# Cochlear Implants in Developing Countries

by Fan-Gang Zeng, Ph.D.

As the only medical intervention that can restore partial hearing to a totally deafened person, the cochlear implant has been used by more than 12,000 deaf people worldwide. From the early single-channel device in the 1970s to the present multi-channel device that incorporates multi-processing strategies, the cochlear implant has evolved from mostly assisting lip reading to enabling the use of a telephone in a significant portion of implant users. However, the benefit of the cochlear implant comes with a hefty price tag: the cochlear implant device alone, excluding surgery and rehabilitation, is priced between US$15,000 and $35,000, depending on the implant type and the specific market. Consequently, the majority of cochlear implants have been distributed in developed countries in North America and Western Europe.

According to the World Health Organization (WHO), more than 80% of the world's 120 million people who have disabling hearing difficulties live in developing countries. With a personal average annual income of well below US$2,000, the present cochlear implant is virtually unavailable for deaf people in developing countries. Even in countries where the medical system is socialized, applications of the cochlear implant are not only limited but often face serious ethical dilemmas. For example, if you were the head of a national medical agency with only $200,000 in annual budget, would you buy ten cochlear implants for ten totally deafened people, or would you buy 400 hearing aids, or pay for immunization which can prevent hearing loss resulting from infectious diseases for thousands of children? Despite numerous difficulties, the cochlear implant started its infancy in developing countries in the 1980s. This article discusses issues related to deafness and cochlear implants in developing countries, and is based on personal visits to China and Egypt in the last few years, on public materials published in journals or presented at international meetings, and on exchange of information with many clinicians from Asia, Eastern Europe, and South America.

## (1) Deafness in developing countries

Deafness has often been regarded as an invisible disability. Hearing loss is primarily caused by presbycusis (aging), infectious diseases such as otitis media, congenital factors, ototoxic drugs, and noise exposure. Traditionally, hearing loss has received little attention in developing countries. As a result, more people suffer from hearing loss in the general population of these countries compared with the proportion in developed countries. According to Hearing International, a not-for-profit organization focused on global hearing loss prevention, in developing countries more than 10% of children under 10 years old suffer from otitis media and four in 1000 are born with severe hearing loss which results from either hereditary (genetic) factors or infections during pregnancy. These numbers are approximately four times greater than that in developed countries.

Several surveys also revealed a difference in the cause of hearing loss between developing and developed countries. In 1983, the Indian Council of Medical Research published a study of hearing loss based on a survey from 4 different parts of India. The Indian study found that for almost half of the 10.7% hearing-impaired people in rural areas, the

*House Ear Institute (HEI) researchers visiting the PLA Institute of Otolaryngology in Beijing, China in November, 1993. L to R, front row: Fan-Gang Zeng, Elaine Minehart and Bob Shannon of HEI, Profs, Zhang and Fang. Rear: President of the Institute Prof. S.C. Jiang (behind Ms. Minehart), Vice President Prof. Li (first from left), and Institute researchers.*

hearing loss is due to chronic middle ear infections, whereas sensorineural hearing loss is more prevalent in the 6.8% hearing-impaired population in urban areas. Dr. S.K. Kacker at India Institute of Medical Sciences attributed the chronic middle ear disease to the "poverty-underdevelopment syndrome", i.e., lack of health education, poor environmental conditions, infections and malnutrition. In China, a 1990 official survey of the handicapped found that 23.09 million people have 40 dB or more hearing loss. Among these hearing impaired, 6 million are totally deaf adults and 3 million are deaf children. The Chinese study showed that a primary cause of hearing loss, especially in children, is the use of antibiotic drugs such as neomycin and kanamycin. The ototoxicity of these drugs is often unknown to local physicians, particularly those "bare-foot doctors" who received no formal medical training during the Cultural Revolution in the 1960s and 1970s. In contrast, these drugs seldom cause hearing damage when they are properly used or only prescribed in treating life-threatening diseases in developed countries. In Arabic countries, genetic hearing loss is more frequent because of marriages among blood relatives, which can more than double the chance of hereditary hearing loss. Noise exposure is another significant cause of hearing loss in developing countries where people are subjected to damaging noise in factories, construction sites, and from fire crackers and gunfire. Until better hygienic conditions, greater awareness of ototoxicity among physicians, and more public education in genetics and noise control are achieved, the number of hearing-impaired people due to infectious diseases, ototoxic drugs, hereditary incidence, and noise exposure will continue to increase in developing countries and to exceed the proportion of deaf people in the general population in developed countries.

