Chapter 47
Current State of Critical Patient Monitoring and Outstanding Challenges

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ABSTRACT

Technological advances in the fields of electronics and computer science have given rise to a considerable increase in the number of physiological parameters available to clinical staff for interpreting a patient's state. However, owing to the limitations and flaws in current commercial monitoring devices, this has not resulted in a corresponding increase in healthcare quality. This chapter analyses the reasons why clinical staff are not making full use of information from the monitoring devices currently in use in critical care units; a review is made of the most salient proposals from the scientific literature in order to address the imbalance existing between the amount of data available and the improvement in healthcare; and those problems for which suitable solutions have yet to be found and which have, up until now, hindered the applications of said proposals to clinical routine are analysed.

INTRODUCTION

The history of patient monitoring can be considered to date back to 1887, when the British scientist Augustus D. Waller made the first electrocardiogram (ECG) recording on a human being (Waller, 1887). The invention of the first commercial monitoring device is attributed to the Nobel Prize winner, Willem Einthoven, who in 1903 embarked on negotiations with the Cambridge Scientific Instruments Company to commercialise his "string galvanometer" for recording electrocardiograms (Einthoven, 1903). Since then, the list of advances made in commercial monitoring devices is endless, with these being especially prominent since the beginning of the 1970s. The invention of the microchip and the

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ensuing advances in the fields of electronics and computer science have meant that the recording of a physical magnitude (a physical parameter in the case that concerns us), its subsequent conversion into a digital format, and its computer processing have become commonplace tasks. Consequently, there has been a considerable increase in the number of physiological parameters recorded from patients admitted to critical care units.

One could be forgiven for thinking that the more information there is available on a patient, the easier it will be for physicians to interpret the physiopathological processes that concur in each patient, and thus, the more efficiently the supervision task will be carried out. This, however, is not necessarily true: if the volume of data available exceeds the cognitive capabilities of physicians, they will have no option but to ignore some of those data that take them beyond the limits of their competence, which may lead them to commit errors. This situation is frequently aggravated due to the data being recorded from a patient admitted to a critical care unit often corresponding to situations that require a swift response (Jungk, 2002).

The only support that monitoring devices give to clinical staff for interpreting the patient's state is threshold alarms; these are triggered when the value of a signal being monitored falls outside certain pre-established ranges that are considered normal. The selection of limits defining these alarms is subject to a compromise. Some limits give rise to a large number of false alarms, a high cognitive load for the healthcare staff, and, in the long-term, may lead to a lack of concern regarding the triggering of an alarm. In extreme cases, this may even result in healthcare staff occasionally disconnecting alarms (Mora, 1993). Tighter limits will give rise to a lower number of false alarms, but they increase the risk of not detecting real alarms, and thus, put the patient's health in danger.

The availability of alarms capable of supplying higher levels of pre-interpretation for physiological variables would be extremely useful for healthcare staff. Such alarms would supply information with greater semantic content, and not only information on the membership or not of the instantaneous value of a physical parameter to a range of normality. In the bibliography on biomedical engineering, there are a good many proposals dealing with this problem. Nonetheless, in spite of all the work carried out along these lines, there are still a number of problems that have yet to be solved satisfactorily, and this has prevented these proposals from being implemented in clinical routine to date.

The present study analyses the principal shortcomings and limitations of threshold alarms and the problems which consequently afflict clinical staff. On the basis of this analysis, we shall define a framework for comparing different proposals for providing clinical staff with more effective assistance, and we shall compare the most salient proposals for tackling the problem of real-time patient monitoring. We shall then go on to consider those problems that have not been suitably dealt with by these proposals, and which must be resolved before their application in clinical routine. Finally, a series of conclusions on the work shall be given.

PATIENT MONITORING: WHAT IS NOT WORKING PROPERLY?

In critical care units, the physiological parameters of each patient are recorded by one or more bedside monitors. Among the most commonly monitored parameters are the 12 electrocardiogram leads, ST segment deviation, heart rate, respiratory rate, systolic, diastolic and mean blood pressure, blood oxygen saturation, encephalogram, intracranial pressure, partial pressure of expired oxygen, nitrogen and carbon dioxide, etc. Often, bedside monitor screens do not permit the simultaneous representation of all the physical parameters being recorded; rather they only allow a subset thereof to be viewed. Normally, between 4 and 8 parameters can be represented simultaneously. Also