Rethinking Patient Surveillance on Hospital Wards

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Postoperative complications are much more common than intraoperative and anesthesia-related complications. According to the International Surgical Outcome Study,[1] approximately 17% of inpatients undergoing elective surgery develop at least one postoperative complication. This proportion reaches 27% in patients undergoing major surgery and exceeds 30% in patients with significant comorbidities (American Society of Anesthesiologists status III to IV).[1] A large (84,730 patients) observational study[2] demonstrated that U.S. hospitals having similar postoperative complication rates may report very different mortality rates. These findings are likely explained by differences in the detection and treatment of complications and suggest that postoperative mortality is, at least in part, preventable.

On hospital wards, where the nurse-to-patient ratio is lower than in postanesthesia care units or intensive care units (ICUs), a recent and large study[3] (48,864 patients) showed that approximately one third of vital sign spot checks are not done on time, and one quarter are incomplete. In another study,[4] only 40% of patients' vital parameters were monitored as ordered by the physician. Failure to rescue is defined as the death of a patient after one or more potentially treatable complications.[5] It was found to be inversely related to nurse staffing level.[6] While increasing nurse staffing level might help, the economic constraints makes this intervention unlikely. One goal might be to assist nurses in their patient monitoring tasks with appropriately designed monitoring equipment. Until recently, monitoring systems were bulky, expensive, and designed for use in operating rooms and ICUs, where a nurse or doctor observes and interprets real-time physiologic waveforms. Over the last decade, several continuous monitoring solutions have been specifically designed for the wards.

In this review, we successively discuss why continuous monitoring of vital signs may help and which variables should be monitored in priority. Then we describe the existing evidence supporting the implementation of both "stay-in-bed" and mobile continuous monitoring systems. Finally, we discuss which patients may benefit the most from continuous monitoring on hospital wards and what are the obstacles to real-life implementation.

Why Continuous Monitoring of Vital Signs May Help

On hospital wards, nurses typically spot check vital signs several hours apart. Because of the intermittent nature of spot checks, they may miss a significant proportion of vital sign abnormalities that typically precede severe adverse events.[7–9] Recent studies have shown that when checking vital signs every 4 h, nurses may miss up to 90% of hypoxemic events[10] and approximately 50% of hypotensive events.[11] In their landmark article on rapid response teams, Jones *et al.*[12] considered intermittent monitoring on hospital wards one of the top contributors to failure to rescue. If true, continuous monitoring of vital signs might help to improve postoperative outcome.[13]

Respiratory depression episodes, defined by an oxygen saturation (Spo_2) of less than 85% or a respiratory rate (RR) of less than 5 breaths/min, have been reported in up to 46% of patients receiving opioids on the general care floor.[14] They can progress to respiratory arrest if undetected. Because opioid-induced death is potentially preventable, there is today a consensus to state that no patient should be harmed by opioids.[15] As stated by Sessler,[16] "it is likely that many catastrophic respiratory events could be prevented by continuous monitoring."

Continuous monitoring may be useful beyond surgical wards, where anesthesiologists may also be involved in patient care as perioperative physicians or members of the hospital rapid response team. Many in-hospital cardiac arrests occur on general or medical wards. A national audit[17] performed in 144 hospitals in the United Kingdom reported the location of in-hospital cardiac arrest for 23,554 adult patients. Most arrests were observed in medical patients (more than 80%) and occurred on the wards (57%). Of note, many patients do not suddenly deteriorate, but healthcare workers suddenly notice. A study[7] compared the modified early warning score (based on the aggregation of vital signs) in ward patients who had or did not have a cardiac arrest. The modified early warning score was not only significantly different 30 min before but also 8 and 24 h and even up to 48 h before the arrest, whereas the two groups had the same modified early warning score at the time of ward admission. Other studies have shown that vital signs are often abnormal hours before cardiac arrest or ICU admission.[8,9] These studies highlight the fact that clinical deterioration is often progressive. In this context, close monitoring, with a focus on trend analysis, may detect abnormal clinical trajectories at an early stage and could reduce the number of severe adverse events. Other factors such as

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the increasing frailty and acuity of ward patients and ICU bed shortage, currently at its climax with the COVID-19 pandemic, are additional incentives to rethink patient monitoring strategies on the wards (fig. 1).

