The Best of 2008: Cochlear Implants

By Fan-Gang Zeng

I am honored to join the Journal Club as its newest member. My task is to select the best papers in cochlear implants (CI). The time is due to highlight CI research, because, as most of you know, CIs have emerged from being an unproven device in the 1980s to becoming the standard treatment for severe and profound sensorineural hearing loss.

If you are unfamiliar with the fascinating CI history, I'd suggest you first read two review papers published in 2008. **Harry Levitt** recounted his personal early experiences in *Journal of Rehabilitation Research and Development* (*JRRD*), when the CI had to fight against both mainstream scientists and the "tactile mafia." In an article I wrote with colleagues **Steve Rebscher**, **Van Harrison**, **Xiaoan Sun**, and **Haihong Feng** in *IEEE Review on Biomedical Engineering*, we reviewed almost everything you need to know about the CI at the systems level. As the lead author, this may sound a bit self-promoting, but I guarantee you will enjoy reading it, at least the first and the last sections, even if you aren't an engineer!

So far, more than 120,000 people have benefited from implantation. There's an explosion of CI research, which produced 580 peer-reviewed publications in 2008 (see www.pubmed.gov with "cochlear+implant" as the search words). It was a daunting task to select the few best from a stack of 580. Here was my strategy: I first read all the abstracts, then selected about 100 papers to read. I also recruited John Galvin, a former associate at House Ear Institute; Juan Huang, a visiting scholar from Beijing; and Janice Chang, an MD/PhD student at UC Irvine, to help select the final papers. I thank them for their contributions, but I'll take the responsibility for the following selections.

GREAT FOR THE CLINICIAN

There are too many good papers in this category, so I'm bound to miss some. I'll start with an article **by René Gifford, Jon Shallop**, and **Anna Peterson** in *Audiology and Neurotology* on a somewhat unexpected problem encountered in evaluating today's multichannel CI users: Many of them simply have maxed out on the simpler speech materials, such as the HINT sentences. Therefore, more difficult speech materials need to be developed. The authors recommended the more difficult AzBio sentences as an alternative.

CI users are getting demanding these days. Most of them can converse well on the phone, but now they want to appreciate music. Of the 26 papers last year on evaluating and improving CI music performance, I selected a comprehensive article by **Kate Gfeller** and colleagues in *Journal of the American Academy of Audiology*. They tested over 200 CI users and tried to predict their music performance using a wide range of parameters. Not surprisingly, music background and residual hearing are positively correlated with CI music performance. But surprisingly, music and speech performance are not strongly correlated. Why is this? Read the paper and find out!

Another 120 articles addressed some aspect of language development, an important yet still unsettled issue in CI research. Writing in the *International Journal of Audiology*, **Ann Geers** and colleagues followed a large sample of 181 CI subjects from elementary grades to high school. A unique aspect of their study is that all the subjects were implanted as pre-schoolers. This allowed the authors to see if early implantation made normal language development possible. Also, they were able to collect comprehensive speech, language, and reading data from 84 of these subjects. The remarkable finding was that 44% of these CI wearers achieved age-appropriate reading levels in high school, and most of the subjects broke the infamous "fourth-grade reading barrier" that many deaf persons encounter. Perhaps you remember the landmark article by **Bob Bilger** identifying the main function of the early single-channel CI as assisting in lip-reading? CIs have truly come a long way.

BEST QUICK READS

I selected the following papers not only because they were short (six pages or fewer), but also because each brought together an interesting point or two. In keeping with this theme, I'll keep my reviews short as well:

Wes Grantham and colleagues reported in *Laryngoscope* that some unilateral implant users can localize sound sources using a single CI, though not as well as their bilaterally implanted counterparts.

Gary Rance and **Elizabeth Barker** reported in *Otology & Neurotology* that implanted children with auditory neuropathy, while doing reasonably well with speech discrimination, perform less well than implanted children with sensorineural loss.

