FOETAL PHONOCARDIOGRAPHY USING THE STORAGE OSCILLOSCOPE*

A PRELIMINARY REPORT

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Foetal heart sounds appear to have been known at least as early as 1650. About that time a physician, Philipe le Goust,[11] of Niort, France, wrote a poem making fun of his colleague Marsac for claiming to hear the heart of the foetus 'beating like the clapper of a mill'.

According to Hirschfelder,[7] the first method for recording heart sounds was introduced by Donders in 1856, and was revised by Martius in 1888. It consisted of beating the time of the sounds on the receiving tambour and recording the movements of the lever.

The first published record of foetal heart sounds was that of Hofbauer and Weiss[5] of Gena in 1908. The one foetal heart record which was made by Hofbauer and Weiss, though very poor in contrast with present standards, was sufficiently distinct to permit of analysis of the time relations in the cardiac cycle. Apparently they published only one such record.

The development of the electrical stethoscope and the amplification of foetal heart sounds was a logical parallel to the developments in the fields of hearing aids, telephony, electronics and the invention of the wireless valve. Soon after the wireless valve was used to amplify the adult heart sounds, apparatus was designed to magnify the sound of the foetal heart.[1-5,9,10,16,17]

In 1926 Sampson, McCulla and Kerr[14] attempted to determine the duration and pitch of the sounds and the duration of systole and diastole. They also tried to establish the criteria for the prenatal recognition of congenital heart lesions. Since then many other workers have described various apparatus and methods which have been used for foetal phonocardiography.

*Based on a paper read by one of us (J.A.) to the Department of Obstetrics and Gynaecology of the University of the Witwatersrand, June 1965.

As recently as 1953 Gunn and Wood[6] presented a report of their work to the Royal Society of Medicine. They were prompted to publish their work as they believed that until then no British recording apparatus had been described. They used a high-gain amplifier, an oscilloscope screen and a pen writer. This work is quoted extensively and is well summarized in their paragraph: 'Our photographs show that the foetal heart sound is a single beat and has 3 main components; it extends over a period of approximately 7/50 of a second. There may be a longer interval at times between one of the components and the next, and thus the sound may appear double to the human ear. We have not been able to confirm the 2 nearly equal sounds as demonstrated by Paley and Krell,[12] nor the systole and diastole which Sampson and McCulla measured.'

To date other workers have also produced studies on foetal phonocardiography, but in only a few of these were the graphs of a standard whereby the actual complexes could be studied. In 1964 Richeson *et al.*[13] designed a transducer which was introduced into the amniotic sac through the anterior abdominal wall using a size 15 gauge hypodermic needle. They claimed that the 'sonic activity' of the foetal heart can be measured with a high projection of maternal and other sounds. The foetal heart rate was measured by using a heart rate circuit being driven by the sonic transducer. In addition to developing this procedure for sonic measurement, it was also determined that the intra-uterine fluid sonic level, due to the foetal heart, was between 1·01 and 4·04 mm.Hg.

In February 1965, Scott Russell and Shelley[15] described the use of the phonocardiograph as a rate meter. This is most probably the most recent paper written on foetal phonocardiography and yet despite our advanced electronic age it is interesting to quote: 'Equipment for foetal phonocardiography is available commercially but none of the many models that were tried was found to be satisfactory'.

To date most of the work done on foetal phonocardiography has been with the use of high-gain amplifiers but using filtering circuits. This immediately interferes with the true record obtained, although it is also true that when unfiltered circuits are used much interference is obtained in the resulting graph. One is thus offered the choice of either restricting the scientific content of the record to the level of the interpreter or the latter's standards, interpretation and understanding to the level of the apparatus and recording. From the scientific viewpoint this latter approach is obviously the desired one. It was with this in mind, and after rejecting many combinations of apparatus, that it was decided to use the storage oscilloscope as a means for recording the foetal heart sounds.

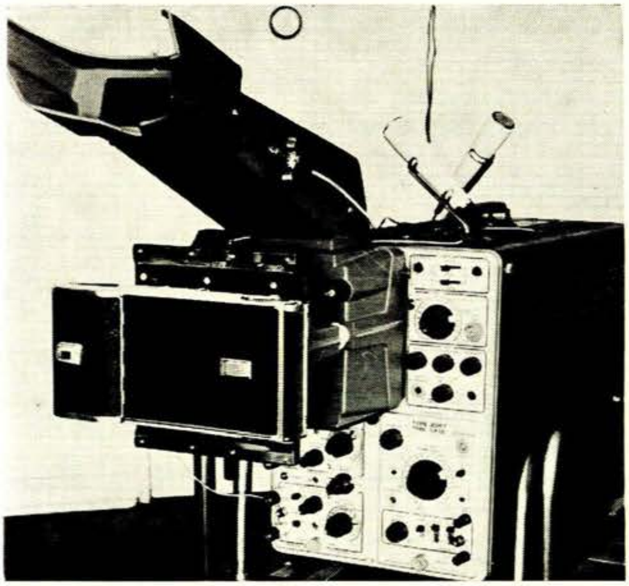

Fig. 1. Photograph of the apparatus showing the amplifier, camera attachment and 2 transducers.*

