William F. House, MD, Audiology Pioneer

By Fan-Gang Zeng, PhD

William F. House, MD, created the first practical cochlear implant and the first auditory brainstem implant, and he developed innovative surgical approaches for removing acoustic tumors and treating Ménière's disease. Dr. Bill, as his colleagues and patients refer to him, is 88 and terminally ill.

He was interviewed by Fan-Gang Zeng, PhD, the director of the Center for Hearing Research at the University of California, Irvine, and *The Hearing Journal*'s editorial board chairman. Dr. Zeng started his career at the House Ear Institute in 1990, and has known Dr. Bill for more than 20 years. Dr. Bill, in this interview from Oct. 18 2012, talked with Dr. Zeng about cochlear implant development and reflected on his career.

Dr. Zeng: Dr. Bill, how are you doing this morning?

Dr. House: Well, I'm wheelchair-bound, but otherwise I feel pretty good. I don't have any pain, thank God. I have so much fatigue that I couldn't really get myself around in a wheelchair. But my brain seems to be pretty good.

Dr. Zeng: You look good, and you sound good, too, so I'm sure the brain works.

Dr. House: It does very well. So I'll leave the questioning for you then.

Dr. Zeng: As you probably know, you have been nominated for a Nobel Prize in the last few years. I guess the committee recognizes your contribution to cochlear implants, which are now used by over 250,000 deaf people in the world. My first question is, where did you get the idea in the first place?

Dr. House: Well, the story started shortly after I finished my residency in ENT at the USC Los Angeles County Hospital [in 1956]. Several parents brought their children who were obviously hearing impaired. The trouble is that there was so little that we could do. It gave me a bad feeling [because] all I could do would be to say, go and see if you can get a hearing aid and learn lip reading at the John Tracy Clinic [in Los Angeles]. Fortunately, about this time a patient brought me a newspaper clipping.

Dr. Zeng: The French connection here?

Dr. House: Yeah, it was about a patient in France who had a destroyed cochlea. Two French doctors [André Djourno and Charles Eyriès] put a coil of wire where the patient's destroyed cochlea should have been, at the nerve stub, and found that the patient could hear sound. I was very impressed with this [finding] because I thought in order for electric currents to be able to stimulate a sense of hearing, you would have to have a cochlea.

[I felt] this was a breakthrough that we should explore. So I dissected the facial recess, which is in the area near the mastoid into the middle ear on a patient that was totally deaf. This was an adult because I needed to have someone who could tell me what they were hearing when we put electric currents in. And I achieved that with Jack Urban, a very innovative person.

Dr. Zeng: The engineer.

Dr. House: Yes. He derived the electric stimulation system, and I devised a surgical system. [I inserted] a wire called the electrode into the cochlea through the round window, which opens into the scala tympani of the inner ear.

Dr. Zeng: Was it a balled electrode or just a wire?

Dr. House: Well, no. I started off with a system of five electrodes spaced over a distance of about 20 millimeters, inserted at various points around the cochlea. The idea was that they would each stimulate individual areas along the basilar membrane in the cochlea.

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Dr. Zeng: Was it bundled or just five individual wires at that time?

Dr. House: It was five individual electrodes with the ends being exposed. We found that he heard different tones according to which electrode was stimulated. This was all very promising. Because the wires were hardwired to a through-the-skin button, it began to fail in a period of time. The button got loose, and the insulation on the wires was not biocompatible. There were no biocompatible materials at that time. That was why we left the work for so long. We started in the late 50's and then started again ten years after.

[Before we explanted the patient,] we tried just connecting all of the electrodes together. It was an amazing finding that he could hear essentially just as well or better than when we tried to stimulate one electrode at a time.

And we further found that [you could] complete the circuit [by allowing] the current to flow from an interior electrode in the cochlea to the ground electrode, which was in the temporalis muscle.

Dr. Zeng: You save a lot of battery by doing it that way. Everybody's doing it that way now.

Dr. House: Right. So that's become a popular way to do it. With an external ground, the cochlea is saturated with any stimulus.

Jack and I first tried different types of electrical configurations in a battery-operated system with [the adult patient]. And we had to be very careful because putting an electrode sitting that close to the brain [can be dangerous].

