Centralised interpretation of electrocardiograms

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British Medical Journal, 1977, 1, 345-347

Summary
A system was devised so that a peripheral hospital could transmit electrocardiograms (ECGs) to a central computer for interpretation. The link that transmits both ECGs and reports is provided by the telephone network. Initial results showed that telephone transmission did not significantly affect the accuracy of the ECG interpretation.

The centralised computer programme could be much more widely used to provide ECG interpretations. A telephone link would not be justified in health centres, where the demand for ECGs is fairly small, but ECGs recorded at a health centre can be sent to the computer for interpretation and returned the next day. The most cost-effective method of providing computer interpretation for several health centres in a large city would be to have a portable electrocardiograph and transmission facilities, which could be moved from centre to centre.

Introduction
Computer-assisted methods of interpreting electrocardiograms aim to overcome the problems of observer variation, inaccurate reporting due to fatigue of the reviewer, and the uncertain availability of suitably trained and experienced physicians. To obtain greater cost-effectiveness telephone transmission systems can be used to link remote hospitals or health centres to a centralised computer. A three-channel analogue telephone transmission system was developed to enable ECGs to be sent direct from Law Hospital, a district general hospital, to the computer centre in the department of medical cardiology, Glasgow Royal Infirmary. A separate telephone link was also installed to enable digital information such as clinical details and ECG reports to be transmitted. We describe here how our system works and the results of our initial experience.

Methods
ECGs are recorded on a multichannel tape recorder at Law Hospital. The 3-orthogonal-lead ECG is used in conjunction with modified axial lead system\(^1\) electrode placements. The 12-lead ECG can also be recorded using the same cable, but this is not necessary for the computer interpretation; rather it helps the physicians in the transition period between the use of 12-lead ECGs only and computer-assisted 3-lead ECG interpretation.

Two public telephone lines link the transmitting station with the computer. One is for transmitting digital information—the patient’s name, age, etc typed on a keyboard send-receive terminal (capable of printing 30 characters/second), which is linked to the telephone line via a Post Office modem. This line can also be used to send immediate interpretations from the computer to the terminal in Law Hospital.

The second telephone link is used for transmitting the 3-orthogonal-lead ECG. The equipment is more fully described elsewhere,\(^2\) but, briefly, the three (modulated) signals are summed together and fed via an isolating transformer into the telephone line. In the computer laboratory the transmitted signal is separated to recover the original ECG waveforms. The band width of each ECG channel is DC-100 Hz with an overall signal/noise ratio of about 40 dB.

A special room at Law Hospital houses the computer terminals (fig 1). There is also a multichannel FM tape recorder for replaying the ECGs recorded in the wards and outpatient department, while a multichannel oscilloscope is available for monitoring the replayed signals during telephone transmission. A three-channel ink jet recorder is also used for a direct write-out of the ECG.

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![Diagram](http://www.bmj.com/)

**FIG 1**—Telephone links between Law Hospital and Glasgow Royal Infirmary.

Principles of operation
The program\(^3\) enables the operator at Law Hospital to completely control the system via the terminal. Details of the date of recording, etc are fed into the computer followed by the patient’s name, age, clinical classification, hospital number, etc. This information can be repeated if the operator makes a mistake. The ECG, together with its calibrations, is then transmitted to the computer. The operator can select the portion of tracing to be analysed. When the transmission is completed the operator then indicates to the computer whether she is satisfied with the portion selected, and if so, preprocessing of the ECG starts immediately. The computer itself performs checks on the re-
received ECG and may return messages such as "signal lost," indicating that the ECG should be transmitted a second time. If the transmitted signal is acceptable, the technician can then transmit the next ECG.

All the transmitted ECGs are stored on disc within the computer for later analysis, when the interpretation of Law Hospital ECGs has priority. Once the ECGs have been analysed the interpretations are returned in quick succession by the telephone line direct from the computer to the printer at Law Hospital. The results of one ECG can be printed out in about a minute. If the output section containing wave measurements is omitted the total print out time for the interpretation alone is reduced to about 20 seconds for the average ECG. Fig 2 shows an ECG received at the computer centre and the interpretation printed out at Law Hospital.

Discussion

The lack of adequate telephone transmission facilities for ECG interpretation was highlighted recently in the British Medical Journal. We have described a system that links a central computer to its terminals via the telephone network. Alternative approaches do exist, but our method is thought to be the best way of ensuring that the remote hospital maintains complete control of the transmission and the selection of data. The name of the patient can also be transmitted and printed on the report. This feature is not available on any other system.

The need to store all the ECGs on one disc before the computer starts to interpret them may be justified for two reasons. Firstly, the program has a facility for comparing previous ECG reports to check for serial changes. To do this one of the two discs on the computer has to be set aside for each hospital's records (the other stores the ECGs) and therefore the computer can report ECGs from only one hospital at a time, even though several hospitals may transmit ECGs into the computer system simultaneously. Thus, while Law Hospital ECGs are queueing within the computer ECGs from another hospital, normally Glasgow Royal Infirmary, are being interpreted. When the Law Hospital ECGs are to be interpreted the appropriate disc containing Law Hospital records is inserted into the computer system. Secondly, only one printer is available at Law Hospital. If it is being used for the input of information it cannot be used for print out of results at the same time unless the operator waits for one ECG to be analysed and returned before starting the next report. This technique was used initially but it is inefficient.

