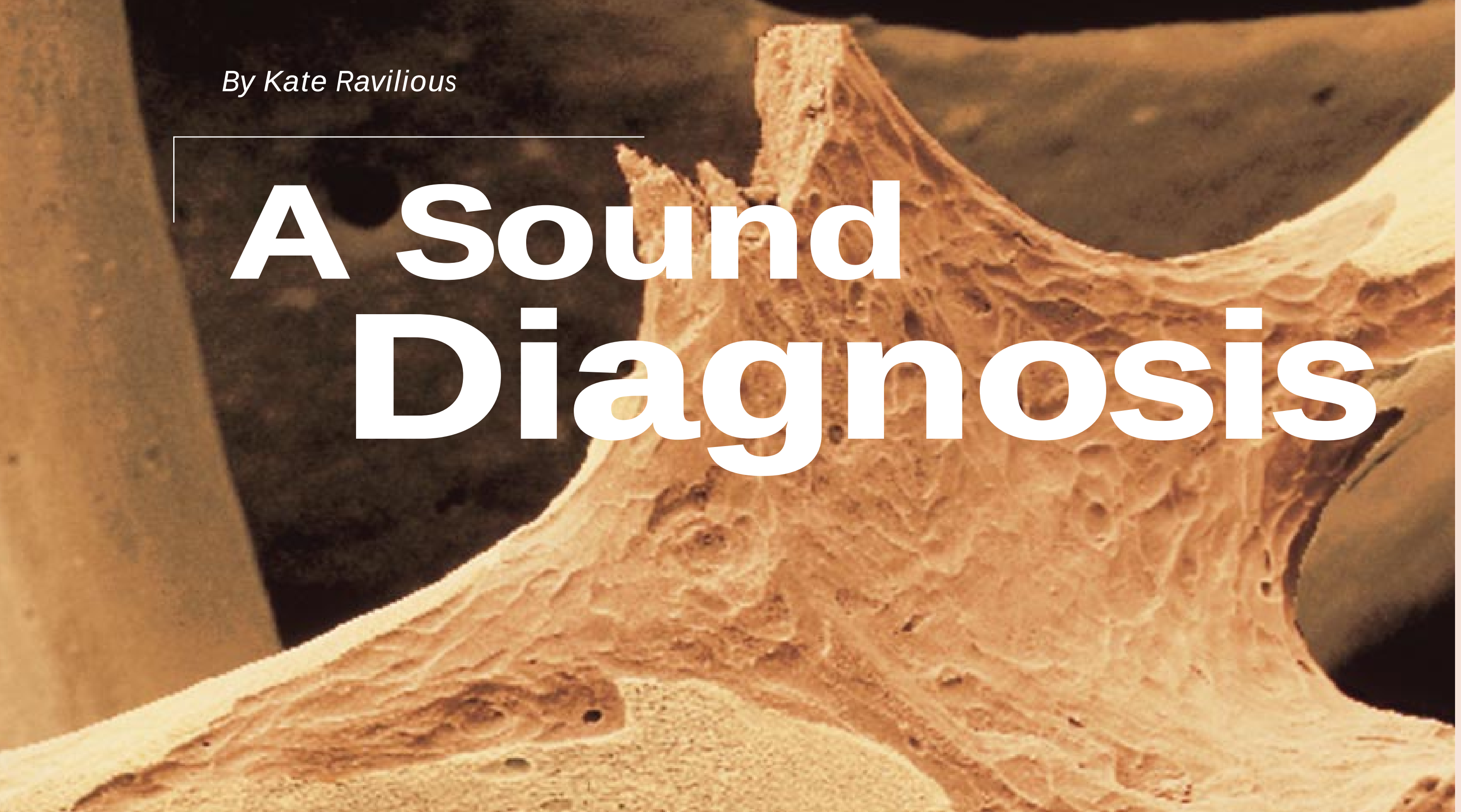


By Kate Ravilious

A Sound Diagnosis

The word ‘ultrasound’ conjures up images of unborn babies being scanned in the womb. However, these high frequency sound waves could have many other uses: One of these could be in estimating the health of bones and diagnosing those risking a painful fracture.

False-colour scanning electron micrograph of the trabeculae in the cancellous (spongy) bone tissue affected by osteoporosis.

Photo: Science Photo Library

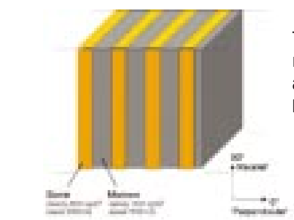
Every year osteoporosis contributes to 60,000 hip fractures in the UK alone. This costs the NHS an unbelievable £5 Million per day – a lot of pain and money could be saved if osteoporosis was diagnosed earlier. If the condition is caught in time treatments such as Hormone Replacement Therapy (HRT) can significantly reduce the chance of fractures occurring. The problem is that spotting who will fracture in the future is not easy. This is why Professor Tim Leighton has been coordinating a team of experts from the University of Southampton and Southampton University Hospital's NHS Trust. Helped by EPSRC funding, this team have been experimenting with using ultrasound to detect the onset of osteoporosis.

