Active Suppression of Pulsatile Tinnitus: Step 1 – Ear Canal Measurement

By Robert Levine, M.D.
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Pulsatile tinnitus is very distinct; patients hear it with every heartbeat. One cause of pulsatile tinnitus is abnormal blood flow in arteries or veins so close to the inner ear that the patient hears it.

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Sometimes, we can pinpoint the exact cause with imaging studies such as MRI scans, CT scans or angiograms. Often, surgery can safely correct the problem, and the pulsatile tinnitus ultimately disappears.

For others, despite exhaustive testing, we find no abnormality that accounts for their pulsatile tinnitus. For these people, there are two possibilities: 1) blood vessels near the inner ear may be generating sound that is beyond our present diagnostic capabilities or 2) like most types of tinnitus, no acoustic sound is generated; the pulsatile tinnitus is due solely to some type of neural activity that varies with the person's heartbeat. This might be happening because a blood vessel is pressing on a nerve related to hearing, such as the auditory nerve that connects the inner ear with the brain. Or a blood vessel may be pressing on other structures such as muscles, tendons or joints. Nerves extending from these structures to the brain may affect hearing-related brain activity.

An examining doctor trying to track down the cause of pulsatile tinnitus can listen in and around the ear either with a stethoscope or something similar to determine if they can hear a sound responsible for the tinnitus. An examination enhancement is the Ausculscope, an electronic stethoscope, which amplifies and filters sounds picked up by a microphone placed in the patient's ear canal.

Our research

We planned to optimize recordings from the ear canal by recording two things at the same time: 1) all sounds present in the ear canal, using a very sensitive state-of-the-art microphone placed inside an earplug in the ear canal and 2) the patient's electrocardiogram (EKG), which indicated each time the heart beat. If nothing was obvious from the microphone recordings, we planned to use digital *signal processing* techniques to extract any extremely weak pulsatile sounds that appear with the heart beat as indicated by the EKG.

Interpreting recordings

With these optimized recordings, we would be able to tell if there was any sound present that was causing the pulsatile tinnitus. If no sound was present, it was likely that future research would show that there would be no need to do extensive, expensive and sometimes dangerous imaging studies, e.g., cerebral angiography. Rather, further evaluation of these patients' pulsatile tinnitus would go in other directions, as we discuss later.

On the other hand, if we detected sound, the next research step was to try canceling the pulsatile sound. Unlike masking that covers one sound with another, the cancellation technique actually silences the pulsatile sound. We planned to use the same technology found in commercially available noise-canceling headphones, e.g., Bose QuietComfort® headphones.

Our results

Over the year of project funding, we assembled our equipment, namely, the low-noise, wide-band ER-10C microphone; EKG recording equipment; and a computer with LabView™ software. Our consultant, a mechanical engineer with expertise in signal processing and noise suppression, set about developing software for recording both EKG and microphone recordings.

By June 30, 2005, we had used the system on a patient with pulsatile tinnitus and were able to suppress her tinnitus by compressing her jugular vein on the side with pulsatile tinnitus. The test was successful.

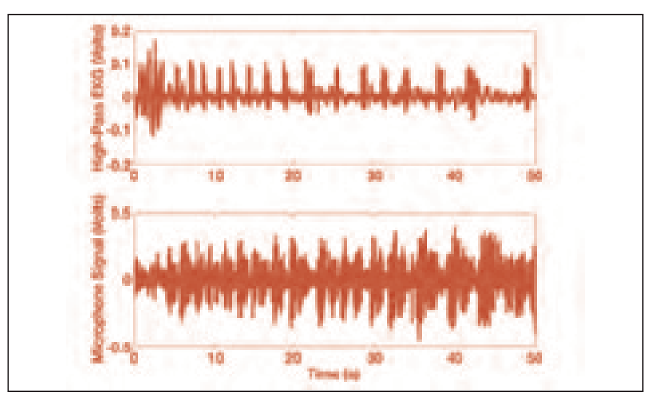

Figure 1. We could record both EKG (top trace) and sounds picked up by the microphone in the ear canal (bottom trace).

Successful recording innovation

The first recordings in Fig. 1 confirmed the validity of our approach and showed that our initial recording system – able to obtain only 50 seconds of data – was inadequate to fully perform the analysis. By November 2005, we had established a new system with the required capabilities. On Jan. 19, 2006, we did our first recording of data with the new system. We simulated pulsatile tinnitus by recording the cardiac sounds ("lub-dub") that occur with each heartbeat. We accomplished this by recording the EKG along with the output of a microphone placed over the aortic valve region of the chest wall.