Which Variables Should Be Monitored

Heart Rate and Electrocardiography

The continuous monitoring of heart rate (or pulse rate, if derived from a pulse oximeter) may be useful to detect bradycardia, tachycardia, and cardiac arrhythmia (from the analysis of heart rate variability). During the postoperative period, heart rate may increase in multiple clinical situations, including stress, pain, atrial fibrillation, sepsis, and bleeding. It is therefore not a specific but a sensitive marker of clinical deterioration.[18] An abnormal heart rate was responsible for 21.6% of 402,023 rapid response team activations in a cohort study done in 360 U.S. hospitals by Lyons *et al.*[19] Continuous electrocardiographic monitoring, also known as telemetry, is frequently used in cardiology departments. Of note, cardiac arrhythmia was the third most common postoperative complication (after bleeding and surgical site infection) in the large International Surgical Outcome Study.[1] Therefore, continuous heart rate and electrocardiographic monitoring may also be useful on surgical wards.

Blood Pressure

Blood pressure monitoring may detect both hypertensive and hypotensive events. Whereas the impact of postoperative hypertension on patient outcome remains unclear,[20] postoperative hypotension is known to be associated with adverse events such as acute kidney injury, myocardial infarction, and death.[21] Recent studies suggest that postoperative hypotension is frequent, prolonged, and often overlooked for hours.[11,21] In the above-mentioned cohort study by Lyons *et al.*,[19] hypotension was responsible for 15.7% of rapid response team activations. Therefore, continuous or more frequent monitoring of blood pressure—combined with clear actionable nursing protocols—has potential to decrease the duration and depth of hypotension.[22]

Oxygen Saturation

In patients susceptible to develop respiratory complications (either respiratory depression related to opioids or respiratory failure related to nosocomial pneumonia or pulmonary edema), the use of stand-alone pulse oximeters is common practice. It enables the continuous monitoring of Spo_2 and pulse rate. In the U.S. study by Lyons *et al.*,[19] a decrease in Spo_2 was responsible for 21.2% of rapid response team activations. In patients who receive oxygen, Spo_2 may be a late indicator of respiratory complications.[23,24] During postoperative

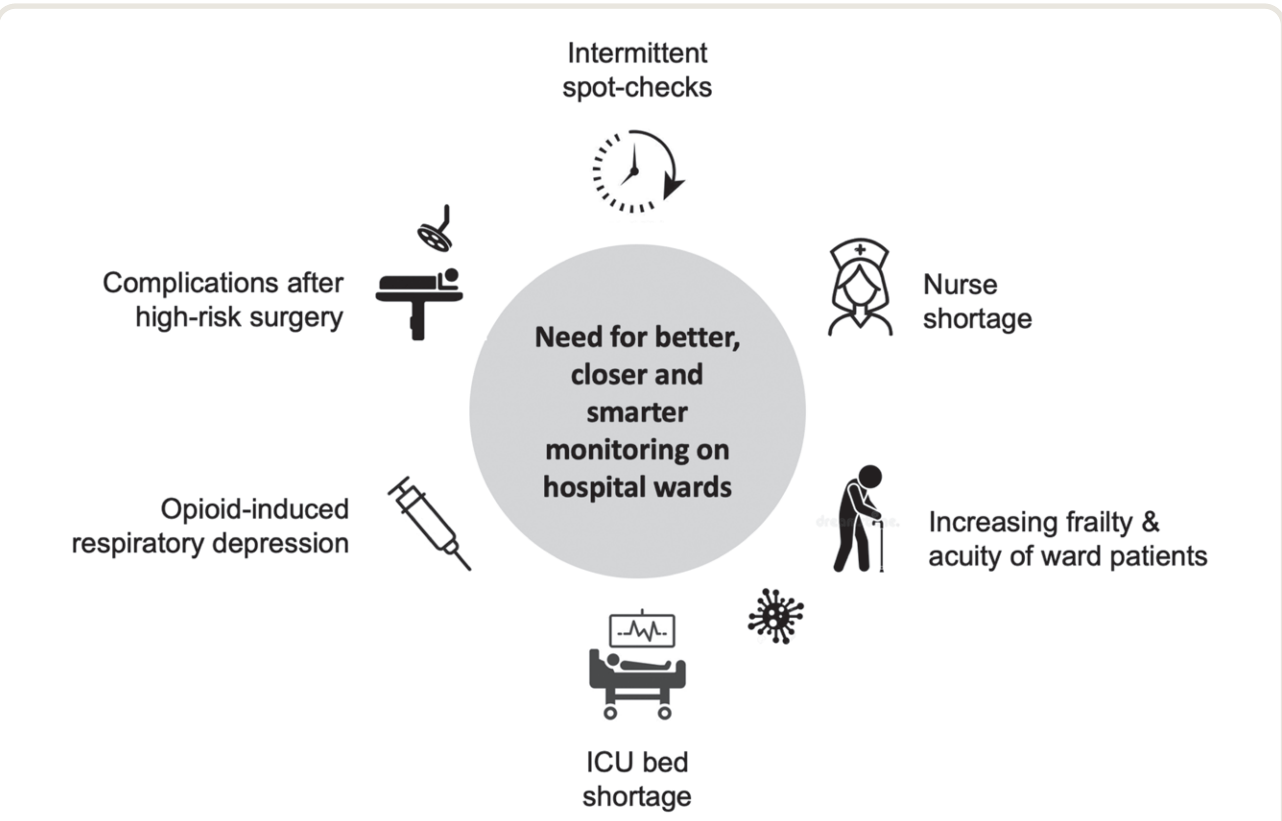

Fig. 1. Main incentives to upgrade patient monitoring strategies on hospital wards. ICU, intensive care unit.

