25 years of partial deafness treatment – milestones in the world's science. Own experience

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A – research concept and design, B – data collection, C – data analysis and interpretation, D – article writing, E – critical review of the article, F – final approval of the article

DOI: 10.26399/rmp.v28.1-2.2022.1a/h.skarzynski/p.h.skarzynski

SUMMARY

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Review of Medical Practice, 2022; Vol. XXVIII, No. 1-2

Over the past 25 years, cochlear implant patients' inclusion criteria have significantly expanded. Advances in implant technology and surgical techniques allow most patients to maintain good preoperative hearing during and after cochlear implantation. The paper presents the latest concept of partial deafness treatment, including the development and improvement of this method. The course of the surgical procedure is discussed and tips are given regarding the electrode lengths and combinations of acoustic and electrical stimulation; important information is also provided on the preservation of the preoperative structures of the hearing and the inner ear. The work is supplemented by the classification of hearing impairment and the presentation of the development and application of specially designed electrodes used in various types of hearing loss.

Key words: *Partial deafness treatment, cochlear implant, round window approach, electrodes, acoustic stimulation, electric stimulation*

STRESZCZENIE

25 lat leczenia częściowej głuchoty – kroki milowe w światowej nauce, doświadczenia własne

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Review of Medical Practice, 2022; Vol. XXVIII, No. 1-2

W ciągu ostatnich 25 lat kryteria kwalifikacji pacjentów do wszczepienia implantów ślimakowych zostały znacząco poszerzone. Postęp, jaki dokonał się w dziedzinie technologii implantów oraz technik chirurgicznych, pozwala obecnie na zachowanie u większości pacjentów dobrego słuchu przedoperacyjnego w trakcie i po zabiegu wszczepienia implantu ślimakowego. W pracy przedstawiono najnowszą koncepcję leczenia częściowej głuchoty, w tym rozwój i doskonalenie tej metody. Omówiono przebieg zabiegu chirurgicznego i zamieszczono wskazówki odnośnie stosowanych długości elektrod, kombinacji stymulacji akustycznej i elektrycznej; podano także istotne informacje dotyczące zachowania przedoperacyjnych struktur słuchu i ucha wewnętrznego. Uzupełnienie pracy stanowi klasyfikacja wad słuchu oraz prezentacja rozwoju i zastosowania specjalnie zaprojektowanych elektrod stosowanych w różnych rodzajach niedosłuchu.

Słowa kluczowe: *Leczenie częściowej głuchoty, implant ślimakowy, dojście przez okienko okrągłe, elektrody, stymulacja akustyczna, stymulacja elektryczna*

This paper reviews the development of the new treatment method for partial deafness with the pioneering application of the minimally invasive surgical procedure and the consecutive generations of cochlear implants.

Treating total deafness in children and adults with cochlear implants concerns tens of thousands of patients annually. For many years, this treatment was unavailable for millions of patients with either various degrees of residual hearing or even normal, socially efficient hearing but only in the low and medium frequency range. The strategy of developing the cochlear implant program in the treatment of congenital and acquired hearing impairments had to address these enormous social expectations. Good results in the treatment of total deafness, especially in young, even several-month-old children, have encouraged researchers and clinicians to broaden indications for the effective application of the surgical treatment with cochlear implants to include patients with preserved non-functional or functional hearing.

The research was conducted independently in several centers – Europe, the USA, and Australia. In the beginning, the extension of indications mostly involved the electric stimulation of one ear with an implant while the other ear (usually the better-hearing one) was stimulated acoustically with a hearing aid. Less often, researchers studied the possibility of combining acoustic and electric stimulation in the same ear. Since 1997, leading researchers introducing their pioneering solutions in this area were *H. Skarżyński* (1997)[1,2], *Ch. Von Ilberg* (1999)[3] and *B. Gantz* (2002)[4].