Kelvin Hawker and colleagues reported in *Ear and Hearing* that disproportionately poor performance by CI users may be attributed to the same mechanisms that underlie specific language impairment in normal-hearing children.

Andreas Buchner and colleagues reported in *Otology & Neurotology* that the same masking algorithm used in

an MP3 player can also improve CI performance. The algorithm transmits only the dominant sound frequency if two are close together.

Oliver Adunka and colleagues reported in *Laryngoscope* that pre-operative residual hearing cannot predict post-operative CI performance. In fact, those with too much residual hearing may actually experience an initial drop in performance.

Is there a "right" CI advantage? **Yaakov Henkin** and colleagues reported in *Otology & Neurotology* a small, yet significant advantage in speech perception for children who were implanted on the right side over those implanted on the left side.

NOT READY FOR PUBMED

Interestingly, my three favorite papers in this category all had something to do with hearing aids. **Dave Fabry's** Page Ten article in *The Hearing Journal* identified an important industrial trend: Cochlear implants and hearing aids are on a converging course. Both devices will likely go beyond traditional audiograms to adopt similar functional measures. Technologically, both will likely use very similar front-end processing technology from directional microphones to modern wireless devices.

Tina Childress wrote an informative piece on the latter topic in *Hearing Review*: Breaking the silence with Bluetooth technology, she not only endorsed the modern wireless connectivity, but also gave specific recommendations to avoid interference and maximize benefit.

Camille Dunn and **Hua Ou** compared performance of bilateral implants with that of a combination of an implant on one side and a hearing aid on the other in *Audiology Online*. They cautioned that bilateral implantation may not always be the best option, and should certainly not be the standard in managing bilateral sensorineural hearing loss.

MOST THOUGHT PROVOKING

This is the second time I've mentioned an article by **René Gifford**, who must have been busy last year. This one was written with **Michael Dorman**, **Anthony Spahr**, **Sid Bacon**, **Henryk Skarzynski**, and **Arthur Lorens**, and published in *Journal of the Acoustical Society of America*. They discuss the use of a sensitive psychophysical measure to show that the so-called "soft surgery" may prevent elevation of pre-operative audiometric thresholds, but is unlikely to preserve the non-linear processing in the apex of the cochlea. I found this paper thought-provoking because it may provide a psychophysical mechanism to explain the somewhat perplexing finding in combined electro-acoustic stimulation (EAS); that is, the functional gain achieved with EAS is not correlated with the patient's residual acoustic hearing as measured by pure-tone thresholds. In other words, their study forces us to think what "hearing preservation" truly means, and perhaps to re-define how we measure the degree of preserved hearing.

The other thought-provoking article I liked is by **Paul Van de Heyning**, et al., who used CIs to treat unilateral tinnitus in patients with single-sided deafness. Their published results in *Annals of Otology, Rhinology, and Laryngology* showed a twofold or greater reduction in tinnitus with the CI over the pre-operative baseline. The study is thought provoking because, normally, one would not think a unilaterally deafened person with almost contralateral normal hearing needs a cochlear implant. Furthermore, this unique patient population presents a golden opportunity to study electric pitch map and hybrid binaural hearing that cannot otherwise be done.

UPCOMING TECHNOLOGY

Because of the rapid development in CI technology, I asked Gus Mueller, the captain of our Journal Club, if I could add this as a new category. He said yes, but only this year when I'm new to the Club. I'd better keep it short and sweet.

Is a totally implantable cochlear implant around the corner? Yes, and for more information, read the article by **Robert Briggs** and colleagues from Down Under in *Otology & Neurotology*.

Does a penetrating auditory brainstem implant (PABI) do better than a traditional surface ABI? The answer is a disappointing no. Read the latest results from **Steven Otto** and colleagues in *Otology & Neurotology*.

