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Review

The role of radiology in active middle ear implantation

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ARTICLE INFORMATION

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Active middle ear implants (AMEIs) have been available for a number of years and yet most radiologists have never heard of them. Some bear a striking resemblance to cochlear implants whereas others are more similar to conventional hearing aids. The aims of this review are to provide an introduction as to the types of implants available, how they work and when they are indicated. Also, to highlight important pre-operative imaging features that can influence surgery and to consider the role of imaging in the post-operative setting. As patient choice increases, it becomes more likely that radiologists will encounter these devices in daily practice and knowledge of them may prove useful.

Introduction

Active middle ear implants (AMEIs) have been available since the mid-90s and many have been inserted, mainly in Europe, since then. However, most radiologists have never heard of these devices and have little or no knowledge of the imaging issues relating to them. In the UK, problems with funding have limited the number of operations performed but this seems likely to change with increasing patient choice and mounting evidence regarding the efficacy of such devices. Radiological assessment is key in helping surgeons choose a suitable implant from a number on the market, and optimize surgical technique. The remit of this article includes introducing those devices one might encounter (how they work and when they are indicated), providing a systematic preoperative computed tomography (CT) reporting checklist, and considering issues pertaining to the implants in the postoperative setting.

What is an AMEI?

AMEIs amplify sound by conversion of sound waves to electrical impulses (as seen in cochlear implants) and then to mechanical vibrations. These are then transmitted to either the ossicular chain or the round/oval windows by direct coupling.

Devices on the market include the Vibrant Soundbridge (Med-El), the MAXUM system (Ototronics) and the Esteem system (Envoy Medical). The Carina system was previously produced by Otologics (LLC) who filed for bankruptcy in July 2012. A new version of the Carina is now on the market, produced by Cochlear, and has been successfully implanted. Although there are some significant differences in the ways these work, all involve fixation of a transducer to part of the ossicular chain and mechanically increase vibrations along it.

How do AMEIs work?

Vibrant Soundbridge

At first glance the Vibrant Soundbridge by MED-EL appears quite similar to a cochlear implant, which the

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company also produces. Instead of an electrode array inserted directly into the cochlear, however, this is a direct drive system with a single point of attachment, usually to the ossicular chain. Fig 1 demonstrates its components.

The external part (audio-processor, AP) contains a microphone, digital signal processor, and a battery. It is held over the internal implant by magnetic attraction, is small, and can be discretely covered by the patient's hair. This replaces the large body-worn boxes previously associated with cochlear implants. The AP converts sound waves into electrical impulses that are transmitted across the skin to the implant, which is recessed into the mastoid behind the pinna.

The implanted component (vibrating ossicular prosthesis, VORP) consists of a receiver/stimulator, conductor link, and transducer. It relays electrical impulses to the floating mass transducer (FMT) that converts them into mechanical vibrations. The FMT has a clip and variety of coupling devices that permit attachment to the ossicular chain, usually the long process of the incus or to the stapes. These vibrations induce pressure waves in the inner ear that are perceived by the patient as sound (Fig 2). As sound is not transmitted via the external ear canal, there is no need for a patent meatus and these devices are suitable for patients with congenital aural atresia.

It is possible to remove the FMT clip, and since work by Colletti et al.[1] in 2006, round window implantation is now regularly performed in those patients with no suitable ossicular remnants. A recent publication has also combined placement of a total ossicular replacement prosthesis (TORP) with the FMT, placing the TORP through the oval window and attaching the FMT to this to stimulate vibration.[2]

Esteem system

Another device is the Esteem system by Envoy Medical (Fig 3). This differs from the Vibrant Soundbridge in a number of ways. First, it is totally implantable, with no visible external components. Second, the patient requires a patent external ear canal and intact tympanic membrane to transmit sound to the middle ear.

The implant uses two piezoelectric transducers as the sensor and driver to replace middle ear function.[3] Vibration

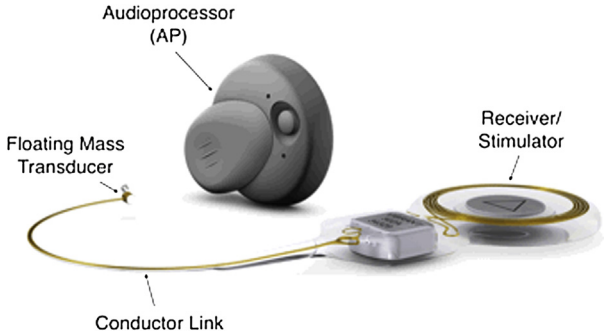

Figure 1 Vibrant Soundbridge (Med El) components (source: MED-EL with permission).

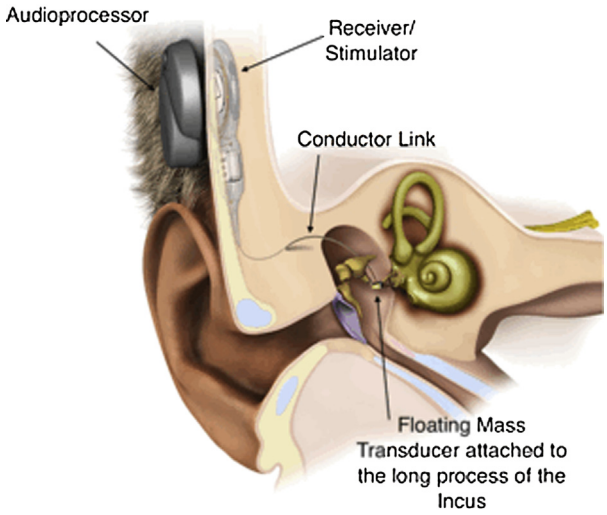

Figure 2 Vibrant Soundbridge *in situ* (source: MED-EL with permission).

of the tympanic membrane generates electrical signals in the device, which are then modified and amplified in the sound processor implanted into the mastoid. Signals are then relayed to the driver, which is attached to the stapes and generates vibrations that are transmitted to the inner ear and perceived as sound (Fig 4). The sound processor also contains an implanted lithium battery. It is indicated in those with moderate to severe sensorineural hearing loss.

Carina system

The Carina system, now produced by Cochlear under the Otologics name, is also fully implantable and indicated in those aged 14 years or over with moderate to severe sensorineural, mixed or conductive deafness. The implant is composed of three parts: an electronics capsule housing a battery, magnet, AP, and connector, a microphone and the middle ear transducer (Fig 5). The microphone picks up sounds that are amplified and transmitted to the transducer, which is placed against/drilled into the body of the incus and causes it to vibrate.[4] These vibrations are very tiny, over distances of about 1–2 μm for a sound of 94 dB at 100 Hz. At higher frequencies, the vibrations are even smaller. Although usually attached to the incus, if one has non-active middle ear pathology, one of the six coupling

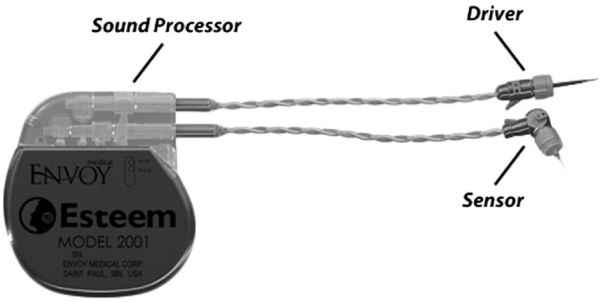

Figure 3 Esteem system (source: Envoy Medical with permission).