The first signal of the future breakthrough in the development of hearing loss treatment with electric and acoustic stimulation was the presentation of *H. Skarżyński et al.* in New York in 1997 at the V International Cochlear Implant Conference [1]. The authors presented the principles of the minimally invasive surgical technique developed for preserving the preoperative residual hearing in the low-frequency range and intact inner ear structures. In 2000, *H. Skarżyński et al.* presented at the European Symposium on Pediatric Cochlear Implantation (ESPCI 2000) in Antwerp the first results of 67 children treated using this method [5]. Preservation of their preoperatively slight residual hearing and inner ear structures allowed for applying simultaneously electric stimulation through the cochlear implant and, in the same ear, acoustic through the hearing aids. This approach was a milestone confirming the feasibility of expanding the previous cochlear implantation criteria to new groups of patients. The results of a 2-3 years follow-up of this first implanted group of children confirmed that this is a justified approach and needs to be further developed. In the same year, during the EUFOS 2000 congress in Berlin, the same team presented the first results of preservation of preoperative residual hearing after cochlear implantation in a group of adult patients [6].

Later, several-year-long follow-up of both groups – children and adults – in terms of the residual hearing preservation has provided the grounds for extending the indications for cochlear implantation as the electric complementation of the normal hearing in low but useful for speech understanding frequencies up to 500 Hz [7]. The first electric complementation of hearing that in low (below 500 Hz) frequencies was within the hearing norm was performed by *H. Skarżyński* in an adult patient in 2002 and later in a child in 2004 [2,8]. It was the next milestone in broadening the indications for cochlear implantation in the treatment of classical partial deafness [9].

The surgical procedure proposed by *H. Skarżyński* comprises six steps [10,11]. It involves the approach to the tympanic duct through the round window as the most physiological way to insert an electrode into the inner ear without damaging the tympanic duct walls. Results of the long-term, systematic follow-up of the growing group of patients, at the start, numbering hundreds and later having overpassed ten thousand, justify further development of this direction [12]. The development of the program is corroborated by the subsequent multiple reports and regular presentations of the research material at all continental and global congresses and conferences on hearing implants, audiology, and otology. This activity aimed to systematically present new groups of patients and the results of a growing period of follow-up of the preoperative hearing preservation in the implanted and the contralateral ear. Later, it was also important to show novel technologies, such as the flexible cochlear implant electrodes of different lengths. In this context, it was also important to present the Polish school of otology in that field of science and medicine.

As the result of these activities conducted between 1997 and 2009, *H. Skarżyński* was able to present the new, comprehensive concept of partial deafness

Table 1. The newest concept of applying the acoustic (AS) and electric (ES) stimulation in the treatment of different hearing impairments and partial deafness (PDT), according to *Skarżyński et al.* (2014) [11,17]

No.	Groups of patients with partial deafness
1.	Acoustic amplification of hearing with a hearing aid, bone conduction device, or middle ear implant (Acoustic Stimulation – AS)
2.	Combined natural-electric stimulation: amplification of the preserved efficient hearing up to 1.5 kHz through electric stimulation – the electric-natural hearing (PDT – Electro-Natural Stimulation: PDT-ENS)
3.	Electric complementation of existing good hearing in low frequencies up to 500 Hz (PDT-Electric Complementation 500 Hz: PDT-EC^{500}), 750 Hz (PDT-EC^{750}) and 1 kHz (PDT-EC^{1000})
4.	Combined acoustic-electric stimulation with acoustic amplification of the preserved residual hearing in low and mid frequencies with a hearing aid or a Duet/ Hybrid system, and electric stimulation of the remaining part of the same ear (PDT-Electro-Acoustic Stimulation: PDT-EAS)
5.	Modified electric stimulation in cases of post-implantation hearing deterioration in implanted and contralateral ear, without reimplantation, with appropriate re-programming of the sound processor (PDT-EMS)
6.	Only electric stimulation in the case of an existing but non-functional residual hearing on different frequencies with preservation of inner ear structures necessary for future applications of new solutions (PDT-Electric Stimulation: PDT-ES)

treatment (PDT) to participants of the 9th European Symposium on Pediatric Cochlear Implantation ESPCI in Warsaw in 2009. The presentation included both the theoretical demonstration and practical – in the form of demonstration surgeries performed using for the first time the new type of electrode (SRA) designed by the author of the concept [13,14,15]. Then, in 2010, the concept was published, presenting different configurations of preoperative low-frequency hearing and specific approaches to each of these groups of partial deafness patients [11,17,18,19,20]. The concept is shown in tab.1 and fig.1.