Healthy bone is composed from a complex lattice of fine calcified strands of bone, known as trabeculae, surrounded by fluid bone marrow. “Strength of bone depends upon two main factors,” explains Professor Leighton. “Density of the calcified tissue in the bone is very important and accounts for around 60-70% of bone strength, while internal bone structure accounts for a further 10-20%.” When bone growth and replacement is not fast enough the density of bone decreases and the trabeculae become thinner with wider spaces in between. The skeleton becomes much weaker with bones vulnerable to fracture and the condition is termed osteoporosis. In Britain nearly a quarter of women over 50 years of age are affected by this bone wasting disease.

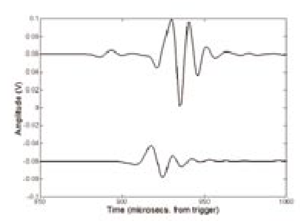
“We believe that the accuracy of fracture prediction may be improved…” Dr Graham Petley

Assessing risk

Currently, osteoporosis is diagnosed by measuring bone mineral density using X-rays. A low dose X-ray beam is passed through bone and a machine counts the emissions on the other side. The denser the bone, the lower the count rate and so an estimate of bone mineral density can be obtained. The problem with this technique is that it is not 100% accurate at identifying those whose bones have a high risk of fracturing. “We believe that the accuracy of fracture prediction may be improved if the microstructure were measured as well as the density,” explains Professor Leighton. This led Professor Leighton and his colleagues to thinking about non-invasive ways of looking at bone structure and they decided to investigate the effect of ultrasound on bone. Dr Graham Petley, another researcher on the team, explained how ultrasound had been used before. “We were not the first people to try using ultrasound,” he reveals, “a method known as the Broadband Ultrasonic Attenuation (BUA) technique was developed during the 1980s.” BUA involves transmitting a range of ultrasonic frequencies through the bone and measuring how much the emerging intensity is reduced by. Osteoporotic and normal bone affects the ultrasound in different ways and this is taken as an indicator of the onset of osteoporosis. “The problem is how to relate these measurements to the microstructure of bone,” says Dr Petley “but the results do suggest that the ultrasound is responding to the change in structure of the bone and this confirms the idea that ultrasound can be used as a measure of internal bone structure.”



The simple stratified bone model, made of alternating layers of bone and marrow, used by Professor Leighton and colleagues.



Time series of a pulse through bovine bone. Ultrasound sent parallel to the layers (top) results in two waves but sent perpendicular (bottom) elicits only one.

“We are excited by the possibilities of using ultrasound to diagnose osteoporosis” Professor Tim Leighton

The researchers decided to go right back to basics and test the effect of passing ultrasound through a model of bone. “To simplify things we modelled the trabecular structure as a series of parallel layers of bone and then marrow,” says Professor Leighton. “This enabled us to observe what happens to the ultrasound transmission when it is passed through the bone at different angles.” To their delight they immediately spotted a difference in the ultrasound that travelled parallel to the layers compared with the perpendicular direction. “The velocity and amplitude of the sound wave emerging parallel to the layers is completely different to that travelling in a perpendicular direction,” explains Dr Petley. When the ultrasound travels parallel to the bone a low amplitude sound wave arrives very quickly (the fast wave) followed by a larger amplitude wave some time later (the slow wave). In contrast only one wave arrives from ultrasound travelling perpendicular to the bone layers. “Our theory is based upon previously established theories that predict that the fast wave is created by the sound travelling through the marrow and the bone moving in phase, while the slow wave is due to the sound moving out of phase through the marrow and the bone,” explains Dr Petley. “When the sound travels perpendicular to the bone and marrow layers all the sound waves are travelling through the same material at the same time and so they remain in phase.”

The experimental apparatus being used to test how ultrasound travels through bone.

Sound model

Although human bone has a more complex structure than the parallel layers model, these results are an important start. “This shows that the transmission of ultrasound through bone can give some information on the structure of the bone and marrow that it travels through,” says Professor Leighton. “Eventually we would hope that we can extend our theoretical model to predict the microstructure of real bone by passing ultrasound through a bone from many different angles.”

Their next step is to carry out some tests on volunteers. Already trials on animal bone have given very promising results so now they are keen to apply it to human bone. “We are excited by the possibilities of using ultrasound to diagnose osteoporosis,” says Professor Leighton. “Ultrasound has the potential to be a very sensitive indicator of bone health. Combined with the results from X-ray emissions, osteoporosis could be reliably diagnosed at an early stage, giving people a warning and a chance to prevent it leading to fracture.” ■

Contacts

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Bone Stories

Inside our bones lie distinctive patterns that tell the story of the bone's life and how it was used. The fine calcified strands, trabeculae, generate an electric potential when under stress. This causes the trabeculae to grow along the direction of stress. For example, in our heel bones the trabeculae are reinforced where the bone meets the floor due to the constant pounding we give our feet while walking. These patterns are so characteristic that they have even been cited as evidence for apes walking upright: The stress patterns in the 7 Million year old hominoid pelvis fossils showed all the signs of a strenuous upright human gait.