EVALUATION OF CONVENTIONAL AND COMPUTERISED MONITORING OF CARDIAC FUNCTION IN THE CORONARY CARE UNIT

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SUMMARY

One of the important functions of the Coronary Care Unit (CCU) is the continuous and intensive monitoring of cardiac function. To date, many monitoring techniques have been developed and tested.

In this paper, both the conventional and computerised monitoring techniques are reviewed and evaluated. It is shown that a computerised system has several definite advantages over the conventional system, e.g. lower false alarm rate, accurate and fast data processing, retrospective studies. However one also ought to be aware of the limitations.

INTRODUCTION

The basic functions of a Coronary Care Unit (CCU) is continuous and intensive monitoring of cardiac function, both invasive and non-invasive. Monitoring techniques serve three main purposes, namely to protect the patient by ensuring that any abnormal variations are immediately evident; to indicate the pattern of the patient's response to treatment so that it can be modified as required; and to provide data from which a better understanding of the particular disease process may be derived.

ECG MONITORING OF CARDIAC FUNCTION

The conventional system is based on a preset rate tachometer or heart rate meter alarm (Fig. 1).

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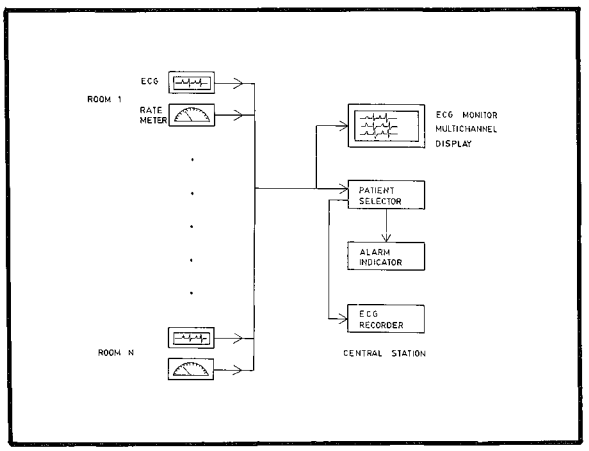

Fig. 1 A typical conventional ECG monitoring system.

It selects QRS complexes from the patient's electrocardiogram (ECG) and presents a flashing light and/or audible tone with each ventricular depolarisation. The tone provides for audible detection of changes in heart rate and rhythm. If the rate speeds up or slows down and exceeds the preset limits, a visual and audible alarm occurs. The monitoring equipment is placed at the bedside and connected to an audiovisual display at the central nursing station. The ideal system should provide for display of the heart rate at the bedside and also have heart rate meters and alarms at the station. The alarm, once triggered, can only be turned off and reset manually by the nursing staff.

The most common problem in the rate meters is false alarms caused by motion artifacts. This can be minimised by providing an alarm delay, the setting (0 — 10 sec) depending upon individual circumstances. A build-in memory in some systems record the events (15-30 sec) prior to the setting-off alarm in order that further analyses may be performed.

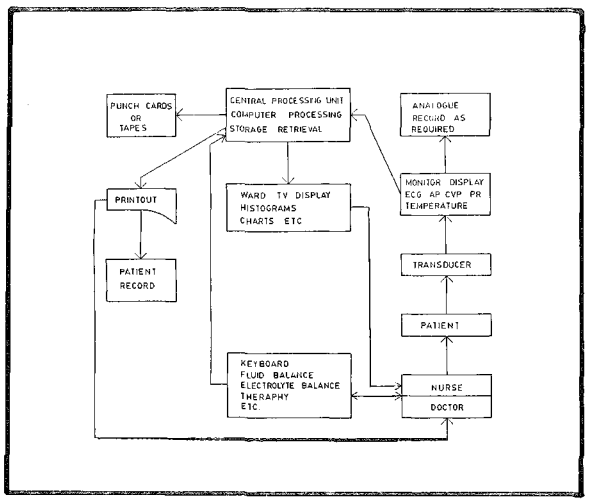

Fig. 2 Block diagram of a computerised patient monitoring system with facilities for automatic and manual data entry. [4]

Most of the computerised monitoring systems emphasise QRS complex detection and recognition of premature ventricular beats. Many of them are designed to be used simultaneously on several patients for continuous monitoring of heart rhythm, detection of premature event, determination of changes in heart rate and activation of various alarms on a priority basis. Unlike conventional systems, they permit storage and retrieval of patient data for retrospective studies as well as on-line analysis for decision making. They can also print out patient histories and assist in treatment based on specific programmes. Fig. 2 shows a typical computerised monitoring system. Hill and Dolan [1] describe the various monitoring techniques using computer system. These include physiological variables other than cardiac function.