On the basis of talks with clinicians and deaf people from developing countries, there seems to be no apparent existence of deaf culture in most. The general public opinion in these countries is that deafness is a

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handicap and should be treated if possible. During my 1993 trip to China, I asked many individuals, including deaf people, about reasons for the lack of deaf culture in China. They suggested the following three reasons: (1) the majority of deaf Chinese people live in a hearing community — hearing neighbors, hearing parents and, most likely, hearing children, (2) signs used by deaf Chinese are not as fully developed as American Sign Language and signing is not uniformly recognized as a language; (3) deaf people are generally in adverse economic conditions and about two thirds of them rely on financial support from government, parents and relatives. About 80% of deaf Chinese children are not able to go to regular or deaf children's schools and 40% of the handicapped including the deaf are unemployed in China. No specific data are available in other developing countries, but it is believed that hearing-impaired people generally have less income and less employment opportunities than the normal-hearing population. Deafness remains an obstacle for many deaf people wishing to improve their employment opportunities and quality of life.

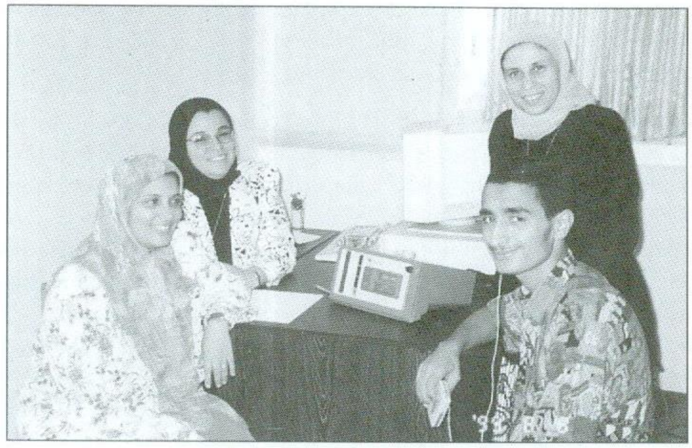
## (2) Development and applications of cochlear implants

Two European doctors, Djourno and Eyries, have been credited for their inventive demonstration using electrical stimulation to evoke hearing in a totally deaf person in the 1950s. Dr. William House and an engineer, Jack Urban, were the first to reduce the concept to practice and developed the first FDA approved "3M-House" device in 1984. At present, there are at least 5 multi-channel cochlear implants that are commercially available in the West: Australian Nucleus-22, Austrian Med EL, Belgian Laura, French 15-channel MXM, and US Clarion devices.

In developing countries, application of cochlear implants has either been based on development efforts by local researchers at a low cost or relied on the import of western devices at a high cost. Since 1980, four different groups in China have independently developed single-electrode cochlear implant systems. These systems included both percutaneous [direct connection through the skin) and transcutaneous [radio frequency transmission across an intact skin] transmission, and both intracochlear and extra-cochlear stimulation. A review of published data revealed that, up to 1993, a total of 382 patients had received these single-electrode implants in China at a cost of about US$100, although the number of total implantees may be as high as 1000 (for further information, see Zeng, Audiology, 1995;34:61-75). Post-surgical tests demonstrated that not only do single-electrode implants show a clear advantage in speech recognition over hearing aids (from which these totally deaf people can not benefit), but they also enhance their ability to read lips and to be more aware of environmental sounds. Moreover, some implant users achieved moderate open-set speech recognition with sound only. The results are generally similar to the performance of single-electrode implant users in western countries. To further improve implant performance, multi-electrode implant systems are also being developed in a number of places in China. Facing technological difficulties in hermetic sealing and integrated circuit design, commercial products of these multi-electrode implants appear to be many years away.

