses for the service has elected to claim the Medicare benefit for the service, and not the private health insurance benefit;</p> <p>- to a maximum of 5 services (including any services to which items 10950 to 10970 apply) in a calendar year</p> <p>Fee: \$57.55 Benefit: 85% = \$48.95</p>
T8.75	<p>Reconstruction of Auditory Canal</p> <p>When associated with Item 41557, 41560 or 41563 the multiple operation rule applies</p>
20120	<p>INITIATION OF MANAGEMENT OF ANAESTHESIA for procedures on external, middle or inner ear, including biopsy, not being a service to which another item in this Subgroup applies (5 basic units)</p> <p>Fee: \$91.50 Benefit: 75% = \$68.65 85% = \$77.80</p>
41509	<p>EXTERNAL AUDITORY MEATUS, surgical removal of keratosis obturans from, not being a service to which another item in this Group applies (Anaes.)</p> <p>Fee: \$150.55 Benefit: 75% = \$112.95 85% = \$128.00</p>
41518	<p>EXTERNAL AUDITORY MEATUS, removal of EXOSTOSES IN (Anaes.) (Assist.)</p> <p>Fee: \$858.05 Benefit: 75% = \$643.55</p>
41521	<p>Correction of AUDITORY CANAL STENOSIS, including meatoplasty, with or without grafting (Anaes.) (Assist.)</p> <p>Fee: \$913.55 Benefit: 75% = \$685.20</p>
41524	<p>RECONSTRUCTION OF EXTERNAL AUDITORY CANAL, being a service associated with a service to which items 41557, 41560 and 41563 apply (Anaes.) (Assist.)</p> <p>Fee: \$263.95 Benefit: 75% = \$198.00</p>
41527	<p>MYRINGOPLASTY, transcanal approach (Rosen incision) (Anaes.) (Assist.)</p> <p>Fee: \$542.85 Benefit: 75% = \$407.15</p>

41530	MYRINGOPLASTY, postaural or endaural approach with or without mastoid inspection (Anaes.) Fee: \$884.40 Benefit: 75% = \$663.30
41533	ATTICOTOMY without reconstruction of the bony defect, with or without myringoplasty (Anaes.) (Assist.) Fee: \$1,057.20 Benefit: 75% = \$792.90
41536	ATTICOTOMY with reconstruction of the bony defect, with or without myringoplasty (Anaes.) (Assist.) Fee: \$1,184.10 Benefit: 75% = \$888.10
41539	OSSICULAR CHAIN RECONSTRUCTION (Anaes.) (Assist.) Fee: \$1,006.95 Benefit: 75% = \$755.25
41542	OSSICULAR CHAIN RECONSTRUCTION AND MYRINGOPLASTY (Anaes.) (Assist.) Fee: \$1,103.30 Benefit: 75% = \$827.50
41554	MASTOIDECTOMY, intact wall technique, with myringoplasty and ossicular chain reconstruction (Anaes.) (Assist.) Fee: \$1,734.00 Benefit: 75% = \$1,300.50
41563	MASTOIDECTOMY (RADICAL OR MODIFIED RADICAL), MYRINGOPLASTY AND OSSICULAR CHAIN RECONSTRUCTION (Anaes.) (Assist.) Fee: \$1,365.85 Benefit: 75% = \$1,024.40
41564	MASTOIDECTOMY (RADICAL OR MODIFIED RADICAL), OBLITERATION OF THE MASTOID CAVITY, BLIND SAC CLOSURE OF EXTERNAL AUDITORY CANAL AND OBLITERATION OF EUSTACHIAN TUBE (Anaes.) (Assist.) Fee: \$1,766.25 Benefit: 75% = \$1,324.70
41596	RETROLABYRINTHINE VESTIBULAR NERVE SECTION or COCHLEAR NERVE SECTION, or BOTH (Anaes.) (Assist.) Fee: \$1,607.05 Benefit: 75% = \$1,205.30
41599	INTERNAL AUDITORY MEATUS, exploration by middle cranial fossa approach with cranial nerve decompression (Anaes.) (Assist.) Fee: \$1,607.05 Benefit: 75% = \$1,205.30
41603	OSSEO-INTEGRATION PROCEDURE - implantation of titanium fixture for use with implantable bone conduction hearing system device, in patients: - With a permanent or long-term hearing loss; and - Unable to utilise conventional air or bone conduction hearing aid for medical or audiological reasons; and - With bone conduction thresholds that accord to recognised criteria for the implantable bone conduction hearing device being inserted. Not being a service associated with a service to which items 41554, 45794 or 45797 (Anaes.) Fee: \$465.50 Benefit: 75% = \$349.15 85% = \$397.40
41604	OSSEO-INTEGRATION PROCEDURE - fixation of transcutaneous abutment implantation of titanium fixture for use with implantable bone conduction hearing system device, in patients: - With a permanent or long term hearing loss; and - Unable to utilise conventional air or bone conduction hearing aid for medical or audiological reasons; and - With bone conduction thresholds that accord to recognised criteria for the implantable bone conduction hearing device being inserted. Not being a service associated with a service to which items 41554, 45794 or 45797 (Anaes.) Fee: \$172.30 Benefit: 75% = \$129.25 85% = \$146.50
41608	STAPEDECTOMY (Anaes.) (Assist.) Fee: \$1,006.95 Benefit: 75% = \$755.25
41611	STAPES MOBILISATION (Anaes.) (Assist.) Fee: \$647.85 Benefit: 75% = \$485.90
41617	COCHLEAR IMPLANT, insertion of, including mastoidectomy (Anaes.) (Assist.)