Taylor [2] describes a time-weighted approach using 'exponentially-mapped past' to analyse trends and trend patterns involving many parameters. This technique allows most decision-making significance to be attached to the most recently monitored events instead of instantaneous limited value of monitored parameters.

The modern trend of computerised system is towards continuous monitoring of several physiological variables and improved patient management. [3] Blackburn [4] describes a computer-based patient-monitoring system with facilities for automatic and manual data entry. Many of the data are automatically collected by the computer from bedside monitors, particularly systolic and diastolic blood pressures, central venous and left atrial pressures, heart rate and temperature. This ensures that clinically important information is still displayed on the bedside monitors in the event of computerised system failure.

COMPARISON OF CONVENTIONAL AND COMPUTERISED ARRHYTHMIA MONITORING

There is good evidence to show that conventional monitoring systems fail to identify a substantial number of arrhythmias which are considered as potentially serious. A survey of the literature indicates the increasing role of computerised monitoring system and subsequent improved reliability. Macy and James [5] emphasised the need for automated real-time arrhythmia detection performed on-line in the Coronary Care Unit to achieve reliable recognition of all arrhythmias.

Romhilt *et al.*, [6] evaluated the reliability of a conventional electrocardiographic monitoring system in 31 patients. All were monitored routinely with conventional equipment, and at the same time the electrocardiogram for each patient was recorded on magnetic tape and stored for analysis by an automated real-time arrhythmia detection system. The results clearly showed the unreliability of conventional monitoring system for precise and early detection of arrhythmia. This had previously been indicated by Whalen *et al.* [7] In order to improve the ability of a conventional monitoring system in the detection of arrhythmia, more frequent sampling techniques or more frequent and careful observation of monitors by trained personnel or both are required. Increased observation and sampling techniques would demand much greater time and are susceptible to human error.

Vetter and Julian [8] carried out the first clinical evaluation to compare the efficiency of the two methods in detecting arrhythmias in 64 patients. The result is summarised in Table I. Half of them were monitored by a commercially available arrhythmia computer; the others were monitored by conventional means with a rate-triggered alarm system. More than 99% of the arrhythmic episodes were detected by computer and 95% of these patients were treated immediately. (According to therapeutic procedure, arrhythmias regarded as premonitory to ventricular fibrillation should be

TABLE I
FIRST CLINICAL EVALUATION OF CONVENTIONAL AND AUTOMATED DETECTION SYSTEMS[8]

Arrhythmia	Positive detection	
	Conventional detection system (%)	Automated detection (%)
Premature Ventricular Contraction	64.5	100 ($p < 0.01$)
Premature Atrial Contraction	45.2	96.8 ($p<0.001$)
Serious Ventricular Arrhythmia	16.1	93.5 ($p < 0.001$)
Multifocal Premature Ventricular Contraction	6.5	87.1 ($p<0.001$)

corrected immediately with antiarrhythmic drugs.) A large proportion were unrecognised by conventional means: only 17.4% received immediate antiarrhythmic treatment. In 30.4%, treatment was delayed for several hours, and none was given in 52.2% of the cases!

False alarms were common in both the above systems but their causes were different. The conventional system was difficult to set for bundle-branch complexes and was susceptible to electromyographic and movement artifacts. The computerised system gave little trouble in these respects but in some cases tall T waves following small QRS complexes were misinterpreted as ventricular ectopic beats. On the average, a computer system generated less than two false alarms per day compared with over 13 false alarms per day when conventional system was used.

Frost *et al.*, [9] have examined the causes of alarm generated in the two systems during 200 patient monitoring hours over a two month period, the result of which is presented in Table II.

