A Novel Stethoscope Array for Healthcare Practitioners with Cochlear Implants

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Abstract: The increasing number of cochlear implant users has raised the problem of auscultation among this population. Although several reports have been published about stethoscope and hearing aids, there are no publications concerning the use of stethoscopes by medical population among cochlear implant recipients. We present a novel array that allows the connection of the stethoscope to the cochlear implant system through the sound processor and two cases where this has been successfully applied. The lapel microphone was inserted in the distal part of a compatible stethoscope's plasticized tube and monitoring headphones were also connected to the implant in order to evaluate the accuracy of the findings. Two medical students using cochlear implants were assessed by a medic in listening to the heart sounds of a healthy volunteer. Auscultation demands not only hardware connection between the stethoscope and the sound processor of the implant but also remapping in order to adjust the hearing thresholds to the target frequency range.

Keywords: Medical Devices, Auscultation, Stethoscope, Cochlear Implants, Clinical Examinations.

I. INTRODUCTION

For centuries although diagnostic techniques have developed, auscultation remains a valuable tool in gathering a large amount of information when it comes to physical examination. Indeed stethoscopes, the medical devices for listening to the action of cardiac circulation and breathing, are emblematic for healthcare workers, and a requisite tool for many branches of medicine like primary care, pathology, pediatrics or physical therapy.

The operation of acoustic stethoscopes relies on the transmission of sound from the chestpiece to the listener's ears using high acoustic sensitivity, hollow, air-filled, plasticized tubes. The chestpiece is versatile, usually made of two sides that can be placed against the patient for sensing sound: the pediatric side, which converts to a traditional open bell (hollow cup) when its single piece diaphragm is replaced by a non chill rim, and the bigger, adult side, with a tunable diaphragm (Fig. 1). When the chestpiece is placed on the patient, internal body sounds, ranging from low frequency whoops up to heart, lung and bowel sounds cause the diaphragm to vibrate. The acoustic pressure waves travel through the tubing up to the practitioner's ear canals. If the bell shaped side of the stethoscope is placed on the patient, the vibrations of the skin directly produce on the chestpiece low frequency acoustic pressure waves transmitted via the tubing to the listener's ears. The bell transmits low frequency sounds, while the diaphragm transmits higher frequency sounds. So, the practitioner is able to receive multi-frequency, versatile responses, not only by choosing which side makes the contact, but also by adjusting the pressure of the diaphragms: light contact of the chestpiece monitors low-frequency sounds, while firm pressure delivers high-frequency acoustic sounds.

As clinicians seek outstanding acoustic performance, they ameliorate their diagnostic techniques, trying to eliminate background sounds of the moving fingers, or outside noise interference. Even the ergonomics of the stethoscope parts may influence the assessments.

Undoubtedly, however, a very important factor for not hearing clearly are the clinicians hearing disorders which are quite common in our days, not only due to congenital causes, environmental factors abut also due to normal age related hearing loss.

As the population of medical students, doctors and other healthcare professionals having underwent cochlear implantation increases, important issues rise when it comes to auscultation learning and clinical practice. Cochlear implantation is getting widely applied and according to the National Institute for Deafness and other Communication Disorders (NIDCO), about 324.000 cochlear implantations have taken place worldwide until December 2012 [1]. There are no reports in the literature up-to-date concerning the use of stethoscopes by medical population among cochlear implant recipients.

We are aiming to present the first array in the literature that allows the connection of the stethoscope to the cochlear
implant system through the sound processor and two cases where this has been successfully applied.

II. DEVICES, MATERIALS AND METHODS

A cochlear implant [2] is an electronic device that replaces the auditory system, mainly the sensory capillary cells in the organ of Corti in the cochlea. A contemporary cochlear implant is composed of two parts: one is the cochlear implant that is surgically implanted in the recipient and the second is the speech processor that is commonly worn behind the ear and communicates with the implant via an RF transmitter (Fig. 2). In order to successfully stimulate the auditory nerve so that the recipient can perceive sound, sound waves must be transformed to electric pulses. This process begins at the speech processor where the sound wave is collected through a microphone. Afterwards sound waves are converted into an electric sound signal that is filtered, encoded and transformed through a very specific procedure. This signal is channeled through the speech processor's transmitter to the implant's receiver via an RF link.

The implant consists of antenna, magnet, receiver stimulator in titanium casing, electrode array with electrode contacts No 12 (apical) through No 1 (basal) spaced at 2.4 mm intervals. The overall length of the implantable electrode array is 30.3 mm and its width 1.3 mm at the base and 0.8 mm at its apical end.

The electrode is inserted from the middle ear cavity into the vestibule, then it was sharply bend posteriorly and upward finally it can find its way into the posterior semicircular canal damaging the facial nerve, or creating an unsupervised electrode contact within the vestibule.

Anyway, the human brain is able to adapt to the new representation of sounds, to a certain degree typically after a year [3]. For post-lingually deaf subjects, the initial sounds are described to be robotic, distorted, cartoonish, or similar to a noisy street. After training and calibration, performed by the doctor, most users are able to recognize voices, and enhance lip reading. Many, after recent advances, are able to retain and comprehend speech and language.

The process of sound transmission into the cochlea can be identified as a flow process: sound is transformed into electrical signals. The processor then samples, processes and maps the signals to specific locations within the cochlea, depending on the waveform frequency spectrum [4].

What will be examined in this research article is how a clinician relying for an accurate auscultative examination on hearing aids, like cochlear implants, can achieve adequate diagnoses despite his hearing loss.