In 2013, the first classification for the assessment of the level of preservation of preoperative hearing was presented [21]. It was developed by *H. Skarżyński* and 43 experts invited from the leading centers from all over the world. It has provided the basis for further development of the program of partial deafness treatment, combining electric stimulation with acoustic or natural hearing and preserving intact inner ear anatomy.

All implantations with different cochlear implants in the treatment of partial deafness are performed using the surgical technique known as „Skarzynski's 6-step procedure" to preserve the inner ear's existing structure [2,10]. Further development of the partial deafness treatment program involved perfecting the surgical method and continued broadening of indications for cochlear implantation in new, growing target groups of patients [11,19,30].

The next milestones were related to the impact of these activities on progress in developing new technologies, including soft, flexible cochlear implant electrodes of different lengths [13,15,22,23]. Thanks to them, one of the latest elements in the development of that concept was the application of the tailored, limited electric stimulation with 19-20 or 24-25 mm electrodes as the complementation of the normal hearing preserved in the frequency ranges up to 0.5, 0.75, 1, or 1.5 kHz in the specific groups of patients [23,24]. The latest approach involves using the deeper insertion (26-28 mm) and preserving the existing hearing up to 250 Hz, which creates a real chance for its effective amplification during the postoperative rehabilitation using the acoustic stimulation through the sound processor type Duet or Hybrid [24]. Electrodes used in this method included the consecutive generations of the SRA electrode designed by *H. Skarzynski*: Cochlear CI422, CI522, CI622. Another implant company MEd-El offers the widest choice of very soft electrodes: Flex20, Flex24, Flex26, Flex28, and MEdium, as well as special electrodes. Most recently, flexible electrodes type HiFocus™ SlimJ are available from Advanced Bionics and Neuro Zti Evo from Oticon.

The newest, significant step in developing the partial deafness treatment concept was the first in the world classification of partial deafness by *Skarżyński et al.* (2010)[11], mentioned earlier. This classification is crucial for the further study of cochlear implantation results in homogenous groups of patients with different levels of preserved preoperative hearing. Results presented by other authors obtained in different homogenous groups of patients with the use of different technological solutions should be analyzed as the foundation for the further broadening of indications and increasing the availability of partial deafness treatment, especially in the growing group of older patients. The development of this method also has a significant effect on the development and application of new technologies in managing postoperative care, e.g., telemedical networks and e-health technologies. The satisfaction of patients and their families with the results of treatment of partial deafness they receive in the World Hearing Center (WHC) and the resulting increase in the number of patients looking to be treated with this method have influenced the decision about enlarging the clinical infrastructure of the WHC in 2012.

