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WHAT'S NEW IN INTENSIVE CARE

The rise of ward monitoring: opportunities and challenges for critical care specialists

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Introduction

Many hospitals have implemented rapid response teams (RRTs) for rescue interventions outside the ICU. The outcome impact of RRTs is still a matter of debate but there is a consensus regarding the fact that timely detection and notification of clinical deterioration (aka the afferent limb) is a key determinant of success [1, 2]. To improve the detection of clinical deterioration, multiple monitoring systems have recently been developed for the wards. They include wireless pulse oximeters, adhesive patches containing electrodes, accelerometers, thermistors or piezoelectric sensors, and bioimpedance necklaces [3–5]. These new tools enable the continuous monitoring of heart rate (or pulse rate), ECG (one or more leads), respiratory rate, SpO_2, peripheral perfusion, axillary temperature, and the detection of changes in thoracic fluid content and blood pressure. The rise of ward monitoring creates opportunities and challenges for critical care specialists that are discussed in this article.

Finding patients before they crash

On hospital wards, nurses typically spot-check vital signs every 4–6 h. Continuous monitoring of vital signs provides the opportunity to detect and treat clinical deterioration at a very early stage. First, this may help to prevent ICU admission. Taenzer et al. [6] continuously monitored pulse rate and SpO_2 in 2841 surgical ward patients and observed a significant decrease in RRT activations and ICU transfers. Second, if patients are admitted at an earlier stage in the ICU, it should enhance recovery and decrease length of stay [7]. In this regard, Brown et al. [8], who continuously monitored heart rate and respiratory rate in 2314 medical-surgical ward patients, reported a significant reduction in ICU days for transferred patients. Other studies involving 18,305 [9] and 4402 [10] patients respectively have reported a reduction in hospital length of stay and mortality when intensifying and automating ward monitoring.

Continuous monitoring of vital signs may also help clinicians once they have been called for a rescue intervention. Indeed, looking at trends of physiologic variables is often very useful to identify what the primary determinant of clinical deterioration was. Miniaturized echo devices and non-invasive cardiac output monitoring systems are also now available [5]. When RRTs are called on the wards for hemodynamic instability, these tools may help to quickly identify the root cause and determine the appropriate treatment.

False alarms and additional workload

The frequency of alarms in ICUs has been reported to range between 2 and 15 alarms/bed/h, with false alarms being as common as 90% [11]. Monitoring systems and solutions designed for the wards have to differ from those used today in the ICU [12]. First, to decrease sleep disorders and unnecessary stress, alarms have to be excluded from patient rooms. The information has to be displayed on central stations and, when appropriate, redirected to the clinician in charge via a notification system (Fig. 1). Second, machine learning systems are needed to filter artifacts and cross-check physiologic signals in order to decrease false alarms (e.g., no need to alert for asystole if there is a pulse oximetry waveform) [13, 14]. Third, physiologic variables should be fused so that clinicians

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can focus on a single variable or deterioration index [9]. Visual information with simple color coding (e.g., green/yellow/red) may further simplify the interpretation of monitoring information and facilitate implementation in low acuity units [5]. Predictive algorithms can be used to analyze electronic medical record (EMR) data, which include intermittent vital signs, and identify, with more accuracy than classical early-warning scores, which patients are at risk of deterioration [15]. Such risk stratification would help to select ward patients who may benefit from more frequent spot-checks (e.g., every 1 or 2 h) or continuous monitoring (Fig. 1). Other predictive algorithms have been designed to continuously analyze signals from physiologic sensors. They have potential to detect clinical deterioration beforehand [16].

The potential impact on workload of nurses and physicians is another key issue. In a large study (> 18,000 patients), Bellomo et al. [9] did not report any significant increase in the number of RRT interventions after implementing a ward monitoring system (24 vs 21/1000 admissions) but observed an increase in the number of abnormal physiologic criteria present at the time of activation. More recently, Heller et al. [17] implemented an automated early warning system with paging functionality in 1931 surgical patients and reported an increase in the number of notifications to the ward surgeon. However, the number of RRT calls significantly decreased. These findings suggest that ward monitoring may not necessarily increase workload at the hospital level, but rather redistribute it, with more adverse events managed by ward clinicians (since they are detected earlier) and less by critical care specialists. One may also assume that the introduction of smart continuous monitoring systems will prevent unjustified spot-checks in stable patients, who, fortunately, remain the vast majority of ward patients. This should contribute to a decrease in nurse workload and an improvement in patient comfort, quality of sleep, and satisfaction. However, one should not underestimate the importance of one-on-one interaction with the patient, and the fact that the detection of clinical deterioration may rely on signs (e.g., mottling) or symptoms (e.g., "not feeling well") not captured by current monitoring systems [18].

