



Review

The early days of the multi channel cochlear implant: Efforts and achievement in France

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ABSTRACT

On September 10th 2013, the clinical medical research Lasker award winners were rewarded for their work on multichannel cochlear implant. It has been my pleasure to see that such a major topic had caught the attention of the Members of the Jury for this prestigious award. That is why I accepted an invitation to participate in a special issue of Hearing Research devoted to the three winners. Here I highlight four scientific contributions made by the French team in late 1970s and early 1980s to modern multichannel cochlear implant development.

1) Chouard and MacLeod plotted an approximate frequency map of the whole length of the human cochlea, including its “hidden face” corresponding to speech frequencies. Moreover MacLeod suggested a sequential display of electrical stimulation as a function of each electrode, a precursor to today's electrodegram and interleaved stimulation.

2) Chouard performed total cochlear implantation in a deaf adult male with 8 electrically independent electrodes that were evenly distributed along the cochlea.

3) Chouard and MacLeod described in a patent detailed sound signal processing for a functional multichannel cochlear implant and reported speech discrimination without help of lip reading in some totally deafened patients.

4) Chouard experimentally demonstrated in the guinea pig the advantage of early cochlear implantation in treating profound neonatal deafness.

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1. Introduction

I knew André Djourno, professor of physics and electrotherapy in Paris, well; and I was a student of Charles Eyriès. Between 1960 and 1966, I worked on neuroanatomy in relation to the pathophysiology of the inner ear with Eyriès. He taught me Born's method for histological magnification (Eyriès et al., 1966, 1970) which I was to use 20 years later for children with profound neonatal deafness. Very early on, by recounting the saga of his research with Djourno, he made me aware of the tragedy that is

total deafness. It is thanks to him that I devoted a significant part of my medical research activity to the multichannel cochlear implant between 1973 and 2001. This link provides an intellectual continuity in the French achievements in the early days of the MCI.

On September 10th 2013 (http://www.laskerfoundation.org/awards/2013_c_presentation.htm), the Clinical Medical Research Lasker Award winners were rewarded for their work on MCI. It has been my pleasure to see that such a major topic had caught the attention of the Members of the Jury for this prestigious award. That is why I accepted Professor Zeng's kind invitation to participate in this special issue of Hearing Research devoted to the three winners.

1.1. Historical background

In the second half of the 20th century, in the sixties, W. House took up from where Djourno and Eyriès left off, with the single-channel implant. It only allowed profoundly deaf subjects to

Abbreviations: MCI, multichannel cochlear implant; SSP, sound signal processing

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perceive rhythms and frequencies up to around 300 Hz. Beyond that point, frequency discrimination was not possible, even using several electrodes of different lengths. This was due to the refractory period of the auditory nerve, whose fibers were all stimulated by the release of electrical impulses into the labyrinthine fluids. In 1966, Simmons, (1966) managed to achieve a differentiated frequency response in a deaf volunteer by applying local stimulation directly to the narrow tributaries of the fan formed by the afferent auditory nerve fibers, before they clump together at the bottom of the internal auditory canal. The results in humans were then confirmed in animals by Merzenich et al. (1973). However B. Simmons work on the nervous structures was far too dangerous to translate it into standard practice.

In order to stimulate these small tributaries of the auditory nerve in several ways and without taking too many risks, Robin Michelson created the first investigational electrode array, by encasing the electrodes in a mold shaped like the entrance to the scala tympani, (Michelson et al., 1973). The story of the efforts of all these pioneers responsible for the progressive birth of the MCI during the seventies has been recently detailed (Eshraghi, et al., 2012).

Both House (House et al., 1973), and Michelson reported their results in 1972. I was informed of this by chance, as was Robert Charachon from Grenoble, by Alain Morgon in Lyon. I immediately submitted a summary of the questions remaining to be answered to Patrick Mac Leod, MD and neurosensorial physiology research professor at the École Pratique des Hautes Études, then located at Collège de France in Paris. In a few weeks we decided to join forces by forming a multidisciplinary team (Chouard et al., 1973).