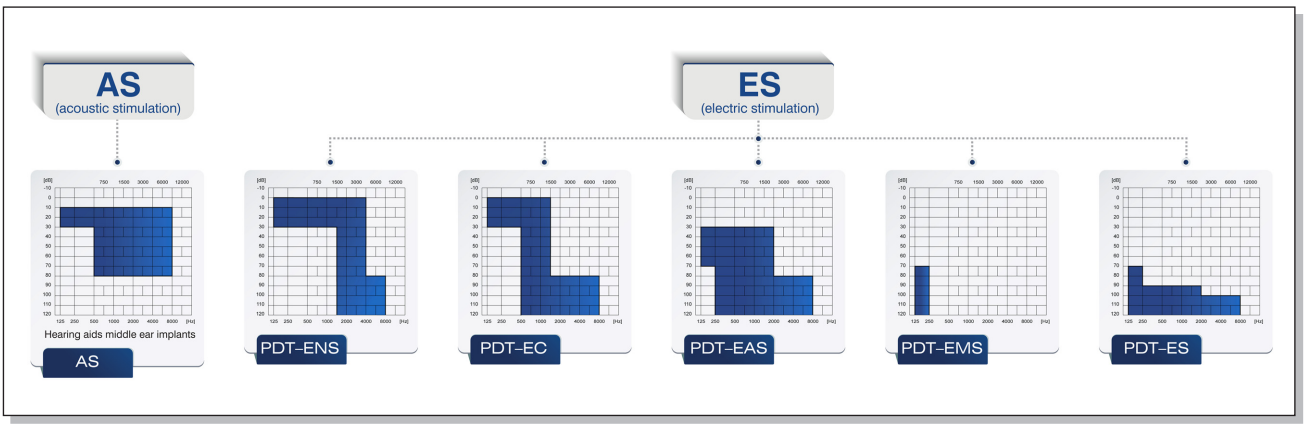

Figure 1. Stimulation ranges: acoustic, electric, and modified according to *Skarżyński*

In many hearing loss cases of different etiologies, the classic hearing amplification with a hearing aid is ineffective or impossible. In these cases, the modern treatment approach means using various combinations of electric stimulation (cochlear implants) with acoustic. In some patients, only acoustic stimulation with hearing aids, middle ear implants, or bone conduction implants is possible and sufficient. But there is a group of patients in whom it is insufficient because a small part of the ear, e.g., above 3 kHz or 4 kHz, is deaf. For that reason, the AS group has been included in the concept of treatment of different kinds of partial deafness (fig.1).

MATERIAL AND METHOD

The total material encompasses more than 10 thousand operated ears with different preoperative hearing levels – from non-functional residual hearing in low and medium frequencies to fully socially efficient hearing in the same range. The results were presented in detail in several hundreds of scientific reports. They are also presented as individual cases in the monograph 'Methods of Partial Deafness Treatment' [25]. Surgical cases presented in the monograph included the 'live' demonstration surgeries performed during the clinical workshop series 'Window Approach Workshop'.

Results presented for the individual, homogenous groups illustrate the degree of hearing preservation directly after the surgery and in the following years, demonstrating a significant improvement in speech understanding, which determines social communication.

In the past twenty-five years, the treatment of different cases of total deafness with small residual hearing or partial deafness using *Skarzynski's* 6-step procedure and flexible electrodes of various lengths has been applied in more than 10 thousand ears in patients from 8 months to 85 years old. In that group, almost 40% were children up to 18 y.o. and a little more than 60% were adults. In children older than 5 years and adults, the preoperative hearing threshold was determined with audiometry. In younger children, the preoperative hearing threshold was tested with the ABR performed for 0.5 kHz, 1 kHz, 2 kHz, and 4 kHz.

The two most important patient groups were PDT-ENS and PDT-EC. These two groups include patients with normal or fully socially efficient hearing up to 250 Hz, 500 Hz, 750 kHz, or 1500 Hz, that is PDT-EC^{250}, PDT-EC^{500}, PDT-EC^{750}, PDT-EC^{1000}, and PDT-ENS. These patients, needing only electric complementation of the existing hearing, are the most significant challenge for the surgeon while also being predisposed to obtaining the best and fastest effects in postoperative rehabilitation. In the beginning, adults, especially older adults, comprised 80%, and children and youths less than 20%. The increase of the pediatric group is related to the large-scale actions of school-children hearing screening for early detection of different hearing disorders.

The next group, PDT-EAS, including patients with indications for combined electric-acoustic stimulation, is presently the most numerous. It is likely because acoustic-only stimulation has little or no effect for these patients, so they are the most motivated to have cochlear implantation.

The PDT-ES group is not particularly numerous. It comprises two sub-groups: adults (sudden deafness cases with severe but not total hearing loss) and a much more numerous group of children who show no reactions in the ABR test within the device's capacity range, i.e., from 0.5 kHz and up to 100 dB. Most patients in that sub-group (over 70%) had preserved small residual hearing below 0.5 kHz observed at 125 Hz, and 250 Hz in pure-tone audiometry performed when the child was older – about 5 y.o. For this reason, the author of this method recommends implanting young children (<1 y.o.) with the least invasive surgical technique and flexible electrodes to preserve intact inner ear anatomy. It is crucially important in cases of bilateral implantation; departure from that principle may lead to the bilateral loss of vestibular functions.

