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Cutting The Noise Out Of Heartbeats

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Hypertension is a major health problem of the western world. In one year alone, it has killed in excess of 40,000 people in the USA, contributed to the deaths of more than 200,000 and added to the problems of a further 58 million who suffer from the condition. That amounts to one in every four people, but if only those over the age of 65 are considered, the figure rises to two in every three.

In fact, hypertension can be considered an epidemic, and it is not confined to the USA. Other western countries show similar problems, with diet and sedentary lifestyles among the causes. Treatment varies, but increasingly health workers are emphasising the benefits of prevention, where appropriate diet, exercise and early detection of hypertensive problems can help prevent major difficulties from developing later.

One of the most powerful tools has been the ECG, or electrocardiograph. Electrodes placed on the skin record the heart’s electrical activity, displaying the result electronically on a screen or as a printout. Diagnosticians examining the trace can detect a range of problems, such as poor electrical conductivity in the heart and weakness in its muscular contractions.

Another diagnostic tool is the sound of the heartbeat. Recorded as a phonocardiogram (PCG), heart sounds can reveal circulation problems, heart murmurs, faulty valves and coronary artery disease. So important is the heartbeat to clinicians that the stethoscope is the most recognised equipment in the doctor’s armoury.

But sound recordings have their difficulties, too. They are hard to hear in noisy surroundings and, in any case, the heart generates ‘noise’ of its own, compounded by noisy signals from imperfect measuring instruments and conditions.

There are sounds generated by breathing, by the contact of stethoscope on skin, and even by a foetus if a woman is pregnant. To the ear, this noise can be a hissing or scratchy sound, masking the real sounds of normal or abnormal heart function.

When a phonocardiogram is displayed as a trace on a screen, the noise shows as random spikes, interfering with the true record of the heart’s activity. For that reason, PCGs have never realised their true potential as a diagnostic tool.

It is a challenge that is being taken up by Sheila Messer, who is working on the Heard Heart Sound Biomonitor Project in the Adelaide University’s Centre for Biomedical Engineering.

Ms Messer is an electrical engineering graduate from the Sonoma Valley, a wine producing region just north of San Francisco, California. She spent a semester in Adelaide on an exchange program in 1996. When she received the Rotary Ambassadorial Scholarship giving her the opportunity to do graduate study abroad, she chose to return to Adelaide University.

"I am interested in biomedical engineering because it allows me to apply my engineering skills to a real world problem while the resulting application will help people," says Ms Messner. "I am looking at ways to ‘de-noise’ the PCG. If we are successful, we can see whether there is any difference in the PCG before and after the treatment of hypertension," she says.

Ms Messer’s research involves the sophisticated use of wave forms. Perhaps the simplest wave forms is a sine wave; a repeating regular series of hills and valleys. The waveform generated by a heartbeat is, by comparison, a complex one, but the two can be related. In fact one of the most powerful tricks in a engineer's mathematical toolbag is Fourier's theorem which maintains that any signal, no matter what it looks like, can be copied exactly by adding together many sine waves of different frequencies.

It then follows that a complex signal can be broken down into its sine wave components by Fourier analysis. If the signal has unwanted frequencies, these can then be filtered out. However, for heartbeat signals there is no way to tell what is noise and what is pure heartbeat. Simple filtering doesn't work.

Also, complex signals including heartbeat waveforms require millions of sine waves to describe them faithfully. A heartbeat is a sharp and short-lived pulse, whereas a sine wave is a smoothly varying signal that repeats for ever.

It was long thought that the sine wave was the fundamental building block of all signals, but engineers now use another kind of waveform termed a 'wavelet.' Wavelets are generally not periodic. Whereas sine waves repeat endlessly, wavelets do so only for a short time, quickly declining to zero. They come in a variety of shapes and, since under certain conditions any signal can be made up from lots of wavelets, signals can be represented as a sum of wavelets instead of sine waves.

"A wavelet's shape is not far different from a heartbeat signal,' says Dr Abbott, the Director of the Centre for Biomedical Engineering. " It turns out that you can decompose a heartbeat signal using only a few wavelets, whereas it takes millions of sine waves to do that."

"The advantage is that the true signal breaks down into a few big wavelet components, whereas noise breaks down into millions of tiny wavelets, and can easily be filtered out," he says.

Ms Messer is developing a technique to remove the noise from phonocardiograms. "Using wavelets, the signal is decomposed, and any coefficients below a certain threshold are discarded as noise," says Ms Messer. "The remaining coefficients are then recombined to reconstruct the intact signal."

The results, displayed on a computer screen or as a printout show a startling transformation, with both normal and pathological conditions clearly revealed, free from the masking noise.

The research is likely to have wide-ranging applications in health care, as Ms Messer aims to produce a system where heartbeat sounds recordings can be easily, cheaply, reliably, and repeatably recorded in order to promote their use as a diagnostic tool for use by physicians.

Photos at: http//www.adelaide.edu.au/PR/media_photos/

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