DESCRIPTION OF THE APPARATUS

The main components of the apparatus (Fig. 1) consisted of:

1. *A piezoelectric transducer*—the other 3 types of transducers, namely the strain-gauge, inductive and capacitance types, were excluded as being unsuitable. Fortunately any disadvantages arising out of the use of the piezoelectric type are minor. This transducer is the only one which may be classified as an 'active' electrical device; i.e., it is capable on its own accord of generating an electrical voltage without resorting to any intervening electrical circuit. This is of great benefit in reducing the complexity of the over-all apparatus, and also in eliminating the electrical interference mentioned with regard to the previous types of transducers. A piezoelectric transducer is however sensitive to temperature and moisture effects, and due regard must be paid to these considerations in its use.

2. *An amplifier.* It is an accepted electronic principle that the input impedence of the amplifier to which a piezoelectric transducer is connected determines the faithfulness with which the low-frequency components of the vibration are recorded. The input impedence of the amplifier used was 1 megohm, which enabled frequencies of 10 cycles per second to be recorded. A dual trace differential amplifier was used. This amplifier contains 2 independent high-gain amplifier channels. Either channel may be used to produce a display, or the 2 channels may be electronically switched to produce dual trace displays. The sensitivity ranged from 0·1 m.volt to 10 volts per major graticule division. The high-frequency response was a minimum of 500 kc.p.s. The lowest frequency response was 1·5 c.p.s. when the machine was set at 0·1 m.volt.

3. *The recording apparatus* consisted of a storage oscilloscope that also operates as a conventional oscilloscope. It can be used with differential, multitrace, wide band, sampling and delayed-sweep applications. Initial writing rate is 10 micro-seconds per centimetre minimum. The erase time is approximately 0·25 seconds. The plastic screen has 8 vertical and 10 horizontal divisions. Each major division is divided into 5 minor divisions on the centre

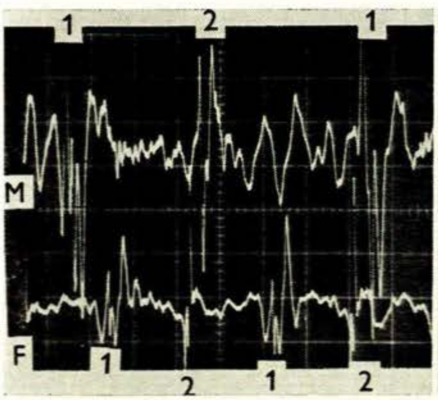

Fig. 2

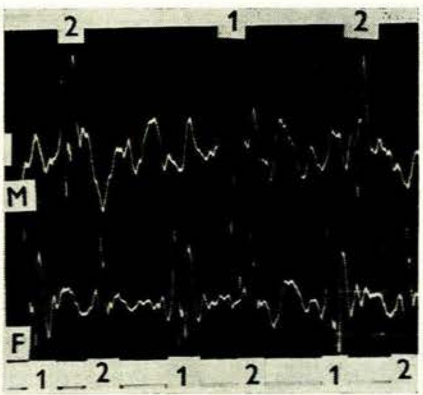

Fig. 3

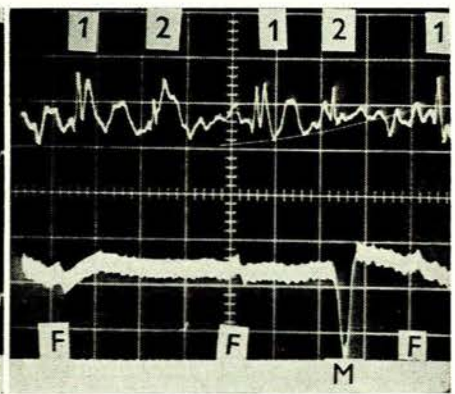

Fig. 4

Figs. 2 and 3. Simultaneous maternal and foetal phonocardiograms done in early labour. These recordings were taken at a speed of 0·1 cm./sec. and a sensitivity of 5 m.volts per upright division. First and second heart sounds are clearly distinguishable. In certain areas the tracing is deficient in either the up or the down stroke and this is due to the speed with which the beam is moving.
Fig. 4. The upper tracing is the foetal phonocardiogram and the lower is the foetal electrocardiogram. The electrical systole precedes the mechanical systole by a small fraction.

*Amplifier and recording equipment from apparatus made by Tektronix Inc.