Because of the superior performance of multi-electrode implants, government and private philanthropic support have brought the expensive multi-channel cochlear implants into developing countries. For example, 3 males and 2 females received the Nucleus device in 1989, thanks to a joint sponsorship by University of Hong Kong and the Hong Kong Society for the deaf. Since 1990, 12 post-lingually deafened adults have received the Nucleus device at Chang Gung Memorial Hospital, Taipei. 2 cases of implantation with Nucleus devices were also reported in Beijing in 1995 through a donation program sponsored by Cochlear Corporation. Implantation of the Nucleus devices is also expected soon in other Asian countries such as Malaysia and India.

At Ain Shams University, Cairo, a cochlear implant team consisting of several western-trained physicians and audiologists has been established through Egyptian government funding and has already implanted 7 Nucleus devices. In Saudi Arabia, the public medical care system and relatively strong economy enable the hiring of highly trained Western professionals to perform implantation and post-surgical rehabilitation. In South Africa, 4 deaf people were reported to have received the Ineraid devices. In Hungary, the government has a special fund to allow up to 10 patients annually to receive multi-channel



*Audiologists Drs. Nadia Kamal, Nagwa Hazzaa, and Wafaa El Kholv programming speech processor of patient Mohamed at the Audiology Unit. Ain Shams University, Egypt in August, 1995.*

implants, including both Nucleus and Med EL devices. In Sao Paolo, Brazil, the government also sponsored a cochlear implant program to allow implantation of several devices every year. Clinical centers have also been established to implant Nucleus, Clarion, and Med EL devices in Argentina, Mexico, Columbia, and other South American countries. While no articles have been published in peer-reviewed journals, good speech performance of these multi-electrode implants were reported at international meetings. Overall, the total number of the multi-electrode implantation is not more than a few hundred in developing countries. According to a recently released report by Cochlear Corporation, about half of clinically eligible deaf people in developed countries have potential access to a cochlear implant center and funding given current reimbursement policies; in contrast, only 1-2% of those are likely to have funding in developing countries. Unless the device cost can be drastically reduced to a level compatible with the economic condition in developing countries, the multi-electrode implant will remain, as one South American doctor put it, "a toy of the few rich or fortunate" in these countries.

### (3) Pre-surgical screening and post-surgical rehabilitation

Success of the cochlear implant not only depends on the device itself, but also on patient selection, surgical skills, and post-surgical rehabilitation. Infrastructure is generally less satisfactory in developing countries than in developed countries. Review of published materials indicates that, at least, in China, Egypt and Saudi Arabia, patient selection and pre-surgical screening procedures have been standardized for cochlear implants and are in many ways similar to standards adopted in western countries. However, there are some distinctive differences in patient selection between developing and developed countries. For example, most Chinese doctors think that the presently available single-electrode implants should not be placed in children less than 10 years old. In Egypt, the procedure requires that patients be middle-to-high socioeconomic classes because patients of low socioeconomic class might not even be able to pay transportation to the follow-up visit. Given the limited fund-

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ing from the government and the importance of having some initial success, it is unfortunate that clinicians have to deny patients access to cochlear implants because of their lower socioeconomic status.

Like their counterparts in developed countries, otological physicians have played the most critical role in the process of device research, development and distribution. All cochlear implant projects in China so far have been initiated by physicians who normally received initial financial support from the government and collaborated with an engineering institute or university to design and implement a prototype device. Many ENT doctors in developing countries have received training in the West and are familiar with cochlear implantation surgery. The surgery fee is much less than that in developed countries. For example, the surgery fee was about US$20 and the cost of hospital stay after surgery about US$100 in China in 1993.

