Critical Review: Does electroacoustic stimulation provide more benefit to speech recognition compared to electrical stimulation for hybrid cochlear implant candidates?

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This critical review examines the evidence regarding hearing performance in hybrid implant recipients. Study designs include cohort, within groups, repeated measures, and single group, pre- and post-test. Overall, the evidence gathered suggests electroacoustic stimulation provides more benefit in speech in noise listening conditions compared to electrical stimulation alone. Recommendations for future research and clinical practice are provided.

Introduction

Advances in surgical techniques and procedures have made it possible to preserve low-frequency hearing post cochlear implantation surgery. For post-lingually deafened implant recipients, the preservation of acoustic hearing may add additional benefit to hearing in regards to speech recognition and sound quality of speech and music.

Pre- and postoperative hearing level thresholds are frequently used to assess the extent of the hearing preserved. A hybrid cochlear implant is used when there is intent to conserve low-frequency hearing in the implanted ear. A hybrid cochlear implant can be either a short electrode array, with a length of 6-10mm, or a short insertion of a traditional electrode array which is 18-24mm in length but inserted up to 17mm (James *et al*., 2005). The short implant is placed in the basilar end of the scala tympani but does not reach the apical region in order to preserve the residual low-frequency hearing (Dorman *et al*., 2009).

Conserving residual hearing during cochlear implantation provides the recipient with the possibility of acoustic stimulation through the use of a hearing instrument in addition to electrical stimulation provided by the cochlear implant within the same ear. The ability to successfully conserve residual hearing has fuelled research investigating the benefits to hearing provided by electroacoustic stimulation as well as evaluating whether electroacoustic stimulation provides an advantage over electrical stimulation alone. Speech recognition assessment is one method employed to determine hearing performance under various listening conditions.

Objectives

The primary objective to this paper is to provide a critical evaluation of existing literature on the impact of electroacoustic stimulation on speech recognition compared to electrical stimulation alone. The secondary objective is to provide evidence-based recommendations for clinical practice and areas for future research.

Methods

<u>Search Strategy</u>
The computerized databases CINAHL and PubMed were used to search for articles related to the topic of interest using the search strategy: ((“electroacoustic stimulation” OR “hybrid implant”) AND (“word recognition” OR “speech recognition”)). The search was limited to articles written in English.

<u>Selection Criteria</u>
Studies selected for inclusion in this critical review were required to investigate electroacoustic stimulation via a short implantation method and use speech recognition testing as an outcome measure.

<u>Data Collection</u>
Results of this literature search yielded three types of articles congruent with the aforementioned selection criteria: prospective cohort study design (2 articles, level 2b evidence), within groups, repeated measures study design (1 article, level 2b evidence), single group, pre- and post-test study design (1 article, level 3 evidence). Articles are discussed in chronological order.

Results

Study#1: Gantz, Turner, Gfeller and Lowder (2005) conducted a prospective cohort study assessing the benefits of electroacoustic stimulation in cochlear implant recipients implanted with a 10mm electrode based on standardized test scores. Participants were included in this study from the research centre at the University of Iowa and from several associated research centres. This group was divided into two sub-groups with 10 individuals from the University of Iowa and 11 participants who were involved in an FDA multicentre clinical trial. These short-electrode recipients were selected for this surgery based on standard cochlear implant candidacy criteria but with hearing thresholds < 60 dB HL for frequencies ≤ 500 Hz steeply sloping to a severe to profound loss instead of a severe to profound average loss across all frequencies. Monosyllabic word recognition ability was determined using recorded CNC word recognition tests. Speech recognition was assessed preoperatively in the binaural aided condition and post-operatively under cochlear implant, hybrid, and binaural aided + implant conditions for the University of Iowa sub group. The multicentre subgroup compared the preoperative word recognition scores to the scores under the binaural aided + cochlear implant condition at 3 months and again at 6 months post-operatively. The University of Iowa group was also tested to assess speech reception threshold in multitalker babble using the signal-to-noise ratio (SNR) required for 50% correct recognition of spondees. The results were compared to those of other matched groups: traditional long electrode implant recipients, mild to moderate hearing loss patients, and normal-hearing individuals.

Results indicated that there was notable improvement in post-operative word recognitions scores under the hybrid and the binaural aided + implant conditions compared to preoperative scores. In addition, there were also significantly better speech reception thresholds in multitalker babble for those with electroacoustic processing compared to traditional electrical processing. Scores were reported as group means under each condition and no individual data were provided. Neither a statistical analysis of significance nor of comparison were performed.

Gantz *et al.* (2005) concluded that electroacoustic stimulation provided benefit to speech recognition and that electroacoustic stimulation provided more benefit for speech recognition in noise compared to traditional electrical stimulation alone.