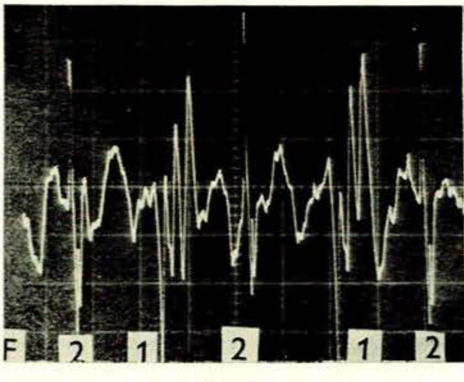

Fig. 5

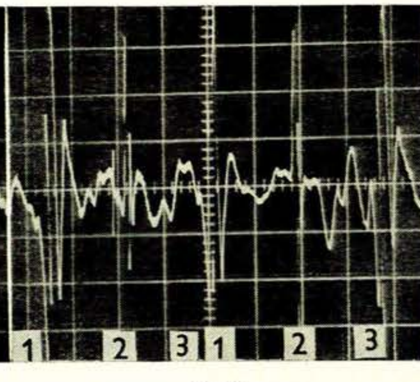

Fig. 6

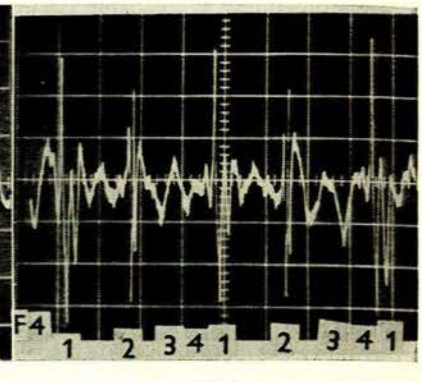

Fig. 7

Fig. 5. Foetal phonocardiograph just before delivery.
Fig. 6. Foetal phonocardiograph 3 minutes after birth. The similarity between this tracing and the previous one is very evident. The third heart sounds were identified because of the constant time relation following on the second sound.
Fig. 7. This is a foetal phonocardiogram taken at 37 weeks and not during labour. Third and fourth heart sounds are identified because of their position and constant time relationship. The first third sound has an upright deflection while that of the second is downward. This does not detract from the diagnosis.

lines. Split screen (store on either half, non-store on the other) provides the operator with new techniques for waveform comparison and analysis. The storage time is up to 4 hours. Variable sweep time/division varies from 1 microsecond to 5 seconds per division. It has a triggering mechanism whereby the recording can be made to start at the required amplitude.

Images which are required to be photographed are done by means of a polaroid camera attachment. The position of the camera can be altered so that various portions of the screen can be photographed at different times.

It can be seen from the above that the instrument is of a very high quality and sensitivity and there are no filtering mechanisms at all. The one feature about the recording device is that there is no inherent inertia to any writers as is found in the galvanometer, tambour and pen writers (i.e. there is no natural frequency hesitation of the apparatus).

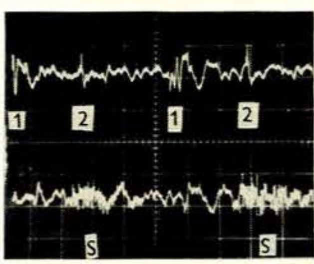

Fig. 8

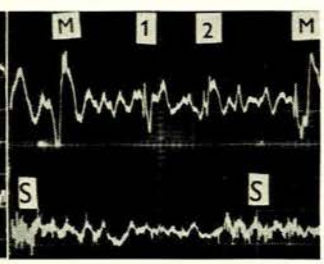

Fig. 9

Fig. 8. The top tracing is that of a foetal phonocardiogram and the lower tracing is that of the sounds being completely replaced by a uterine souffle.

Fig. 9. The top tracing shows the first and second foetal heart sounds and also the maternal sounds coming through on the same tracing. The lower graph shows the uterine souffle taken in the same case but not simultaneously.

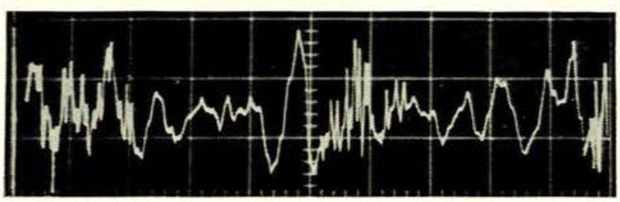

Fig. 10. Foetal phonocardiogram showing the complete replacement of the foetal heart sounds by a gross systolic murmur. This infant died *in utero* and at postmortem the heart was grossly enlarged, particularly the right atrium, and the foramen ovale was abnormally large. The exact cause of death was not known.

Figs. 2-10 are examples of heart traces taken before, during and after delivery.

DISCUSSION

This is a preliminary report on a new method for recording the foetal heart sounds. To date it has been shown that the sounds definitely consist of first and second heart sounds. There is strong evidence to show that third and fourth heart sounds are also recorded.

The pattern of the heart sounds contains more detail than has been shown by previous workers. Whether or not the change in this pattern can be used to predict foetal distress is still being investigated.

SUMMARY

A preliminary report on the use of the memory oscilloscope for recording foetal heart sounds is described.

I should like to thank the Photographic Unit, Department of Medicine, University of the Witwatersrand, for the photographs.

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