World Journal of Otorhinolaryngology-Head and Neck Surgery (2017) xx, 1–15

Available online at www.sciencedirect.com

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journal homepage: www.keaipublishing.com/WJOHNS; www.wjent.org

Review Article

Three challenges for future research on cochlear implants

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Received 1 November 2017; accepted 1 November 2017

KEYWORDS
Hearing loss;
Cochlear implants;
Outcomes following implantation

Abstract Cochlear implants (CIs) often work very well for many children and adults with profound sensorineural (SNHL) hearing loss. Unfortunately, while many CI patients display substantial benefits in recognizing speech and understanding spoken language following cochlear implantation, a large number of patients achieve poor outcomes. Understanding and explaining the reasons for poor outcomes following implantation is a very challenging research problem that has received little attention despite the pressing clinical significance. In this paper, we discuss three challenges for future research on CIs. First, we consider the issue of individual differences and variability in outcomes following implantation. At the present time, we still do not have a complete and satisfactory account of the causal underlying factors that are responsible for the enormous individual differences and variability in outcomes. Second, we discuss issues related to the lack of preimplant predictors of outcomes. Very little prospective research has been carried out on the development of preimplant predictors that can be used to reliably identify CI candidates who may be at high risk for a poor outcome following implantation. Other than conventional demographics and hearing history, there are no prognostic tools available to predict speech recognition outcomes after implantation. Finally, we discuss the third challenge — what to do with a CI-user who has a poor outcome. We suggest that new research efforts need to be devoted to studying this neglected

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Peer review under responsibility of Chinese Medical Association.

Production and Hosting by Elsevier on behalf of KeAi

https://doi.org/10.1016/j.wjorl.2017.12.010

Please cite this article in press as: Pisoni DB, et al., Three challenges for future research on cochlear implants, World Journal of Otorhinolaryngology-Head and Neck Surgery (2017), https://doi.org/10.1016/j.wjorl.2017.12.010

clinical population in greater depth to find out why they are doing poorly with their CI and what novel interventions and treatments can be developed to improve their speech recognition outcomes. Using these three challenges as objectives for future research on CIs, we suggest that the field needs to adopt a new narrative grounded in theory and methods from Cognitive Hearing Science and information processing theory. Without knowing which specific biological and neurocognitive factors are responsible for individual differences or understanding the underlying sensory and neurocognitive basis for variability in performance, it is impossible to select a specific approach to habilitation after a deaf adult or child receives a CI. Deaf adults and children who are performing poorly with their CIs are not a homogeneous group and may differ in many different ways from each other, reflecting the dysfunction of multiple brain systems associated with both congenital and acquired deafness. Hearing loss is not only an ear issue, it is also a brain issue too reflecting close links between perception and action and brain, body and world working together as a functionally integrated information processing system to support robust speech recognition and spoken language processing after implantation.

Introduction

Cochlear implants (CIs) are now universally considered to be the standard of care for the medical treatment of severe-to-profound sensory-neural hearing loss in adults and children. There is no longer any disagreement about the efficacy of CIs among specialists working in the medical community such as neurotologists, otolaryngologists and audiologists who diagnose and treat hearing loss. The anticipated benefits of implantation in restoring the sense of hearing to profoundly deaf adults and children is generally held to warrant the attendant risks of surgery and potential adverse side effects. For example, in the pediatric population, without a CI and access to the sounds of speech, prelingually-deaf infants and very young children with severe-to-profound hearing loss would be unable to acquire knowledge of the grammar of a natural language or develop the receptive and expressive spoken language skills needed to communicate effectively with family, friends and other people in their immediate environment using spoken language. Without cochlear implants deaf children may also have significant global developmental delays and functional limitations over their entire lifetime affecting their quality of life and social interactions with people they encounter in the real-world on a daily basis. Similar benefits are routinely observed in post-lingually deaf adults who have successfully acquired spoken language prior to the onset of their hearing loss. In the elderly adult population, a significant hearing loss acquired later in life has been found to be associated with cognitive declines and may underlie early onset dementia and Alzheimer's disease in some individuals.[1–4] Hearing loss may also be a significant, and potentially independent, risk factor for depression and other psychiatric disorders. Recently, Blake Wilson and his colleagues concluded that cochlear implants represent "one of the great success stories of modern medicine" and that "the cochlear implant is the most successful neural prosthesis developed to date" and "exceeds by orders of magnitude the number for all other types of neural prostheses".[5] The restoration of hearing with a cochlear implant and the stimulation of the auditory nerve with novel sensory input in both prelingually-deaf children and postlingually-deaf adults is now viewed as a significant landmark achievement in the fields of biomedical engineering, neurotology and speech and hearing science.[6]

In this paper, we discuss three major challenges for future research on cochlear implants in adults and children: (1) individual differences and variability in outcomes, (2) lack of preimplant predictors of outcomes and (3) the pressing need for novel interventions for patients who achieve poor outcomes after implantation. We believe these three particular issues are the most important and perhaps the most challenging research problems in the field that will need to be addressed in the future to insure that all patients who are candidates for CIs will be able to obtain maximum benefits from their CIs and reach optimal levels of speech recognition and spoken language performance. In some broader sense, we can think of these three issues as "grand challenges" for future research on CIs. It is our hope that discussing these issues here and making these challenges explicit will serve as a springboard for new research efforts on these three problems in the future.

This paper is organized into five main sections. We will not present any new research findings, but instead will focus our discussion on the existing research literature pertinent to the following three questions. First, why has so little progress been made in understanding and explaining the enormous individual differences and variability routinely observed in outcomes following implantation? Second, why are there no valid and reliable preimplant predictors of outcome? And, third, what does a hearing healthcare provider do for an adult or child who has a poor outcome after implantation? In the first introductory section, we review the efficacy versus effectiveness of CIs, process versus product measures, and the use of converging methods from the field of Cognitive Hearing Science. In the second section, we discuss why there has been so little substantive progress made in understanding the enormous individual differences and variability observed in speech and language outcomes in deaf children and adults who

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