[The] problem was getting a type of electrical stimulation that the brain could interpret as meaningful sound. Most of the kinds of stimulation Jack and I tried didn't work too well.[1] We finally came to the amplitude-modulated [AM] system that stimulated a single electrode. AM means that a signal is superimposed on a carrier wave.

Dr. Zeng: The 16 kilohertz carrier! You know, every implant uses amplitude modulation these days with just a different carrier.

Dr. House: So finally we were able to produce a wearable device. Up to that time we had a plug-in system, where we screwed the plug into the bone. We then developed a way of transmitting the current through the skull using an [outside] coil and an implanted coil that led to a single wire in the cochlea and a ground electrode that was in the temporalis muscle. Both coils had magnets in their center, and the outside coil was held in place over the inside coil by the magnet.

Dr. Zeng: Who came up with the idea of using coils to transmit power and information?[2] Was it Jack?

Dr. House: Yeah, Jack was the one who came up with transmitting transcutaneously rather than hardwired. And because our testing showed that our few patients reported no difference between the quality of the sound whether they got the signal through one or several electrodes, we developed a single electrode system. Then, Howard [House] and I were on the Barbara Walter's show, which was a news show [on CBS] at the time. Patients around the country saw that [show], and asked NIH [National Institutes of Health] what was being done about this so-called breakthrough.

So we had a meeting at Bethesda with an [NIH] committee that had been formed with audiologists primarily. [The meeting] was very hostile because [they thought] I was doing something to take advantage of these deaf who desperately wanted to hear. But at the time, I didn't charge anybody for what I was doing. I thought it was highly unethical to make money when we were all just trying to Figure out what worked. In addition, some researchers who were studying the inner ear felt that we were invading their turf; as otologists we shouldn't be doing that.

Anyway, Jack and I tested various stimulus systems, working with patients in the evenings for several years. We finally came up with an amplitude-modulated system with a carrier wave being modulated by frequencies of the sound.

Dr. Zeng: Then 3M took over your device, which had become the first FDA-approved cochlear implant in 1984. However, they just pulled out as quickly as they got in. Well, how do you feel about 3M now?

Dr. House: Well, 3M took over a lot of my work and [the 3M/House cochlear implant] became the first device to replace a human sense. They pulled out of it because the Australian device came on so strong. They sold everything to the Australian company, which was interested in transferring my patients from single electrode to multi-electrodes.

One thing that I regret very much is that they did not first test the patient with the single-electrode device, then with the new multi-electrode device to compare open-set speech discrimination. So there's no peer-reviewed, longitudinal (same-ear) comparison between these two systems that I know about.

Dr. Zeng: What were the differences between the single- and multi-electrode systems?

Dr. House: The main difference is that the single electrode device uses analog stimulation, providing all the frequencies in ambient sound. The multi-electrode devices are pulsatile devices, with the number of frequencies being restricted to the number of electrodes.

We were aware of other work that was going on, particularly in Australia, under Graeme Clark who devised a multi-electrode system. They found that when they tried to stimulate different electrodes all at once, there was just cacophony, because the pulses reinforced and cancelled each other. So they devised a system that sent a pulse to one electrode, then there would be a brief "radio silence" to allow the current to drain away and another stimulating it. It seemed to work pretty well, and the device has become the most popular cochlear implant today.

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But I've always felt that method was unnecessarily complex because, working with our patients, we found that when you stimulate just one electrode and put in amplitude-modulated current you can hear quite well. Basically, one system is very complex with multi-electrodes. The other is relatively simple, and so it's also much cheaper.

Dr. Zeng: When was the last time you saw Dr. Clark?

Dr. House: He came to Los Angeles once [after 3M took over but before they stepped out], and that was the only time he visited with me. We also met at a couple of meetings but never kept in touch.

Dr. Zeng: There was other exciting work going on at that time. Can you describe what it was like at that time? Was it fun?

Dr. House: It was. Blair Simmons at [Stanford], [Robin] Michelson at UCSF, and I formed a cochlear implant study group. Each of us contributed certain things, and we'd have meetings, at least once a year, usually at Stanford.