They found that the false-positive alarms from a computerised system occurred only 25% as often as from an analogue rate meter. However, it is worth pointing out that a 53% true-positive alarms is still far from ideal.

TABLE II
FREQUENCY OF COMPUTER AND ANALOGUE ALARM[9]

Result	Computerised arrhythmia alarm	Analogue rate meter
Total Alarms	79	167
True Positive	42 (53%)	13 (8%)

Some of the problems identified in using computerised systems include isolated noise spikes which may be diagnosed as being premature ventricular or premature atrial beat; demand pacemakers (longer QRS durations associated with paced rhythm) cause a wide QRS alarm in patients who alternate between normal and paced rhythms; and improper adjustment of electrocardiographic amplifier sensitivity resulting in the inability of the computer to find sufficient QRS complexes for accurate signal analysis.

The advantages and limitations of both the systems are summarised in Table III below.

TABLE III
SUMMARY OF ADVANTAGES AND LIMITATIONS OF CONVENTIONAL AND COMPUTERISED MONITORING SYSTEM

	Conventional System	Computerised system
1.	Frequent False Alarms - staff tends to ignore or reset to a less sensitive range	Low False Alarms rate - graded series of alarms, when false alarms occur, they do not trigger 'arrest' alarm
2.	Antiarrhythmia treatment frequently delayed or not given at all	Antiarrhythmia treatment given immediately to all those for whom it is indicated
3.	Large nursing staff and skilled medical personnel	Reduction of nursing staff but additional computer staff needed
4.	Time consuming	Less time consumng, changes nursing routine activities
5.	Rely on human visual observation and interpretation - slow and limited	Immediate processing and display of data, some irrelevant data tend to obscure interpretation
6.	Manual data manipulation - subject to human errors, slow and unreliable	Data storage and retrieval - rapid, accurate, reliable
7.	Human Decision - subjective, better insight into clinical impression but has limitation	Decision making capability based on retrospective and current studies - can predict future trends based on programmed patient's normal QRS complex
8.	Better patient-nurse relationship	Patient-computer interaction - dehumanised and impersonal
9.	Reasonable cost	High cost - equipment and maintenance, but cost effective expected in the future

TELEMETRY MONITORING

Patients with acute myocardial infarction are monitored for two to five days, on the average. Most of those succumbing do so within the first three days. There is evidence to suggest that electrocardiographic monitoring beyond the time provided in Coronary Care Unit is a necessity in the care of patients if the mortality rate is to be further reduced. [10]

Some hospitals are using telemetry to monitor patients who may be showing transient arrhythmias while ambulating. Post-myocardial infarction patients are ambulated in an area near the central station. The patient wears a transmitter which picks up his electrocardiogram, converts it to a frequency modulated (FM) signal, and transmits it to the station where it is demodulated and monitored.

Though this technique is relatively new it has contributed to our understanding of the occurance and significance of arrhythmias. [11,12] It has also improved the prognosis of post-myocardial infarction patients in the Coronary Care Unit. However, its clinical value and reliability have yet to be evaluated.

IS COMPUTER THE SOLUTION?

Monitoring techniques in the Coronary Care Unit are constantly undergoing improvement. They work most of the time, but also requires a good deal of careful attention, maintenance and special skill. However, trying as it may be, without the experience gained as a result of such problems we may never reach the stage where real benefits can be reaped.

The ultimate test of a monitoring system is in the response to which it leads. In the Coronary Care Unit, the best criterion is the speed with which antiarrhythmic treatment is given. The many computerised monitoring systems developed so far indicate that improvements are being realised.

The future of monitoring in the Coronary Care Unit depends on smaller, more rugged transducers and sensors; improved measurement techniques; and greater utilisation of computer hardware and software.

There is an inclination to assume that if advantages are seen to arise from using a new technique, it should not be withheld from any patient - especially one who may have a potentially fatal disease such as that of myocardial infarction - regardless of expense. One should also consider the costs and economic benefits. On the other hand one ought not to believe that computerised system will ever be able to replace skilled clinical staff, since certain types of information could not possibly be monitored automatically.

The computerised system offers real but limited values in the Coronary Care Unit. Therefore we need to adopt a practical and balanced perspective in the usage of computerised monitoring of cardiac function in the Coronary Care Unit.

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