COMPUTER-AIDED BIOMEDICAL IMAGING AND GRAPHICS PHYSIOLOGICAL MEASUREMENT AND CONTROL

PROCEEDINGS

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METHODS OF SOURCE LOCATION OF CLICKS FROM A TORN CARTILAGE

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INTRODUCTION

Diagnosis of knee joint pathology is notoriously difficult (1). We describe a new method to assist the diagnosis by objectively recording the vibration emission from joints (the "clicks"). The method uses lightweight accelerometers taped on over bony prominences. This makes the technique non- invasive and therefore suitable for repeated testing and widespread screening by relatively inexperienced technicians.

The previous attempts to improve diagnostic accuracy by using microphones have been limited by the poor response at low frequency of these transducers (2,3). Also, the vibration looses energy at the joint/air and air/microphone interfaces. Recent German workers have used a 34 gramme accelerometer and found some improvement (4). The present work involves the use of 0.5 gramme EGAX accelerometers from Entran Devices, New Jersey 07006, USA. This followed work, by Ziegart and Lewis (5), who showed no significant difference, in the output, between skin- and bone- mounted accelerometers, when lightweight transducers were used.

We have previously described how a single channel of vibration emission may be analysed using a twin microprocessor system (6); an Apple II linked to a Bruel and Kjaer spectrum analyser, type 2031. Various single channel signal processing techniques have been suggested (7). The interested reader might also refer to an application of these techniques to congenital dislocation of the hip- so difficult to diagnose at birth (8).

Figure 1 shows the anatomical positioning of the transducers in the case of knee injury: one is attached at each side of the joint- over the medial and lateral femoral condyles- and one over the patella. In these injuries we find impulse vibrations, of about 50- 220 Hz and between 1.0 and 17.0 ms^{-2} in acceleration range, as the patient actively flexes and extends the joint. The impulse is recorded on all three channels on each and every flexion of the joint, when the cartilage is torn as shown. We have found that single channel analysis methods are not sufficient to accurately confirm a diagnosis of a torn cartilage, and two methods of source location are indicated.

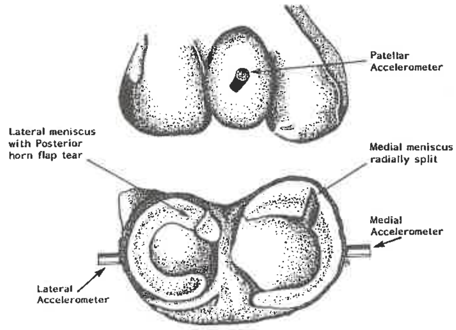

FIGURE 1

The damaged knee joint showing the position of the transducers

METHODS OF LOCALISATION

Tobias (9) was involved in the rapid location of defects in a nuclear reactor, while working with the CEGB in Berkley, Gloucestershire. He used the difference in time of detection of an emission from the defect at different sensors to compute the position of the defect. An examination of the three traces on a fast digital oscilloscope showed that the signal appears at the three transducers almost simultaneously. The short (up to 5cm) distances involved in transmission from source to detector and high speed of vibration transmission in bone (about 500ms-1) give an expected maximum delay across the joint of 100usec. Now this length of delay could be measured, but, given the relatively low frequency (about 100Hz) of joint vibration, the resolution is very poor and so the traditional source location estimates made by time delay measurements have been neglected.

The alternative is to estimate source point by using the relative sizes of the waveform recorded at each pick-up. Figure 2 shows the click recorded from a patient with a suspected torn cartilage. The acceleration range of the medial signal is 3.3 ms^{-2}; the patellar is 1.8 ms^{-2}; the lateral 3.1 ms^{-2}. We assume that the vibration wave dissipates through the joint following an inverse square law - as vibration dissipates on passing through any medium.

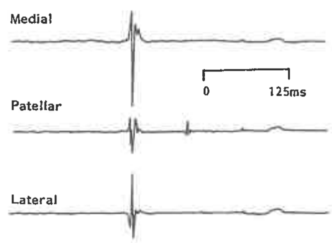

FIGURE 2

We can simplify the geometry of the problem to a plane coinciding with the tibial plateau. Then, using the inverse square law and Pythagora's theorem for the triangles produced in the plane, it is possible to define circles of possible sources for each pair of transducers. This is clinically feasible since clicks can be assumed to originate on this plateau, where the cartilages are.

The result of this consideration for the example presented in figure 2 is shown in figure 3. There are three unique pairs of transducers and so three circles can be drawn. The centre of one of them is so remote that the segment shown is a straight line. Where they cross gives the possible source of vibration: at the back of the knee (:posteriorly) on the medial side of the mid-line. This was confirmed at surgery when the injury was dealt with. The technique of recording joint vibration is carried out frequently in the department but the source location procedure described herein has not been in use for long enough to ascertain its accuracy. However, our initial impressions are that it will provide the orthopaedic surgeon with a useful additional aid, when he is attempting to diagnose difficult pathology.

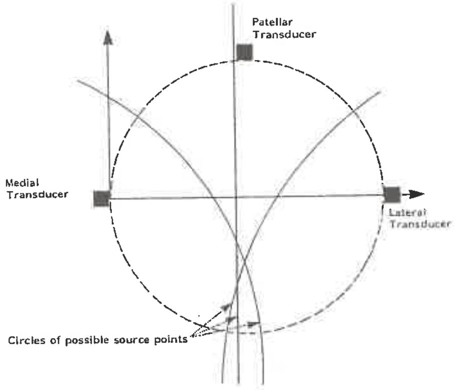

FIGURE 3

A plot of the three source curves gives the solution: posterior tear, medial meniscus

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