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Four-point impedance as a biomarker for bleeding during cochlear implantation

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***Abstract*— Cochlear implantation has successfully restored the perception of hearing for nearly 200 thousand profoundly deaf adults and children. More recently, implant candidature has expanded to include those with considerable natural hearing which, when preserved, provides an improved hearing experience in noisy environments. But more than half of these patients lose this natural hearing soon after implantation. To reduce this burden, biosensing technologies are emerging that provide feedback on the quality of surgery. Here we report clinical findings on a new intra-operative measurement of electrical impedance (4-point impedance) which, when elevated, is associated with high rates of post-operative hearing loss and vestibular dysfunction. In vivo and in vitro data presented suggest that elevated 4-point impedance is likely due to the presence of blood within the cochlea rather than its geometry.**

***Clinical Relevance*— Four-point impedance is a new marker for the detection of cochlear injury causing bleeding, that may be incorporated into intraoperative monitoring protocols during CI surgery.**

I. INTRODUCTION

The preservation of cochlear structures and natural hearing has become the standard of care for cochlear implantation (CI) [1]. Currently in cochlear implant surgery, there is no method for real-time detection of cochlear injury, which may include the infiltration of blood for a damaged lateral wall. Blood in the cochlea creates a hostile environment, causes a larger inflammatory response, and may lead to the loss of natural hearing. Four-point impedance (4PI) can be used to distinguish different biological mediums and may be useful to detect intra-cochlear bleeding as it occurs.

II. METHODS

The aim of this work is to monitor 4PI directly from the intracochlear electrodes on the implant, and to correlate these measurements with hearing preservation. 51 adults with some natural acoustic hearing prior to surgery underwent cochlear implantation. Four-point impedance was measured immediately after insertion. In a preclinical setting, 4PI was measured from custom-built cochlear implants in 13 ears from 9 tri-color guinea pigs, before and after injection of blood into the cochlea.

III. RESULTS

The results from the clinical study showed elevated 4PI values correlated significantly with a loss of residual natural hearing. 13/51 patients showed elevated 4PI, with an associated loss of residual hearing and an increased rate of post-operative dizziness. IN the animal study, 4PI instantaneously increased after blood injection and remained high thereafter, at a similar magnitude to that seen in clinical patients. 2 control ears did not show this increase.

An alternative explanation for elevated 4PI values is the narrowing of the cochlea from base to apex, causing an increase in impedance. To test this, 4PI was measured throughout the insertion of a commercially available cochlear implant into a 3D printed human cochlea model. The 4PI increased slight across the electrode array from base to apex. However, this increase was an order of magnitude smaller than the clinical results, suggesting that cochlear geometry is an unlikely explanation for clinical elevated 4PI.

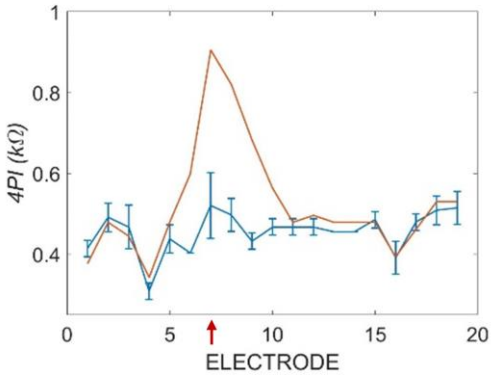

Figure 1. Four-point impedance measurements compared when blood was injected (orange line) into the 3D printed cochlea model, with the average measurements from the insertions. The red arrow indicates the point of blood injection into the model corresponding to the electrdoe array.

IV. DISCUSSION & CONCLUSION

Four-point impedance is a new marker for the detection of cochlear injury associated with increased ratees of post-operative hearing loss and vestibular dysfunction. The magnitude of 4PI elevation is consistent with intra-cochlear bleeding. Four-point impedance may be implemented into clinical intraoperative monitoring protocols during cochlear implant surgery.

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