The last group, PDT-EMS, comprises patients who earlier had been included in different groups with various configurations of hearing. Their common feature is that in the years after cochlear implantation, their hearing worsened bilaterally (not only in the implanted ear). To maintain the adequate level of continued electric stimulation without exchanging the electrode for a longer one, it is enough to re-program a sound processor. This approach has allowed separating a new group of patients with a modified electric stimulation: PDT-EMS. It can be expected that this group will grow, especially in terms of adult patients with partial deafness and progressing hearing loss.

SKARZYNSKI'S 6-STEP SURGERY

In all operated ears, the round window was used to enter the tympanic duct. In over 99% of cases, it was possible to access the round window niche through the posterior tympanotomy. Only in very few patients it was necessary to perform double access through posterior tympanotomy and the external ear canal (EAC). In the latter, visualization of the round window niche was through the EAC, and the electrode was inserted from the back through the posterior tympanotomy. In this way, it was possible to gently insert the electrode to the desired depth through the incision in the round window membrane. The only exceptions were cases with atresic or malformed round window.

Table 2. The surgical procedure of the treatment of partial deafness with a cochlear implant according to *Skarzynski*

Step	Description
1.	Removal of a bone chip from the mastoid cortical layer and conservative, minimal antromastoidotomy
2.	Posterior tympanotomy to visualize the round window niche and membrane. This step sometimes includes removing about 0.2-0.5 mm of the lateral lip, hampering visualization, and introducing the electrode under the correct angle
3.	Puncture and incision of the round window membrane to insert the flexible electrode; it should be minimally invasive; the incision is widened and the opening sealed by the electrode during its insertion
4.	Atraumatic insertion of the electrode into the tympanic duct through the round window, with one, or 2-3 movements, fluidly, in a natural tempo of about 10-20 seconds. In the beginning, the electrode is held in fingers, then with forceps or a guide
5.	Sealing of the electrode in the round window niche with fascia and fibrin glue. It is a critical and decisive step in PDT implantation. Sealing must be complete, around the electrode, without contact with the ossicles so that their mobility is not impaired, affecting hearing
6.	Fixation of the internal part of the implant in the niche under the skin-muscle-periosteum flap in the elaborated pocket with the adequate, usually small bed drilled in the temporal bone squama

The entire surgical procedure was conducted according to the standard proposed by *H. Skarżyński*, which comprises 6 principal steps (tab. 2) [2,10,11].

The first step of the procedure involves limited conservative antromastoidotomy, that is, opening the mastoid cavity. The opening should not be wide, only enough to easily insert the electrode. Before that, a chip of the mastoid's cortical layer is removed using a chisel. This maneuver is particularly recommended in children. It should be done in such a way that at the end of the procedure, the chip can be used to isolate the mastoid cavity from the subdermal space.

The second step of the otosurgical procedure is the posterior tympanotomy to open the approach to the tympanic duct, which will allow visual control when introducing the electrode to the round window niche. In some cases, it is needed to slightly reduce the lateral bony lip limiting the window membrane's visibility. Good visualization of the wound window allows for precise incision and the least invasive insertion of the electrode to the tympanic duct at the optimal angle. Rarely, as mentioned earlier, when visualization of the round window niche is insufficient, a secondary approach through the EAC can be performed. Usually, the window membrane area is well visible, and it is seldom necessary to reduce the lateral lip.

The third step involves a delicate puncture and longitudinal incision of the round window membrane – the way to insert the electrode into the tympanic duct. Earlier, the niche area should be carefully cleaned, adhesions removed, and possible bleeding from small vessels controlled. It allows for excellent access and visual control during the insertion of the soft, flexible electrode into the tympanic duct. Directly before the incision, Dexamethasone is administered to the window niche area [26].