patient-controlled analgesia with opioids, episodes of bradypnea are not always associated with hypoxemia.[14,24,25] In this context, it is therefore recommended to monitor RR.

Respiratory Rate

Whereas the focus is often on opioid-induced respiratory depression, RR may be abnormal in many other clinical situations including respiratory complications (*e.g.*, pulmonary embolism, pneumonia, pulmonary edema), sepsis, and metabolic disorders (*e.g.*, acidosis). In the study by Lyons *et al.*,[19] among 59,720 rapid response team activations driven by RR abnormalities, 71% were triggered by tachypnea, and 29% were triggered by bradypnea. In the general ward population, studies have repeatedly ranked RR as the most sensitive variable to detect clinical deterioration. In a study[26] including more than 260,000 ward patients and using machine learning methods for predicting clinical deterioration, RR had the highest "weight" in the predictive algorithm followed by heart rate, systolic blood pressure, and Sp_{O_2}. In the United Kingdom, the National Institute for Health and Care Excellence stated that "RR is the best marker of a sick patient and is the first observation that will indicate a problem or deterioration in condition" (https://www.nice.org.uk/guidance/CG50; accessed February 3, 2021). Paradoxically, the level of documentation of RR is often suboptimal.[27] When not missing from vital sign spot checks, RR is frequently "guesstimated" to be 16 or 20/min rather than carefully counted for 30 s.[3,28,29] Multiple methods have been proposed to monitor RR (fig. 2). They may help not only to obtain continuous information but also to guarantee reliable measurements.

Other Variables

Other variables or information may be useful to detect clinical deterioration in ward patients. Temperature, urine output, the need for oxygen administration, and the neurologic response to verbal or pain stimulation are often part of early warning scores. Laboratory data are frequently abnormal before cardiac arrests.[8] Therefore, they may help to improve the prediction of clinical trajectories.

Data Integration

Early warning scores are based on the aggregation of several vital signs into a single variable. They are better predictors of serious adverse events than any individual vital sign.[26] In some hospital wards, they are used to trigger nurse intervention and to define the optimal timing for the next spot check. Thanks to the development of connectivity and electronic medical record systems, early warning scores can now be automatically calculated. When automated early warning systems are combined with paging functionality, they enable the immediate communication of clinical deterioration to a responsible nurse or physician. The use of automated early warning systems has been associated with improved outcomes in several prospective implementation studies.[30–33] Continuous monitoring of vital signs would give the opportunity to "refresh" early warning scores in the electronic medical record system on a very frequent basis (*e.g.*, every 5 min) and has therefore potential to further improve their clinical value.