	Fee: \$1,750.90 Benefit: 75% = \$1,313.20
41626	ABSCCESS OR INFLAMMATION OF MIDDLE EAR, operation for (excluding aftercare) (Anaes.) Fee: \$133.05 Benefit: 75% = \$99.80 85% = \$113.10
41629	MIDDLE EAR, EXPLORATION OF (Anaes.) (Assist.) Fee: \$481.55 Benefit: 75% = \$361.20
41632	MIDDLE EAR, insertion of tube for DRAINAGE OF (including myringotomy) (Anaes.) Fee: \$220.65 Benefit: 75% = \$165.50 85% = \$187.60
41635	CLEARANCE OF MIDDLE EAR FOR GRANULOMA, CHOLESTEATOMA and POLYP, 1 or more, with or without myringoplasty (Anaes.) (Assist.) Fee: \$1,057.20 Benefit: 75% = \$792.90 85% = \$989.10
41638	CLEARANCE OF MIDDLE EAR FOR GRANULOMA, CHOLESTEATOMA and POLYP, 1 or more, with or without myringoplasty with ossicular chain reconstruction (Anaes.) (Assist.) Fee: \$1,319.55 Benefit: 75% = \$989.70
41641	PERFORATION OF TYMPANUM, cauterisation or diathermy of (Anaes.) Fee: \$43.85 Benefit: 75% = \$32.90 85% = \$37.30
41644	EXCISION OF RIM OF EARDRUM PERFORATION, not being a service associated with myringoplasty (Anaes.) Fee: \$131.90 Benefit: 75% = \$98.95 85% = \$112.15
41647	EAR TOILET requiring use of operating microscope and microinspection of tympanic membrane with or without general anaesthesia (Anaes.) Fee: \$101.55 Benefit: 75% = \$76.20 85% = \$86.35
41650	TYMPANIC MEMBRANE, microinspection of 1 or both ears under general anaesthesia, not being a service associated with a service to which another item in this Group applies (Anaes.) Fee: \$101.55 Benefit: 75% = \$76.20 85% = \$86.35
41755	EUSTACHIAN TUBE, catheterisation of (Anaes.) Fee: \$42.95 Benefit: 75% = \$32.25 85% = \$36.55
45045	ARTERIOVENOUS MALFORMATION on eyelid, nose, lip, ear, neck, hand, thumb, finger or genitals, excision of (Anaes.) Fee: \$284.90 Benefit: 75% = \$213.70 85% = \$242.20
45206	SINGLE STAGE LOCAL FLAP where indicated to repair 1 defect, on eyelid, nose, lip, ear, neck, hand, thumb, finger or genitals, and excluding H-flap or double advancement flap (Anaes.) Fee: \$354.35 Benefit: 75% = \$265.80 85% = \$301.20
45448	FREE GRAFTING (split skin) to 1 defect, including elective dissection on eyelid, nose, lip, ear, neck, hand, thumb, finger or genitals, not being a service to which item 45442 or 45445 applies (Anaes.) Fee: \$347.35 Benefit: 75% = \$260.55 85% = \$295.25
45485	FREE GRAFTING (split skin) to burns, including excision of burnt tissue - upper eyelid, nose, lip, ear or palm of the hand (Anaes.) (Assist.) Fee: \$487.50 Benefit: 75% = \$365.65
45656	COMPOSITE GRAFT (Chondrocutaneous or chondromucosal) to nose, ear or eyelid (Anaes.) (Assist.) Fee: \$464.05 Benefit: 75% = \$348.05 85% = \$395.95
45659	LOP EAR, BAT EAR OR SIMILAR DEFORMITY, correction of (Anaes.) Fee: \$481.55 Benefit: 75% = \$361.20 85% = \$413.45
45660	EXTERNAL EAR, COMPLEX TOTAL RECONSTRUCTION OF, using multiple costal cartilage grafts to form a framework, including the harvesting and sculpturing of the cartilage and its insertion, for congenital absence, microtia or post-traumatic loss of entire or substantial portion of pinna (first stage) - performed by a specialist in the practice of his or her specialty (Anaes.) (Assist.) Fee: \$2,659.55 Benefit: 75% = \$1,994.70
45661	EXTERNAL EAR, COMPLEX TOTAL RECONSTRUCTION OF, elevation of costal cartilage framework using cartilage previously stored in abdominal wall, including the use of local skin and