The fourth step is the most critical part of the procedure. It involves the minimally invasive introduction of the electrode into the tympanic duct. The electrode should be held possibly at a straight angle to the round window membrane before being inserted into the inner ear. The author of this procedure recommends such position as the least traumatic. At the start, the operator should hold the electrode with fingers to better feel possible resistance. Only the last stages of the electrode's insertion into the tympanic duct are made using forceps or guiding pins. In electrodes equipped with an internal stylet for insertion, it is necessary to use two pairs of forceps: one to introduce the electrode and another to slide out the stylet. However, this kind of inner ear insertion is not very gentle and does not guarantee that the inner ear anatomy will be preserved; therefore, electrodes of that type are not recommended for PDT. Electrocochleography performed during the electrode's insertion provides significant assistance at this stage.

The fifth step includes sealing the electrode's entry point to the tympanic duct and fixing the electrode in the posterior tympanotomy area with fascia and fibrin glue. Fascia fragments should be 1-2 mm large; combined with glue, they should go around the electrode at a safe distance from ossicles to prevent adhesions that could immobilize the ossicular chain. The remaining section of the electrode is coiled in the tympanic cavity, and the bony tunnel after the posterior tympanotomy is sealed with tissue fragments and glue. The cavity is closed with spongostan, and a fragment of the mastoid cortical bone harvested during the first step, fixed with fibrin glue.

The sixth step of the surgical procedure involves preparing the niche or leveling the bone surface for placing the implant's inner part. Sometimes, it needs to be additionally fastened with glass-ionomer cement, non-absorbable sutures, or screws, e.g., in Oticon implants.

This last step of the procedure has been evolving over the previous 25 years. In the first years of the PDT program, exposing a wide area of the temporal bone surface was recommended to prepare a full bony

niche for the implant. Additionally, the implant was fastened to the bone with glass-ionomer cement or non-absorbable sutures to prevent displacement. Subsequent improvements in the cochlear implants have led to the present situation, where an implant may be safely placed in a shallow bony niche or even on the leveled bone surface in a pocket under a skin-muscle-periosteal flap. During the flap dissection, essential factors are avoiding damaging the periosteum, controlling the bleeding, and placing the reference electrode in the bone socket.

Progressing development of cochlear implant design complemented and aided clinical PDT praxis. New solutions allow fixing, if needed, the inner part of the implant to the bone with special screws or dedicated pins. Continued miniaturization of implants involved flattening and thinning the internal part of the device, so it is now often possible to resign from making the bony bed for the implant, which is particularly advantageous in children with thin skull bones. It is now enough to only level the bone surface or even skip that stage and slide the implant's internal part into a tight pocket under the skin-muscle-periosteal flap. That solution also eliminates the necessity of placing the suction drain. Intact periosteum allows the device to fit closely into a naturally developing forming bone imprint. Moreover, with this solution, it is possible to make only a short, about 2.5 cm, skin incision in the shape of an elongated "S".

The periosteum is sutured using the continuous stitch with additional single everted mattress stitches placed on subcutaneous tissues. Skin is sutured with a continuous stitch. If there were visible small bleedings from the bone, or it was necessary to make a deeper bony bed, that is, when we expect the collection of body fluids new the implant, a suction drain is placed for 1-2 days. The drain is unnecessary when the surgical field is dry and when the implant is placed in a small, tight pocket instead of a large skin-muscle-periosteal flap.