Simmons felt that the best system was to actually put the electrode in the internal auditory canal adjacent to the eighth nerve, or the hearing part of the eighth nerve. That wasn't highly successful because they had serious spinal fluid leak, and extra-cochlear devices have never shown that they can achieve good percept.

Dr. Zeng: What about [Ingeborg and Erwin] Hochmair in Austria?

Dr. House: I'm not very familiar with their work. But they have been doing cochlear implants, and I guess they're distributing their device, called Med-El.

Dr. Zeng: What was your relationship to the Doyle brothers?

Dr. House: This was very, very early, before I started working with Jack Urban. James Doyle was an electrical engineer and [John was a neurosurgeon]. They felt that the problem wasn't in the surgery but in engineering. I never patented the implant so that the world could benefit from it freely. Without my knowing it, they started a company using the work I had started, then they began to publicize so that people could invest in their company. I considered [that] ethically questionable because they just didn't have any results at that time. So I stopped working with them. They were not involved in the system.

Dr. Zeng: What happened to Jack Urban?

Dr. House: He had pancreatic cancer, and passed away in 1985. I miss Jack a lot because he was a dear friend and highly skilled engineer. Working together, we devised a lot of accessories for operating the Zeiss microscope, such as adaptation of 16-mm film and TV cameras. He was very instrumental in the development of the microscope to a point where it was a practical system for microsurgical procedures and teaching.[3] The microscope is now widely used by doctors around the world.

Dr. Zeng: Looking back, the contributions you made to the field were amazing. Electric stimulation, transcutaneous transmission, amplitude modulation, and outside ground electrode are still the key components in modern cochlear implantation. Not to mention your new surgical approach to removing acoustic tumors and treating Ménière's disease. Did you play any role in the development of the auditory brainstem implant?

Dr. House: Oh, yeah. I did the first auditory brainstem implant with Bill Hitselberger, a neurosurgeon I worked with. And so we had a patient with multiple benign tumors on several cranial nerves. The patient had neurofibromatosis. This was a very tragic disease. We felt that if we could just cut the tumor part, then we could save her hearing that way. But what we found when we got the tumor, we didn't save the hearing because unfortunately the tumor invades the eighth nerve. So when we cut it out, we cut the nerve.

We thought we might be able to stimulate the cochlear nucleus on the corner of the brainstem. I didn't do a lot of them. Now the brainstem implant has become widely used and is quite successful.

Dr. Zeng: Dr. Bill, you make it sound so easy. I wonder what had influenced you and kept you going?

Dr. House: I just felt that deafness was such a terrible thing. I had to tell parents, 'Your child is deaf. Your child will likely learn a sign language and have to be sent to a special school.' I felt that anything we can do to alleviate this tragic situation is very worthwhile.

When all the criticism was falling on me for trying to make money out of that tragic situation, the thing that kept me going was that patients could hear, and they told me how much they appreciated it. We implanted a number of children who were 2 or 3 years of age, and one of them even became a linguist.

Dr. Zeng: On behalf of those patients and so many of us who have benefited from your work, I say thank you, thank you very much. My last question, what do you think about the future?

Dr. House: Well, I think the future is bright. My great dream is that someone else will now take up the work I started, because there are many millions of patients worldwide who are deaf, but they will never be able to afford an expensive cochlear implant.

Dr. Zeng is the director of the Center for Hearing Research, the research director of otolaryngology-head and neck surgery, and professor of anatomy and neurobiology, biomedical engineering, cognitive sciences and otolaryngology at the University of California Irvine. He is also the chairman of the Editorial Advisory Board of *The Hearing Journal*.

[1] The work was paused for almost a decade, during which time biocompatible materials were developed. Another reason for the slow development was that trying various signals involved building equipment because small computers able to produce signals ad hoc under software control had not been invented.

[2] With the analog design, there was only signal, no "power and information" because the internal device is nothing but a coil.

[3] For example, Jack Urban was apparently the first to devise a viewing tube that provided the student with an image in the same orientation as the surgeon. Previously, because the image was passed through mirrors and prisms, the image seen by the student was upside-down and backwards.

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