	fascia flaps and full thickness skin graft to cover cartilage (second stage) - performed by a specialist in the practice of his or her specialty (Anaes.) (Assist.)
	Fee: \$1,182.05 Benefit: 75% = \$886.55
45662	CONGENITAL ATRESIA, reconstruction of external auditory canal (Anaes.) (Assist.)
	Fee: \$647.85 Benefit: 75% = \$485.90
45665	LIP, EYELID OR EAR, FULL THICKNESS WEDGE EXCISION OF, with repair by direct sutures (Anaes.)
	Fee: \$301.20 Benefit: 75% = \$225.90 85% = \$256.05
45794	OSSEO-INTEGRATION PROCEDURE - extra-oral, implantation of titanium fixture, not for implantable bone conduction hearing system device (Anaes.)
	Fee: \$465.50 Benefit: 75% = \$349.15 85% = \$397.40
45797	OSSEO-INTEGRATION PROCEDURE, fixation of transcutaneous abutment, not for implantable bone conduction hearing system device (Anaes.)
	Fee: \$172.30 Benefit: 75% = \$129.25 85% = \$146.50
52010	FULL THICKNESS LACERATION OF EAR, EYELID, NOSE OR LIP, repair of, with accurate apposition of each layer of tissue (Anaes.) (Assist.)
	Fee: \$234.65 Benefit: 75% = \$176.00 85% = \$199.50
52480	COMPOSITE GRAFT (Chondro-cutaneous or chondro-mucosal) to nose, ear or eyelid (Anaes.) (Assist.)
	Fee: \$464.05 Benefit: 75% = \$348.05 85% = \$395.95

Appendix H Acronyms and abbreviations

ABG	Air-bone gap
ABI	Auditory brainstem implant (ABI)
AMI	Auditory mid-brain implant
ABS	Australian Bureau of Statistics
AC	Air conduction
APHAB	Abbreviated Profile of Hearing Aid Benefit
AR-DRG	Australian Refined Diagnostic Related Group
ASERNIP-S	Australian Safety and Efficacy Register of New Interventional Procedures - Surgical
AV	Aversiveness
BAHA	Bone anchored hearing aid
BC	Bone conduction
BN	Background noise
CHERE	Centre for Health Economics Research and Evaluation
CHL	Conductive hearing loss
CI	Cochlear implant
dB HL	decibels hearing level
DDHS	Direct Drive Hearing System
EAC	External auditory canal
EC	Ease of communication
EMSN	Extended Medicare Safety Net
ENT	Ear, nose and throat
FDA	Food and Drug Administration
FMT	Floating mass transducer
GBI	Glasgow Benefits Inventory
HA	Hearing aid

HEIP	Hough Ear Institute Profile
HINT	Hearing In Noise Test
HL	Hearing loss
HTA	Health technology assessment
ICER	incremental cost-effectiveness ratio
MBS	Medicare Benefits Schedule
MEI	Middle ear implant
MET	Middle ear transducer
MHL	Mixed hearing loss
MPS	maximum phoneme score
MRI	Magnetic resonance imaging
MSAC	Medical Services Advisory Committee
NHMRC	National Health and Medical Research Council
PHAB	Profile of Hearing Aid Benefit
PHAP	Profile of Hearing Aid Performance
PICO	Population, intervention, comparator, outcomes
PORP	Partial ossicular replacement prosthesis
RV	Reverberation
SHACQ	Soundbridge Hearing Aid Comparison Questionnaire
SNHL	Sensorineural hearing loss
SPIN	Speech Perception in Noise (SPIN) test
SRT	Speech Reception Threshold
TGA	Therapeutic Goods Administration
TORP	Total ossicular replacement prosthesis
VS	Vibrant Soundbridge

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