It is obvious, that if the acoustic signal is transferred via the normal acoustic canal, then the performance of the stethoscopic examination will deteriorate significantly, making the diagnosis impossible. Indeed, a clinician with a cochlear implant is not listening the acoustic signals as they are inserted into the acoustic tube of the external ear, but via the speech processor that is positioned above the fleshy external flap of the outer ear. The sound received by the speech processor is transmitted to the actual implant, which transfers appropriate electrical signals aiming to stimulate the cochlea for the production of the actual acoustic nerve impulses.

A compatible stethoscope was used for this array. The tube was cut at about 8cm from the stethoscope’s bell and the standard lapel microphone, Ref: Z60831, of the sound processor was attached to the free end. Both patients had Cochlear® implants carrying Nuclear Freedom processor. For monitoring purposes of the experiment, Cochlear® monitoring earphones, Ref: Z60832, were used (Fig. 3).

Two individuals using cochlear implants were assessed in auscultation of a healthy volunteer and they were asked to
describe his heart sounds. A medic acted as the external assessor, and used the monitor earphones of the set-up to evaluate the integrity of the findings. Following the initial evaluation, both participants underwent remapping of their implants in which we increased the hearing thresholds (T level) for the 22nd and 21st electrodes, adjusted to the range of frequencies of the first and second cardiac sounds (Fig. 4). The Frequency Table was customized from 63 to 7938 Hz. The 22nd electrode’s range was 63 - 188 Hz while the 21st’s was 188 - 313 Hz. In the environment configuration, during saving the maps in their sound processor, the “Accessory Mixing Ratio” was modified from 3:1 to 10:1 given a more focused sound to the stethoscope captions. Auscultation was repeated afterwards and the participants reported clear auscultation and recognition of the heart sounds.

**Case 1**

The first participant was a 23-year-old female, on the fifth year of medical school. She underwent a unilateral cochlear implantation in 2000, with 22 fully functional electrodes and no mapping or electrode problems. Implantation was decided when she was diagnosed with progressive hearing loss, which was deteriorating over the last two years and there was no benefit from the hearing aids.

**Case 2**

The second participant was a 21-year-old female, on the second year of medical school. She underwent unilateral cochlear implantation in 2001. 22 fully functional electrodes were identified, with no mapping or electrode problems. Again, she was suffering from progressive hearing loss with no improvement after hearing aiding and deterioration of hearing acuity over the last two years.

### III. DISCUSSION

Although a few decades have passed since the first cochlear implantation in 1961, no reports are found in the literature with regards to the implanted medical population and their approach to auscultation [5]. The problem was identified years ago and was addressed to healthcare professionals wearing hearing aids. In 1938, a stethoscope-hearing aid set-up was introduced and allowed sound transmission to the ear by the aid’s own microphone earpiece or by a binaural stethoscope attachment [6].

In 1945, Kirschbaum invented a device that connected a
stethoscope bell to the top of a compatible binaural stethoscope via a hearing aid. This allowed amplification of adult and fetal cardiac sounds [7]. Likewise, Jacob et al. in 2013 presented two cases of healthcare students, a female nursing student and a male medical student who had their hearing aids coupled to the stethoscope in order to proceed to auscultation [8]. Both individuals achieved auscultation with no limitation and satisfactory quality according to their opinion.

In 2004 Mendoza proceeded a step further by describing the possibility of connecting a stethoscope with a cochlear implant via a patch cord. The output characteristics in that case specific to the matching of the stethoscope with a cochlear implant’s processor [9]. From a technical point of view, the most challenging part is connecting the hardware and software components between the stethoscope (amplified or not) and the cochlear implant processor [10].

Hearing and hearing loss among physicians and medical students is a field that has not been studied in depth. Rabinowitz et al. in 2006 studied a group of 107 subjects [11]. They concluded that there is a positive correlation between increasing age, deterioration of hearing acuity and difficulties in communication with patients as long as in the use of stethoscopes. Only two subjects of their study group reported hearing loss during childhood and none of them used a hearing aid regularly [12][8]. It can be easily concluded that healthcare professionals wearing cochlear implants need assistance in their everyday communication and stethoscope use.

Stethoscope use demands adequate hearing acuity in a specific range of frequencies, relevant to the sounds involved in auscultation. Thus, normal heart sounds occur at frequencies between 20 and 200 Hz [12][13][14][15][16] (Fig. 5). More specifically, the first and second heart sounds fall respectively in the frequency range of 80-120 Hz and 120-180 Hz. The third and fourth heart sounds are found in lower frequencies; 70-90 Hz and 50-70 Hz respectively [17]. Murmurs can be heard along the frequency range of 30-700 Hz. Vesicular breath sounds extend up to 1000 Hz in healthy subjects, while wheezes cover a range of 100 to higher than 2000 Hz [18].

An important point that requires consideration is the low frequency cutoff that many implants have and make is impossible for the user to hear heart sounds [10]. During the mapping of the cochlear implant, the doctor can easily increase the hearing thresholds to the target frequency range. In our case, that was done for the frequency range of the first and the second heart sounds with good results according to the participants and the external assessor. Obviously, similar process can be followed for heart murmurs, normal and abnormal breathing sound frequencies.

IV. Conclusion

Post-surgical fine tuning for cochlear implant recipients, targeting the development of speech, sound perception and overall sound communication is not enough when stethoscopy is used for diagnostic purposes. Special tuning of the cochlear implant should take place not targeting the continuing existence of auditory memory reserve, but the efficient perception of pulmonary and cardiovascular sound streams.

Auscultation for cochlear implant users can be achieved using the array described in this article with satisfactory results. More studies are required in the field of objective evaluation tools for the credibility of the method as long as the adjustment for various types of pathological findings.

REFERENCES

A special tribute of his work is on audiovisual recordings that demonstrate post-surgical calibration techniques for CI recipients along with phono-tactical exercises that rehabilitate and augment residual hearing memory.

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