In the West, speech processor fitting and post-surgical rehabilitation are normally performed by specially-trained audiologists and speech pathologists. The fitting and rehabilitation will become extremely important and require more training as more children receive the cochlear implant. Inappropriate speech processor settings may cause undesirable stimulatory effects such as dizziness, pain and facial sensation. Presently, there are few audiology and speech pathology programs in developing countries, and, where they are present, lack adequate training in cochlear implants. For example, in China, processor



Peter Stone

*Dr. Gonzalo Corvera and speech and hearing therapist Griselda Magallanes program Marco Antonio Montova's speech processor at the Hospital Angeles del Pedregal in Mexico City. Marco Antonio puts a chip inside the plastic doll whenever he hears a tone.*

## Financing Cochlear Implants in Mexico
**by Gonzalo Corvera, M.D.**

Financing cochlear implants in Mexico is indeed a difficult task, especially since last year's devaluation, which essentially doubled the cost. Only the very well-off can pay for the surgery but our challenge is to bring this treatment to the less fortunate in our society. This we try to do through a public hospital, part of the Mexican Health Secretariat, where I work in addition to my private practice. Each implant costs us $20,000 US dollars, including taxes, freight and insurance. To put this price in perspective, consider that it would take 45 months of my salary at the Government hospital to pay for one. This illustrates the fact that the health system cannot subsidize the cost of the device, but we can offer the surgery and rehabilitation free to our patients. The way we are now working, we have an arrangement with a private clinic that provides us with CT scanning at US $70.00 a patient;

I perform the surgery at the public hospital and provide the surgical instruments and Diagnostic Programming System hardware that the hospital could not acquire (at no charge for the hospital); the hospital provides the facilities for surgery and rehabilitation at no charge for the patient (there is normally a small charge for these services). We also have established a trust fund that allows us to accept tax-deductible donations to finance the implants. Thanks to this arrangement, the price for a cochlear implant is only the $20,000 dollars needed to acquire the device, which I believe is about half the usual cost for this type of surgery in the U.S., but even so we barely can provide one or two implants a year, which frequently puts us in the terrible position of having to decide who gets one and who doesn't.

As you can see, it hasn't been easy, but it is extremely satisfying work. Although our progress is slow, and the current economic situation isn't helping, I do believe that we eventually will be able to provide many more of our patients with this treatment, which I am convinced is ultimately very cost-effective to society.

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Dr. Gonzalo Corvera is an otolaryngologist at Hospital Angeles del Pedregal and is coordinator of the cochlear implant program at Hospital Dr. Manuel Gea Gonzalez in Mexico City.

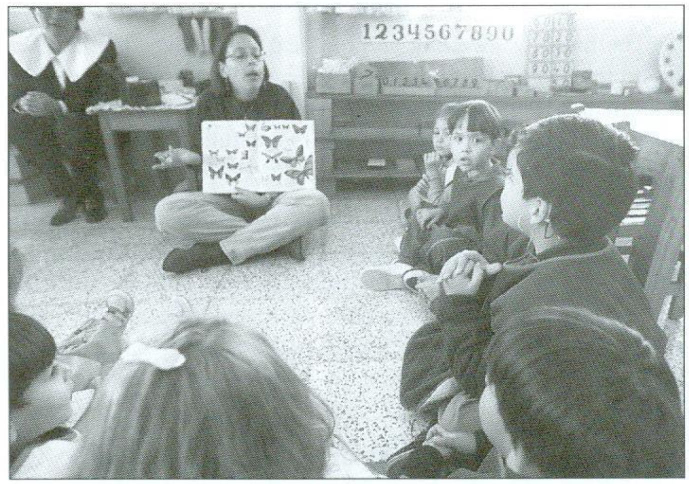
fitting and post-surgical rehabilitation are conducted by otological physicians who are already overburdened with their medical duties and receive little training in audiology and biomedical engineering. The knowledge deficit in audiology and biomedical engineering will pose a more serious problem for future application of cochlear implants in developing countries. Seminars or intensive training may be a short-term cure for this deficit, but a specialized formal program in audiology is definitely needed in the long run.

