Functional Magnetic Resonance Imaging as a Prognostic Tool for Cochlear Implantation Outcomes

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Introduction

Deafness and hearing impairment are leading causes of disability worldwide, with over 360 million people suffering from them, 32 million of who are children. Over the past few decades the number of children and adults receiving cochlear implants (CI) has increased dramatically with over 320,000 people worldwide having received one or two by 2014.

Outcomes from CI surgery are highly variable between individuals, yet there is still no quantitative predictor of outcome available to clinicians, however there has been some interest in the use of Functional Magnetic Resonance Imaging (fMRI) for this purpose.

fMRI Blood-oxygen dependent imaging (BOLD) analyses the interaction between neural activity, cerebral metabolic rate of oxygen consumption, cerebral blood flow and cerebral blood volume. fMRI detects the BOLD changes that arise due to neuronal activity, which are caused by a change in brain state triggered by certain stimuli or tasks.

Aim:
To examine the potential role of BOLD fMRI in predicting CI outcomes.

Method:
This review was carried out by searching the PubMed and Scopus databases.

Cochlear Implantation

Criteria for implantation in the NHS state that the patient must have severe to profound hearing loss and have had a trial of acoustic hearing aids that were not found to be adequately beneficial. In adults, this is defined using Bamford-Kowal-Bench sentence testing (<50% at 70 dB indicates lack of benefit) and in children, age, developmental and cognitive ability inappropriate performance in speech, language and listening. Currently, length of period of deafness prior to implantation is the main prognostic marker of implant success. In adults, less than 20% of CI outcome variation can be attributed to aetiology, duration of deafness, residual hearing or age. This makes it difficult for the clinician to estimate the likely outcome of implantation surgery, and highlights the need for a reliable, quantitative prognostic marker for the prediction of outcomes.

Figure 1: Diagram showing the position of the auditory cortex on the left aspect of the brain **A:** Oblique view showing the relation of the primary auditory cortex (AI), secondary auditory cortex (AII) and Wernicke's area (W). Also shown is Broca's area (B). **B:** Coronal section of the brain showing AI, AII and Wernicke's area in the Sylvian Fissure. Image adapted from (Gil-Loyzaga, 2016).

Results

Study	Number of subjects	Age	General Anaesthetic	Overview
(Weiss et al., 2012)	1	21 months	Yes	Case report of a child with hearing loss secondary to CMV infection. fMRI showed intact right neural pathway but not left, leading to CI on the right side only.
(Patel et al., 2007)	10	49 (11 - 149) months	Yes	fMRI can be used to predict which individuals had the greatest improvements in pure tone audiometry results.
(Deshpande et al., 2016)	11	9 – 23 months	Yes	A passive listening task is used to identify four brain regions that subsequently correlate with increased score on a test of language ability post-CI
(Tan et al., 2015)	44 (23 with hearing loss, 21 controls)	20 (8 – 67) months	Yes	Algorithms were able to predict post-CI language outcomes with 77.8% sensitivity and 85.7% specificity.
(Schmidt et al., 2003)	35	40.1 (20 – 74) years	No	85% of patients who reported the sensation of hearing during electrical stimulation of the promontory, and 25% of those who did not, had contralateral activation of A1 (figure 1). This proved the integrity of the auditory pathway.
(Lazard et al., 2010)	16 (8 deaf, 8 controls)	52 years	No	Phonological processing tasks were undertaken by the patient during fMRI, before and after CI. There was a statistically significant difference in task scores between ‘good’ and ‘bad’ CI performers. Those with good scores used ‘normal’ dorsal phonological circuits, whilst those who performed worse used ventral pathway and the right supramarginal gyrus (figure 1) to compensate for the loss of phonological processing ability.
(Lazard and Giraud., 2017)	35 (18 deaf, 17 controls)	Not recorded	No	Reaction time during a phonological rhyming task was shown to correlate negatively with speech perception 6 months post-CI. fMRI results showed a cross-modal reorganisation process including the frontoparietal region, right posterior superior temporal sulcus and bilateral visual cortex being affected. Increased neural activity in these areas correlated with reaction time.

Conclusion

There is a lack of larger studies showing the usefulness of fMRI in assessing CI outcomes, and several methodological flaws in the currently published papers, such as not fully recognising the effects sedation can have on fMRI results, and not including controls. Also, the usefulness of fMRI as a prognostic tool is questionable as, whilst there is variability in outcome, as long as the benefits outweigh the risks, the patient will receive a CI. However, there may be scope for the use of fMRI in determining ‘absolute’ candidacy for implants as it provides a non-invasive way of assessing neural pathways and has a higher chance of guiding clinical decision-making.