Four implant systems are used in the treatment of partial deafness and inner ear structure preservation. Med-El implants are used with different electrodes (from 20 to 31 mm), mostly Flex20, Flex24, Flex 26, Medium, and Flex28, inserted into the tympanic duct. In PDT, electrode insertion exceeding 25 mm is a deep insertion. The second system used is Cochlear implants with electrodes developed by *H. Skarzynski*: SRA, CI422, and CI522, CI522, length starting from 20 mm and with a possibility of deeper, 25 mm insertion. The third system is Advanced Bionics implants, in the PDT-EAS inserted under the control of electrocochleography. In cases of electric complementation of the normal hearing up to 250, 500, 750, and 1000 Hz (PDT-EC) and the preserved hearing up to 1.5 kHz (PDT-ENS), only the electric stimulation of the scala tympani was used. In cases of combined electric-acoustic stimulation, initially, hearing aids were used independent of the implant type and, later, Duet or Hybrid systems. The process of postoperative implant fitting and further rehabilitation has been comprehensively presented in 'Methods of Partial Deafness Treatment' [27,28,29,30].

SUMMARY

The progressive broadening of the cochlear implantation indications – from residual hearing in 1997 to preserved good, efficient low-frequency hearing in 2002 and normal hearing up to 1.5 kHz in 2014 – enabled longitudinal follow-up of a growing group of patients. The introduction of the new method, comprehensively presenting the possibilities of acoustic and electric stimulation of the inner ear, allowed significantly expanding indications for surgical treatment of different hearing disorders using cochlear implants with different-length electrodes. Indubitably, the most important and challenging task was the introduction, for the first time in the world in 2002, of the program of the electric complementation of good low-frequency hearing (PDT-EC). After this turning point, it was clear that not only small residual hearing and inner ear structures can be preserved, but it is also possible to use electric stimulation to complement normal hearing up to 0.5 kHz both in adults and in children.

Ten years later, the next turning point was combining preserved natural hearing up to 1.5 kHz with electric hearing. It made cochlear implantation available to millions of patients, including elderly adults and patients after different kinds of injuries, who had preserved normal hearing up to 750 Hz, 1000 Hz, or 1500 Hz. Complementing their existing hearing with a cochlear implant with an appropriate electrode results in electric-natural hearing (PDT-ENS).

Excellent results of preservation of preoperative hearing in the long term are remarkable, both the crucial low-frequency hearing and the residual hearing in fight frequencies. The largest deterioration was observed at 1000 Hz in the first six months. Temporarily – for about 2 months after surgery – mean hearing thresholds were lower by 10 dB on all frequencies (measured at the first post-op evaluation). Changes during the 3-6 months post-implantation were minimal; for this reason, the 6-month hearing results were taken as the reference for hearing preservation in the longitudinal observational study. In the period from 12 months to 9-10 years after implantation, there was no significant hearing deterioration in the first group of implanted patients with electric complementation. In the first two years (2002-2004), PDT-EC cochlear

implantation was only performed in adult patients with stable hearing thresholds for about ten years before implantation. For this reason, it can be assumed that the therapy was evaluated based on hearing preservation directly before the surgery and in the period of 6 months – 10 years after cochlear implantation. In 2004, electric complementation of hearing was used for the first time in children. A longitudinal follow-up study of the PDT-EC results has brought about another breakthrough – a new, colossal target group of patients with normal hearing preserved to 1.5 kHz – PDT-ENS (electric-natural hearing).

An important procedure developed by Lorens et al. (2008) [31,32] was the modification of the electric stimulation by adjusting the sound processor programs to compensate for hearing deterioration related to the underlying ear pathology. It means there is no need to remove, e.g., a 20 mm electrode to replace it with the longer, 24, or 28 mm electrode. The new procedure, combining auditory training with appropriate implant programming, allows for replacing lost acoustic hearing with electric hearing. In this way, another subgroup was separated from the PDT-ENS and PDT-EC groups: the PDT-EMS (electric modified stimulation). It includes patients with deteriorating hearing thresholds, whose electric stimulation parameters were adjusted to compensate for the loss.

As mentioned before, the excellent results obtained in the group of adult PDT-EC patients have motivated *H. Skarżyński* to perform cochlear implantation, for the first time in the world, in children with good low-frequency hearing up to 0.5 kHz (PDT-EC). Observation of the post-implantation results in a growing group of small (younger than one year) and older children allowed the development of a new surgical approach as a standard procedure for preservation of the preoperative hearing and inner ear structure. Thus, today's patients can take advantage of potential new technologies that will be developed in the next 10 or 20 years.