Again we had successful recordings and this time with much longer segments of data.

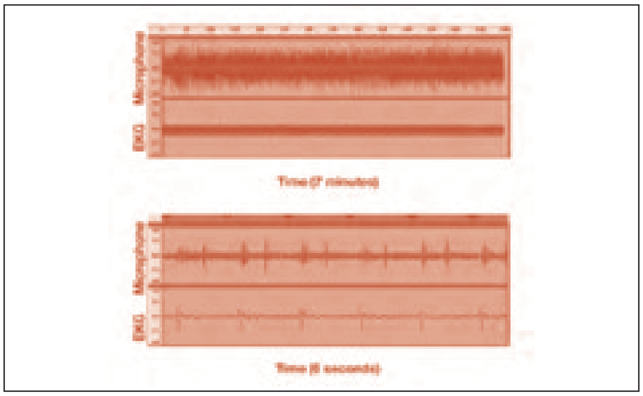

Figure 2. (Top) Microphone recording and EKG for a full seven-minute continuous interval. (Bottom) Expanded six-second interval from the full seven minutes.

In Fig. 2, in the bottom chart, notice that the recorded ear sounds have two components for each heartbeat and that the second component comes later than the EKG event.

Conclusion

We concluded that we can simultaneously record EKG and an ear canal recording microphone system. The technique of using an EKG to extract ear sounds related to pulsatile tinnitus from the other sounds in the ear still requires further refinement and remains under development. Once we can confidently isolate the tinnitus sound, we intend to use noise-cancellation technology to silence it.

Exploring treatment alternatives

Along with investigating this technique for suppressing pulsatile tinnitus we can record with a microphone, we have been pursuing alternative treatment methods for sounds we *cannot* pick up by a microphone.

We have recently identified a group of patients with pulsatile tinnitus whose diagnoses suggest that their tinnitus sound is not due to blood vessels near the inner ear. Rather, as we mentioned in paragraph two of this article, their tinnitus is likely due to blood movement in other parts of the body (the *somatosensory system*) whose nerves then generate signals that trigger tinnitus in the brain.

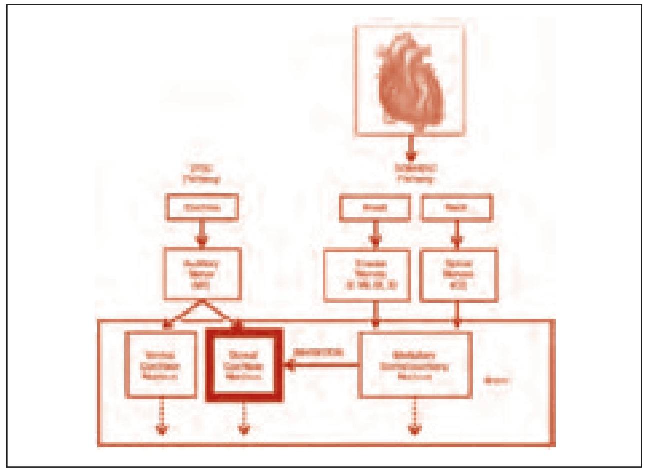

Figure 3. One mechanism by which the somatosensory system can modulate the auditory pathway (dorsal cochlear nucleus).

As shown in Fig. 3, if blood flow modulates the somatosensory system, e.g., through its effect upon muscles and tendons, pulsatile tinnitus could result.

Our five somatosensory tinnitus patients share specific features, i.e., their pulsatile tinnitus is: 1) high-pitched, 2) not localized in one ear, but either in both ears or in the head and 3) the pulsatile component to their tinnitus could be suppressed by strong muscle contractions or pressure.

In addition, we have not found a tinnitus cause through extensive imaging investigation. The tinnitus cannot be heard by auscultation (listening to the heart or other organs, usually with a stethoscope), nor suppressed by compression of the neck arteries or veins. We expect ear canal recordings of these patients to show no acoustic signal correlated to their EKGs.

The presumptive basis for this group's tinnitus is pulsatile tinnitus. We are seeking other treatment methods such as acupuncture and electrical stimulation of the head and neck, which presumably modify the somatosensory system. Clonazepam, a muscle relaxer, has relieved the tinnitus of one of these patients. A better understanding of pulsatile tinnitus will be the focus of future research.

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