There are several technical challenges to the implementation of wireless and wearable monitoring systems on the wards. They include robust communication between devices (via Bluetooth, ZigBee, or Wi-Fi), connectivity with the EMR system, and cybersecurity. These technical issues are beyond the scope of this article. Costs may also be an issue since the concept is to monitor a large number of ward patients to prevent serious adverse events in only a few. Interestingly, two studies already suggest a positive return on investment [19, 20].

To quote Bates and Zimlichman [21], "finding patients before they crash may be the next major opportunity to improve patient safety". Critical care specialists (anesthetists or intensivists) are experts in detecting and treating acute care situations. They are also experienced in using continuous monitoring systems. Therefore, they are ideally positioned to help hospital wards and medical technology companies in the development and implementation of mobile monitoring solutions.

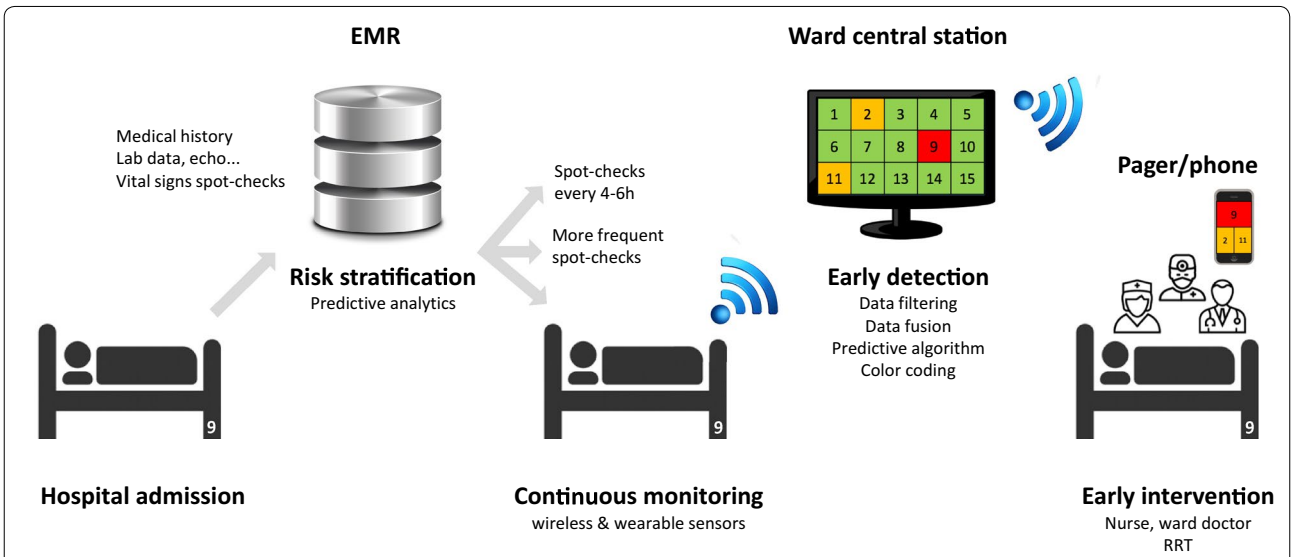

Fig. 1 The afferent limb of rapid response systems in the era of predictive analytics and wearable sensors. EMR electronic medical record, RRT rapid response team

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Compliance with ethical standards

Conflicts of interest
FM is the founder and managing director of MiCo, a Swiss consulting firm. MiCo does not sell any medical products and FM does not own shares or receive royalties from any medtech company. RB has been a consultant for Philips Medical and Edwards Life Sciences. AT has no conflict of interest to declare.

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