More than 20 years of observation of children and adults show stable hearing effects. It allows an optimistic conclusion that this method of treatment of partial deafness is the optimal management of such impairment in elderly patients. Considering that this type of hearing loss affects about 65% of people over 75, this solution is an opportunity for millions of patients.

We should also consider the data showing that a little more than 50% of patients operated in the World Hearing Center of the Institute of Physiology and Pathology of Hearing had some slight hearing deterioration in both ears for about ten years before surgery. Possibly, hearing loss progression will continue after implantation in the operated and contralateral ear. Further analysis of this phenomenon will be possible after collecting and analyzing the longitudinal results obtained in a larger group of implanted patients. It will be the subject of a separate, comprehensive analysis of preoperative hearing preservation and patient satisfaction.

An essential aspect of the assessment of patients' results after implantation is speech understanding tests. The long-term results are very stable, providing the patient receives regular rehabilitation. Speech understanding ratio both in silence and in noise is much higher in the groups of patients with electric-natural hearing (PDT-ENS) and electric complementation of hearing (PDT-EC) compared to the combined electric and acoustic stimulation (PDT-EAS) [19,20].

Summarizing, this paper presents the subsequent stages of development, in the period of over 20 years, of the comprehensive strategy of treatment of partial deafness in patients with different types of hearing loss. It also shows the prospects of hearing preservation in the first, most numerous worldwide group of patients with partial deafness – patients of the World Hearing Center of the Institute of Physiology and Pathology of Hearing – in the years 1997-2000. In 2013, *Gifford et al.* [33] published their results confirming the validity of the classification system and surgical treatment strategy. Other centers have published reports of introducing an analogical surgical technique to *Skarzynski's* 6-step surgery and using the same patient selection criteria: *Dorman & Gifford* 2010 [34], *Van de Heyning et al.* 2013 [35], *Rajan et al.* 2018 [36]. They confirm the growing dissemination of the Polish school of partial deafness treatment in children and adults in modern science and medicine.

The series of 66 international surgical training workshops – Window Approach Workshop (WAW) – organized in 2007-2020 with over 1300 demonstration surgeries performed by *H. Skarżyński* is an excellent way to popularize knowledge of the partial deafness treatment results and the impact of that strategy on technological developments such as a series of novel flexible electrodes of different lengths – from 19 mm to 34 mm.

In the recap, it should be emphasized that, since the mid-1980s, when the multichannel cochlear implants became the turning point in the treatment of deafness in adults and children, the current strategy was the most significant qualitative and quantitative breakthrough. It allowed to single out, define and describe different kinds of partial deafness and their treatment methods, thus creating a genuine opportunity for millions of people instead of earlier indications concerning thousands of patients. Finally, it allows the formulation of several, well clinically documented conclusions.

1. Results obtained in a very long observation period of the growing group of patients of different ages indicate the need for expanding the cochlear implantation criteria in persons with preserved larger and larger preoperative residual or normal hearing in low and mid frequency ranges.
2. Stable results confirmed in long-term observation, measured by good and excellent speech understanding, as well as good audiometric results, confirm the optimal choice of the surgical strategy with access to the tympanic duct through the round window.
3. Clinical results contributed to accelerating the development of new technologies, such as the soft cochlear implant electrodes and systems for the combined electric and acoustic stimulation, which are crucial for preserving preoperative hearing and inner ear structures, protecting vestibular functions, and assuring the potential chances for implementing future technologies.

Proven high effectiveness preoperative hearing preservation had a marked impact on a) elaborating new strategies of early detection of various partial hearing impairments based on the universal, population-wide screening tests in different age groups; it was reflected in two European scientific consensuses adopted in Warsaw in 2011: „European Consensus Statement on Hearing, Vision and Speech Screening in Pre-School and School-Age Children" and „European Consensus Statement on Hearing Screening in Pre-School and School-Age Children" [37]; b) showing new directions for developing the infrastructure and application of the ICT and e-Health tools.

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