To be able to compare between devices and between clinic centers, it is extremely important to use tape-recorded, standard test materials to evaluate the effectiveness of cochlear implants. In contrast to clinicians in the West who have to choose from many available standardized tests, there is a general lack of these standardized test materials in developing countries. In both Beijing and Cairo, two teams have recently developed Chinese and Arabic versions of the Minimal Auditory Capability Tests. However, the large variance in dialects, literacy and age (many deaf children are expected to be implanted) presents a serious problem in evaluating speech recognition via implants. In developing these standardized tests, linguistic differences should also be considered. For example, Chinese is a tonal language in which a vowel with different pitch variation patterns represents different meanings. A classic example is the word: "ma", which means "mother", "linen", "horse", and "cursing" for tonal patterns of flat, rising, falling-rising, and falling, respectively. The tonal feature should make Chinese more easily understood by implant listeners than English because such voicing information can be discriminated even with single-electrode stimulation. An Australian report directly compared Chinese and English recognition in a bilingual subject implanted with a Nucleus 22-electrode device and showed a significantly higher score of open-set word recognition for Chinese (63%) than English (42%). On the other hand, Arabic language has more fricative consonants than English. These fricatives have usually long duration and steady-state spectrum, and thus may be more easily transmitted via cochlear implants than stop consonants which contain fast-changing transients. Systematic studies of these linguistic differences are not only important in speech evaluation and training but also may shed light on the design of better cochlear implant processors that take linguistic information into account.

## (4) Development of an affordable yet effective implant

There is a clear gap between affordability and performance for the application of cochlear implants in developing countries; the affordable single-channel cochlear implant is not effective, while the effective multi-electrode implant is not affordable for deaf people in these countries. To pay for a US$20,000 device would take 20 years' salary for an average working Chinese and 4 years' salary for a Mexican medical doctor. Moreover, as Dr. Gonzalo Corvera from Mexico stated, the current public health system cannot subsidize the cost of the device, even if the surgery and rehabilitation are offered free or at a minimal cost to deaf people in developing countries.

To help deaf people in developing countries, we need to develop an affordable yet effective cochlear implant. This was the central theme for the 1993 Zheng-Zhou International Symposium on Cochlear Implants and Linguistics in China, where leading researchers from the

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*Marco Antonio Montova, 6, in a mainstream class at Monotosori Kindergarten in Ciudad Satelite, outside Mexico City.*

West interacted with over 100 researchers and clinicians from China and shared information on state-of-the-art research and application of cochlear implants. Blake S. Wilson from the Research Triangle Institute, North Carolina reviewed speech processing techniques for cochlear implant systems, particularly the development of the continuous-interleaved-sampling (CIS) strategy. Gerald E. Loeb from Queen's University, Canada and Steven J. Rebscher from the University of California at San Francisco addressed the designing and manufacturing issues in electrode, receiver capsulation, and biocompatible materials. Robert V. Shannon and Fan-Gang Zeng from the House Ear Institute lectured on basic capabilities of electric stimulation of the human auditory system and its relation to implant system design. James Patrick and Lois Higgins from the Cochlear Pty. Limited, Australia discussed the cost and rehabilitation issues of cochlear implant systems from a manufacturer's viewpoint. The interaction between researchers was fruitful in that a consensus was reached among the participants in regard to the design of a low-cost, high-performance cochlear implant system that employs transformer-coupled, four-channel CIS processing strategy. Feasibility studies are being conducted at the House Ear Institute to develop this low-cost, high-performance cochlear implant.

## Acknowledgments

I would like to thank Larry Orloff for his invitation and persistence, without which I would never be able to finish writing this article. I would also like to thank the many clinicians around the world who have kindly provided the information presented in this article. Finally, I thank Alena Wilson, Bob Shannon, and Monita Chatterjee for their helpful comments.