The strength of this study design was the between groups comparisons in order to examine realistic expectations for the hearing ability level of electroacoustic users. Furthermore, results were collected under different listening conditions in order to determine the best listening condition for electroacoustic listeners. Limitations to this study were the exclusion of statistical analysis information and statistical analysis testing as well as the patient-specific data collected was not reported.

Study #2: James *et al*. (2005) conducted a single-group, pre-post test study which examines the benefits of electroacoustic stimulation in cochlear implant recipients who received a short insertion of a Nucleus Contour Advance 17mm perimodiolar electrode array.
Twelve adult implant candidates (based on standard selection criteria) who had hearing thresholds of <60 dB HL up to a frequency of at least 500 Hz participated in this multicentre prospective study. The participants had a range of etiologies, hearing aid experience and duration of deafness.

A “soft” surgery protocol was performed for all participants and a surgical questionnaire was used to monitor any variations and complications during each surgery.

Word recognition in quiet and sentence recognition in noise were used to evaluate the electrical and electroacoustic hearing performance. The implanted ear was tested pre- and postoperatively with the contralateral ear unaided or plugged. The implant-alone condition was tested with the ipsilateral ear unaided or plugged. The word lists consisted of at least 20 items and were monosyllabic in some centres and disyllabic in others. Words were presented at a level of 65 dB SPL and results were scored for percentage-correct. Sentence recognition in noise test was used to determine a signal to noise ratio determined by 50% correct recognition of words in sentences.

Post-surgery, participants were divided into two groups, electroacoustic-users and cochlear implant-only users, based on the residual low-frequency hearing level thresholds (electroacoustic-users retained thresholds of ≤ 80, 80 and 90 dB HL at 125, 250 and 500 Hz). The cochlear implant-only users were treated like traditional implant users. The electroacoustic-users were fitted with an in-the-ear Phonak Aero 33 or 22 hearing instrument for the implanted ear. They were also given one of two program maps for the first month and then the second program for the next month. The first program was the normal default map and the second program was a shift in the frequency:electrode allocation so that the apical electrodes are in use but low-frequency information is processed only by the hearing aid. At the end of first two months post-surgery, the participant was able to switch between the two maps in order to obtain the maximum benefit. Results were used from the preferred and/or best performance setting. No analysis or results regarding the program selection were examined in this study.

Speech recognition results at three months post-surgery were available for six patients, three participants from each group. Results indicated that two cochlear implant-only users experienced good postoperative word recognition in quiet while two electroacoustic-users experienced modest postoperative benefit. Sentence in noise recognition results indicated that two electroacoustic-users performed better than all three cochlear implant-only users post-operatively.

The greatest limitation in this study is the limited number of participants. As a result, the findings cannot be generalized for a group; however, the researchers were careful not to make any generalizations or claims. The hearing background and hearing aid experience was not well-controlled so such factors cannot be isolated when considering post-operative electroacoustic benefit. The researchers did not outline what was considered to be "good" versus "modest" versus "poor" improvement or what amount of change would be considered a significant improvement when comparing pre- to postoperative speech recognition scores. A notable strength in this study was the length of testing post-operatively. Speech recognition scores were collected up to three months post-surgery which allows for acclimatization and monitoring the hearing stability. In addition, the surgical procedure and techniques required for each participant were specific and included a surgical questionnaire to record any variations; thus, making the surgery a controlled variable.

Study #3: Fraysse *et al.* (2006) conducted a prospective, within groups, repeated measures study to assess the benefits of electroacoustic stimulation in short-insertion Nucleus 24 Contour Advance cochlear implant recipients. All participants underwent a soft surgical implantation procedure. Variations to the outlined procedure and techniques were recorded through a surgical questionnaire. Participants ranged in age, etiologies, hearing aid experience and duration of deafness. Participants were divided into two groups post-operatively, electroacoustic-users and cochlear implant-only users, based on the residual low-frequency hearing level thresholds (electroacoustic-users retained thresholds of ≤ 80, 80 and 90 dB HL at 125, 250 and 500 Hz).

Electroacoustic-users were fit with bilateral hearing instruments, Phonak Aero 33 or 22. Participants with limited hearing instrument experience were fit three months before preoperative testing for acclimatization purposes in order to maximize preoperative results.
Hearing level thresholds pre- and postoperatively were recorded and used to assess residual hearing after implantation. Electroacoustic performance was evaluated using word recognition in quiet and sentence recognition in noise. The protocol for surgery and speech recognition assessment was followed from the study conducted by James *et al.* (2005).