The latest version of the computer program embodies more sophisticated processing techniques than were used at the time of study. The program itself makes numerous checks for artefacts and removes as many as possible. If the program decides that the artefact is excessive the operator is informed that the ECG should be transmitted a second time. Likewise, if the occasional complex which is distorted because of noise escapes the artefact-checking procedure, it will not be included in the formation of the modal beat because it will have been typed as being different to the class of beat from which the modal beat is formed.

A need undoubtedly exists for a centralised computer interpretation system in an area such as Glasgow. Indeed, it could be argued that the system is needed for only one "district" of the Greater Glasgow Health Board. The latest version of the program, which embodies time-sharing techniques, can process on average one ECG every two minutes. This time includes the input of the ECG, so that about 250 ECGs could be reported on by the system each eight-hour day. This gives a figure of 65 000 ECGs each year. Clearly, more could be processed if the computer were used for 16 hours a day for five days a week and so on.

The system is best used for processing the routinely recorded non-urgent ECGs. Computer time can be allocated on a regular basis to provide daily access to interpretation facilities. This allows results to be supplied promptly to non-specialists at a reasonable cost. Emergency ECGs will normally be dealt with by a physician at the bedside. The need to tape-record an ECG, take the magnetic tape to the laboratory, dial the computer, and obtain an answer back within half an hour does not seem to
be justified. The alternative of dialling the computer from the bedside is not practical at present in most British hospitals. In any event the ECG report would normally be printed centrally in the hospital and should be checked before being returned to the ward.

WIDER USE OF COMPUTER

With the introduction of health centres there is an increasing need for recording facilities within each centre. We are currently co-operating with two health centres. Each has a data acquisition trolley located permanently within the centre. In one of the nursing staff make the ECG recordings, which are transported daily to the Royal Infirmary by van. At the same time interpretations of the previous day's recordings are returned. In the other health centre a technician from the Royal Infirmary visits the centre at least once a week to make the recordings.

In neither centre has the need for an emergency report been clearly shown. The vast majority of patients who require an ECG as part of their investigation can either wait a few days for an ECG or have an immediate recording and receive the interpretation one or two days later. If the general practitioner thinks that an emergency report is needed then the patient can be sent to hospital from the second health centre, while in the first centre the ECG can be recorded and one of the two trained GPs can scan the ECG to look for acute changes and make any necessary therapeutic decision.

There seems to be a need for a portable multichannel electrocardiograph with magnetic tape-recording or telephone facilities for transmitting the ECG to the computer centre. In this way one technician could provide a half-day session in 10 health centres each week. In our experience 20 ECG recordings per week per health centre is a reasonable number to expect, so one technician could cope quite easily with this work load. Installing an electrocardiograph and telephone transmission with printout facilities in each health centre is not really justified. It would cost about £7000 per centre. On the other hand, one portable recording system taken to each health centre for one half-day session a week would cost perhaps £5000 and minimise maintenance costs. Furthermore, the equivalent of only one technician would be required whereas every health centre would have to employ a competent technician if the other approach were adopted.

Any spare time which the computer has will depend on the number of hospitals or health centres which are directly or indirectly linked to the system. We are currently investigating the possibility of using spare capacity for screening employees at a small charge. This may be one way of helping to meet the severe financial problems which the Health Service is experiencing.

All those engaged in ECG interpretation by computer acknowledge that ECGs should be quickly scrutinised by a physician or cardiologist before being distributed to wards and clinics. The computer interpretation, however, enables the ECGs to be checked much faster (up to five times faster than conventional reporting), while observer variation is minimised. It is quite feasible for well-trained physiological measurement technicians to scrutinise computer output to determine whether any tracings should be referred to a cardiologist for checking or whether they could be distributed immediately. In this way the work load on physicians would be kept to an absolute minimum.

This work was carried out with the aid of grants from the Scottish Home and Health Department. The authors would like to acknowledge the co-operation of the general practitioners in Woodside and Rutherglen health centres, Glasgow.

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(Accepted 2 December 1976)

Perinatal deaths: analysis by clinical cause to assess value of induction of labour

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British Medical Journal, 1977, 1, 347-350

Summary

Over the 10 years 1966-75 the rate of induction of labour in the Glasgow Royal Maternity Hospital has increased from 16.3% to 35.6% of all births. During the same period perinatal mortality fell from 33 to 22 per 1000, mainly because of significantly fewer deaths due to antepartum haemorrhage; trauma; maternal disease; and unknown causes in mature babies. The reduction in the number of deaths of unknown causes in mature fetuses was achieved by preventing deaths occurring after 40 weeks and was recorded in all age and parity groups. The results suggested that increased use of induction of labour has contributed to the improved perinatal mortality rate.

Introduction

Walker\textsuperscript{1} emphasised the importance of postmaturity as a causal factor in perinatal death, and his finding was confirmed in the first British Perinatal Mortality Survey.\textsuperscript{2} Different studies have shown that better results are produced when labour is routinely induced at 41 weeks than when the pregnancy is allowed to continue.\textsuperscript{3,4} Baird\textsuperscript{4} claimed that the risks of prolonged pregnancies were greatest in primigravidae aged over 30 years and