Would the world's first auditory midbrain implant (AMI) penetrating the inferior colliculus fare better than the ABI? Not really (see **Hubert Lim** and colleagues in *Neuroscience*).

Finally, how about an optical CI that uses a laser to stimulate the nerve? This laser thing could be years away from your clinic, but you might want to tell your patients that better days are coming. Read **Claus-Peter Richter** and colleagues in *Hearing Research*.

ALL-AROUND FAVORITES

I'd first like to mention two special issues devoted to CIs that are worth checking out. One was edited by **Bryan Pfingst** in *Hearing Research* and the other by **Harry Levitt** in *JRRD*. The following selections for my *All-Around Favorites* cover three areas and include five articles.

Most of you know about tuning curves, which underlie perhaps the most fundamental concept of audition. However, tuning curves had not been systematically studied in cochlear implant users until **Dave Nelson**, **Gail Donaldson**, and **Heather Kreft's** reported detailed CI spatial tuning curves in *JASA*. They found broader yet comparable tuning curves in CI users to those obtained at high stimulus levels in normal-hearing and hearing-impaired listeners. Their finding casts serious doubt on a long-held opinion in the CI field, namely, that electric tuning is poor and may be the culprit limiting cochlear implant performance. In a paper in *Ear and Hearing*, **Michelle Hughes** and **Lisa Stille** went a step further by measuring both psychophysical and physiological forward masking patterns in the same CI users and reported findings that generally supported the assertion by Nelson et al. that these two measures were highly correlated, but neither was significantly correlated with speech perception.

Recently there has been keen interest in comparing bilateral CI performance with bimodal CI+HA performance. A lot is at stake: Should the criteria for the second implant be the same as for the first? Should we aggressively implant children with two implants even if they have residual hearing? There were 200-300 papers last year closely or remotely related to either bilateral CI or bimodal hearing. I would recommend two papers from **Tom Francart's** doctoral dissertation at Katholieke Universiteit Leuven, Belgium. In the first paper in *Audiology and Neurotology*, **Tom Francart**, **Jan Brokx**, and **Jan Wouters** reported similar sensitivity (1.7 dB) to interaural level differences between CI and HA to that between two CIs. In the second paper in *Journal of the Association for Research in Otolaryngology*, the same authors reported that four of the eight CI+HA users were able to detect 91-341 microsecond interaural time differences, within the range of performance by bilateral CI users. These results are important because, with training and learning, the bimodal users might achieve similar localization performance to the bilateral users at much lower cost and risk.

Finally, I saved the best for last. My selection for *Best All-Around* article in cochlear implants goes to a publication in *Otology & Neurotology* by **Charles Finley, Timothy Holden, Laura Holden, Bruce Whiting, Richard Chole, Gail Neely, Timothy Hullar**, and **Margaret Skinner**, which provided a multidisciplinary, authoritative, and objective explanation of the large individual variability in CI performance. Starting with high-resolution X-ray images of individual inner ears, the authors measured electrode locations and related them not only to surgical techniques but also to speech performance. I believe this paper will be a landmark in CI research.

IN CLOSING

I'd like to note the passing in 2008 of **Margo Skinner**, the last author of my choice for *Best All-Around*. Like many of you, my life has been touched by Margo. In a cherished letter from her in 1993, she encouraged me to continue my work on intensity coding in CI, but also gently pointed out a weakness in my technique. It was upon Margo's recommendation, in 1995, that I gave my first keynote speech at an international CI meeting.

> "...i would like to devote this inaugural piece on the *Best Cochlear Implant Articles* to Margo Skinner..."

Opening up my 2-inch-thick "Skinner folder" recently, I found many of Margo's reprints with her personal greetings and comments as well as a paper of mine with detailed comments and suggestions from her. To honor her professional contribution as well as to thank her for her personal mentorship, I would like to devote this inaugural piece on the *Best Cochlear Implant Articles* to Margo Skinner.

CITED ARTICLES

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