Post-surgery, speech recognition scores were collected from the implanted ear of nine electroacoustic users and seven cochlear implant-only users at three months or more post implant activation. Individual test scores were displayed and group averages were used to compare the performance between different listening conditions within the electroacoustic user group as well as to compare the performance between the two groups. A paired *t* test was used to test for significance.

Results indicated a notable amount of variation in the postoperative speech recognition scores under both quiet and noisy conditions, within each user group. For word recognition in quiet, the mean for the electroacoustic-user group showed significant benefit under the electroacoustic stimulation than the electrical stimulation alone (paired t, $p < 0.05$). For speech recognition in noise, the mean group score for the 5-dB SNR condition showed significant benefit in the electroacoustic stimulation than the electrical stimulation alone (paired t, $p < 0.01$) but no statistical significance in the 10-dB SNR condition. While electroacoustic users had better scores, no statistical difference was found between electroacoustic users and cochlear implant-only users in sentence recognition in noise.

Many variables were controlled within this study including: allowing time for acclimatization to hearing aids pre- and post-operative measurements, postoperative assessments up to six months after implant activation, the surgical protocol, procedures and techniques. The greatest limitation in this study is the small number of participants.

Study #4: Dorman *et al.*, (2009) conducted a prospective cohort study which examines the effects of the length of implanted electrode array on word recognition in quiet. Participants were recruited from four implant centres across the United States and were divided into two groups based on their type of cochlear implant: group 1 consisted of twenty-two participants who received a Nucleus Hybrid implant which has a short electrode array and group 2 consisted of twenty-five participants who received a conventional cochlear implant. All participants had thresholds of 500 Hz or below at ≤ 60 dB HL.

Word recognition in quiet was assessed using two 50 monosyllabic CNC word lists with a presentation level of 70 dB SPL. Multiple t tests were conducted to determine significant improvement postoperatively. While there was variation within group 1 scores, the group mean score under electroacoustic stimulation improved significantly compared to preoperative scores (p=0.18). Group 1's mean score under electrical stimulation alone was not found to provide a statistically significant improvement from preoperative scores. A

Bonferroni correction to the α value was applied in the statistical analysis given the multiple *t* tests conducted. A between-groups comparison was conducted, resulting in a significantly better postoperative performance by group 2 (traditional implant users) compared to group 1 under electroacoustic stimulation condition ($p= 0.0049$). The results of this study indicate that both implant electrode lengths improved word recognition scores post activation but the conventional length made the most significant improvement.

Word recognition testing was controlled and consistent for all participants and the group sizes were large in comparison to the other studies previously discussed.

Discussion

Overall, the examined research provides variable evidence regarding the benefit of electroacoustic stimulation to listening performance. Three of the four articles discussed had level 2 research designs (Gantz *et al*., 2005; Fraysse *et al*., 2006; Dorman *et al*., 2009). The evidence gained from these studies is suggestive but contradicting regarding the benefit provided by electroacoustic stimulation. Given the strengths and limitations to the research conducted by Gantz *et al*. (2005) and Fraysse *et al*. (2006), the evidence is suggestive of electroacoustic benefit for speech-in-noise listening conditions; however, given the strengths and limitations to the study conducted by Dorman *et al*. (2009), the evidence is highly suggestive of less benefit from electroacoustic stimulation across listening conditions compared to electrical stimulation.

The conclusions from the study by James *et al*. (2005) are suggestive, primarily due to the very limited number of participants. As level 3 evidence, in addition to the limitations, this study is weakly suggestive of benefit from electroacoustic stimulation over electrical stimulation in speech-in-noise listening conditions.

Conclusion

While this critical review did not identify a compelling level of evidence in support of a hybrid implant providing more benefit to speech recognition than a standard implant, the research was suggestive that electroacoustic stimulation provided more benefit for speech-in-noise listening conditions as well as more benefit overall than hearing aids alone for hybrid implant candidates.

Given the large amount of individual variation among hybrid implant recipients found across the literature, as well as the small sample sizes, a hybrid cochlear implant can be a clinical option but the selection must be made with caution.

Recommendations

1. Funding for further research with larger sample sizes would enable us to make firmer conclusions regarding the benefits associated with hybrid cochlear implants.

2. Funding for future research distinguishing electrical stimulation hearing performance of traditional length cochlear implant from short electrode length would enable us to compare the performances to electroacoustic stimulation performance. The results may determine whether a hearing conservation surgery is beneficial over a traditional cochlear implant surgery.

3. Funding for research into further areas of benefit to hearing performance provided by electroacoustic stimulation would enable us to create a more complete view of a hybrid implant recipient's hearing ability and compare it to the ability of a traditional implant recipient. Further areas of research may include:
    a. Speech sound quality
    b. Music sound quality
    c. Localization ability

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