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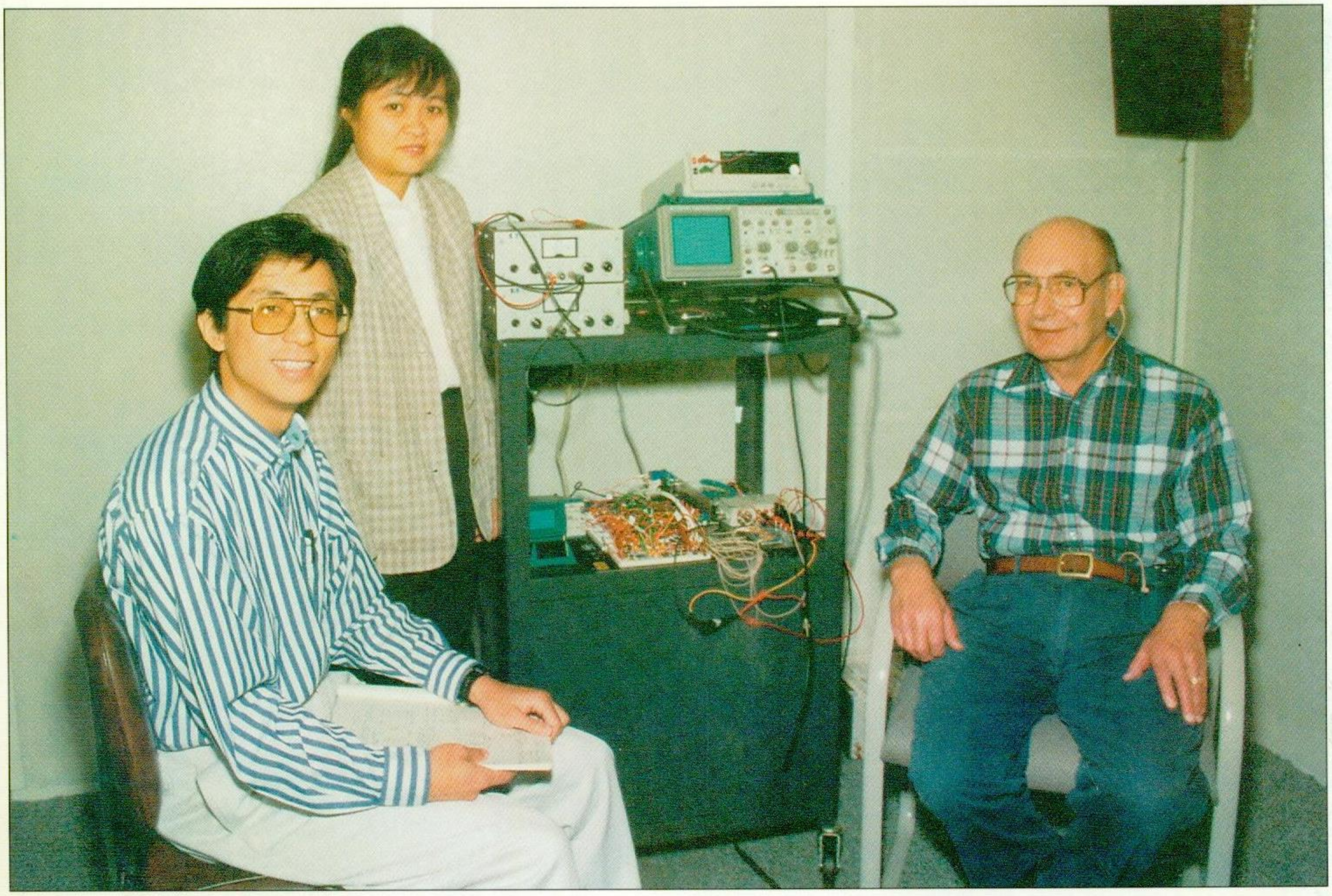

*From left: Fan-Gang Zeng, Ph.D. and technician Thanh Hong evaluating a speech processor with research subject David Columpus at the House Ear Institute. This study is being conducted in connection with a consensus on cochlear implant design reached at the 1993 Zheng-Zhou International Symposium on Cochlear Implants and Linguistics in China. See Dr. Zeng's article, "Cochlear Implants in Developing Counties," starting on page 4.*

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