Thus, we were able to participate, as early as 1973, in a large and long series of exchanges of scientific views, the aim of which was to make the transition from W. House's ten years of experience in single channel cochlear implants to the MCI. As a matter of fact, the implantation of several electrodes was deemed indispensable by all participants in the 10th World Congress on Otorhinolaryngology in Venezia in May 1973, then at the Symposium held on this subject in San Francisco in June 1973. We subsequently tackled this question ourselves. At that time, we had 3 primary concerns: 1) Safety of the implanted material; 2) Supplying the brain with a frequency range large enough to obtain speech intelligibility without lip reading; 3) Avoiding electrical signal diffusion from one electrode to the others through the cochlear fluids. Point 1 appeared almost completely resolved owing to: a) an intense experimental research performed since the end of the sixties, mainly by the Australian and Californian teams; b) the long-term clinical results of W. House; c) electrode placement in the tympanic ramp.

This meeting of an inner ear conservative surgery and facial palsy specialist, and a neurosensory electrophysiology MD researcher was a chance for our Parisian team. These special skills of our Parisian team allowed us to find pioneering solutions to Point 2 and Point 3, with quite rewarding results.

2. French contributions

Our works on MCI dates back forty years. A survey of the efforts and achievement in France requires a chronological and brief summary of the most important achievements by the Parisian team. Then, I will relate some comments. In the last chapter, I will recall the work of the Grenoble team.

2.1. Most important achievements by the Parisian team

2.1.1. The frequency map of the living human cochlea

P. Mac Leod and I were able for the first time, to plot an approximate frequency map of almost the whole length of the

living human cochlea, including its “hidden face” corresponding to the speech frequencies. Three volunteers suffering from unilateral total deafness, and homolateral traumatic facial palsy, resulting from various types of Fallopian canal fractures, allowed us, during surgical treatment of this paralysis, to directly approach the tympanic ramp. Then, we drilled several tiny fenestrations, in front of various frequency sites. In each hole, we placed the bare tip of one or two Teflon-coated platinum–iridium electrodes facing upstream and downstream in the cochlea, separating them from each other by several very small pieces of Silastic™. With a self built stimulator, we could, in an ethically irreproachable way² (Chouard et al., 1976), confirm the electrophysiological parameters (mainly the very narrow dynamic range) of each site in these three patients.

Our paper also described other experimental studies using a temporary percutaneous pedestal carried out on 7 volunteer patients suffering from bilateral total or profound deafness. Owing to these patients' contributions, we were able design the initial features of a SSP for supplying all these 7 totally deaf patients with valuable percentage of speech discrimination without help of lip reading.

However, at this time, in 1975, the clinical researchers were always hesitant. Given the indecisiveness of other teams, our clinical results convinced us that we ought to dare to carry on as soon as the manufacturer we had selected, Bertin Co®, had made the implant designed by P. Mac Leod.

Moreover, while developing the necessary device with the help of Bertin Co®, P. Mac Leod suggested that, instead of simultaneous analogous stimulation, we should take advantage of the possibilities of the first available digital signal processors with a sequential display of the electrical stimulation on each electrode, suggestive of the sequential frames of television sets. This allowed us to: 1) use only one pair of solenoid antennae (Michelson et al., 1973.) to cross the cutaneous barrier; and 2) probably also to decrease the inter-electrode diaphony, although we had no opportunity, at that time, to set up an electrical evaluation of this thereafter trivial procedure. During the early days of the MCI, I always considered that the social and professional constraints of a transcutaneous pedestal had to be removed as soon as possible. The sequential stimulation of the different electrodes and our sound signal processing enabled us overcome this.

2.1.2. Total multi-channel cochlear implantation

At Saint-Antoine Hospital, I performed total cochlear implantation in deaf adult male with the help of Dr. Bernard Meyer, at that time Chef de Clinique in my ENT Dept (Meyer, 1974) on September 22nd, 1976 (Chouard, 2014). This device had 8 electrically independent electrodes regularly distributed along the cochlea and was built by Bertin Co®.

In the light of these founding contributions, I recall that (Table 1):

In their Lasker lectures Graham Clark recalled that his first MCI was implanted on 1 Aug 1978 and Ingeborg Hochmair said her first MCI was implanted on 16 Dec 1977. Table 1 compares the dates and characteristics of the first MCIs. Note that the French MCI was first by more than 1 year and had as many electrodes as the Australian device (Clark, 2013; (Hochmair, 2013).

2.1.3. Patent for an implantable hearing aid in humans

Encouraged by the quality of the results compared to those obtained with single electrode implants, on March 16th, 1977, P. Mac Leod and I applied for a patent for an implantable hearing aid

² In these old days, Ethical Committee did not exist a priori. But, of course, but we pre-operatively obtained an informed Consent from our patients.

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