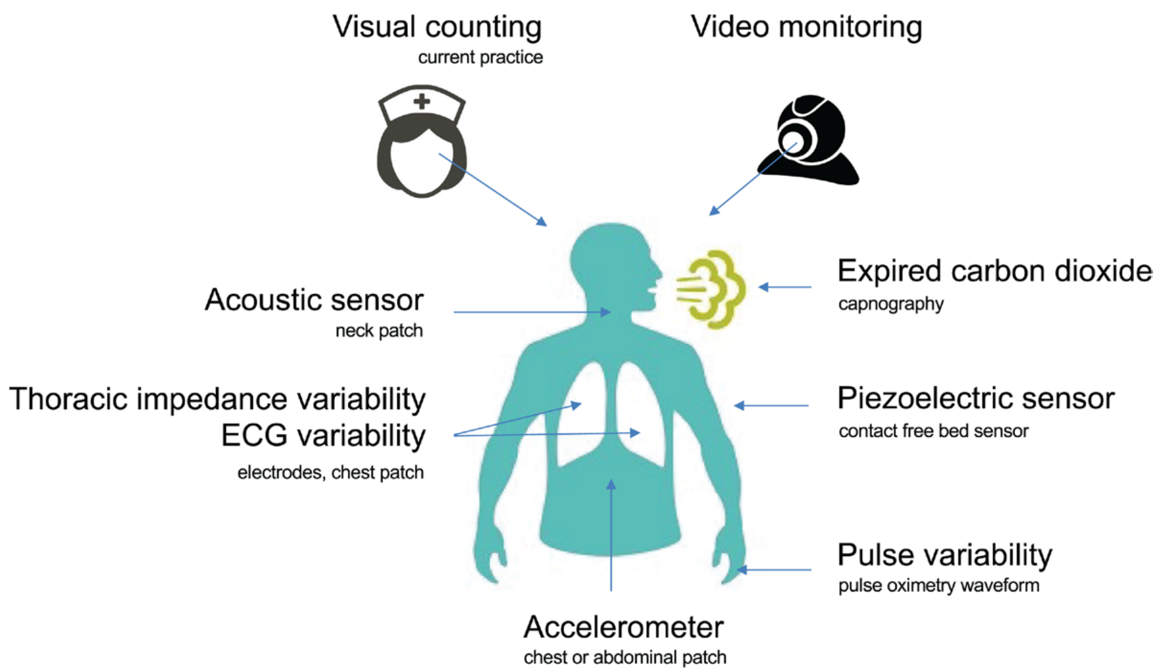

Fig. 2. Multiple methods have been proposed to monitor respiratory rate on hospital wards.

	Heart rate	Heart rate variability	Blood pressure	Respiratory rate	Oxygen saturation	Tempera-ture
No event/alarm						
Cardiac arrhythmia	↑	↑↑	↓			
Shock	↑↑		↓↓	↑		↑*
Respiratory depression				↓↓	↓	
Respiratory failure	↑			↑↑	↓↓	↑**
Sepsis	↑		↓	↑		↑↑
Bleeding	↑		↓			

Numerical pattern
333333
452333
531433/531434*
333123
433513/433514**
432435
432333

Fig. 3. Concept of automatic pattern recognition of clinical deterioration. Clinicians integrate information to suspect specific diagnoses. Similarly, simple algorithms could be used to automatically identify specific vital sign patterns and suggest possible diagnoses. Examples of numerical patterns are presented in the *right column*, assuming that for each variable, 1 means "major decrease," 2 means "decrease," 3 means "stable," 4 means "increase," and 5 means "major increase." The numerical pattern "333333" would mean all variables remain stable, whereas the pattern "433514" could suggest pneumonia-related acute respiratory failure. *If septic shock. **If pneumonia.

The aggregation of vital signs may also have the advantage of revealing specific patterns or phenotypes that could help to suggest a diagnosis. For example, the association of tachycardia, tachypnea, hypoxemia, and fever is highly suggestive of nosocomial pneumonia. As illustrated in figure 3, one may therefore envision the use of simple pattern recognition algorithms to suggest one or more diagnoses and trigger diagnostic tests. This basic but potentially effective approach deserves to be tested in clinical studies.

More sophisticated approaches based on machine learning algorithms have the ability to integrate a large number of variables (in theory all data contained in the electronic medical record system), taking into account their trends over time and complex relationships, to better predict clinical trajectories.[34] The electronic Cardiac Arrest Risk Triage (eCART)[26] and the Hospital wide Alerting *via* Electronic Noticeboard (HAVEN)[35] scores are examples of machine learning–derived fusion of age, vital signs, and laboratory data collected from the electronic medical records. They have been shown to better predict cardiac arrest, ICU transfer, and death than classical early warning scores.[26,35]

Current Methods for Continuous Ward Monitoring

"Stay-in-Bed" Monitoring Solutions

Pulse oximeters are frequently used on hospital wards. Classic stand-alone devices have an audible alarm that sounds in the patient room but may not be heard by the nurse. Effective continuous monitoring requires a system able to centralize the information (at a ward central station or in a command center) and to alert nurses on their pager or cellphone as soon as patients deteriorate. Such a system (Patient SafetyNet, Masimo, USA) has been used by Taenzer *et al.*[36] in postoperative orthopedic patients, most of them receiving opioids (table 1). After implementation, Taenzer *et al.*[36] observed a significant decrease in the number of rescue events, as well as a reduction in ICU transfers. Early detection may allow early intervention and, assuming the problem can be solved on the wards (*e.g.*, naloxone administration), the prevention of some ICU admissions. The same group recently published an evaluation of their practice 10 yr after the first implementation of continuous pulse oximetry on the wards.[41] In continuously monitored patients, they did not report a single death related to opioid administration.

Capnography is the reference method to measure RR in the operating room and has been recommended on the wards to detect opioid-induced respiratory depression, particularly when patients receive oxygen. In a large (128,111 patients) retrospective study, Stites *et al.*[38] reported a significant decrease in the number of rescue interventions for naloxone administration after the implementation of continuous capnographic monitoring (with the Alaris end-tidal carbon dioxide module from BD, USA) in postoperative patients receiving opioids (table 1). Unfortunately, nasal prongs are sometimes poorly tolerated or mispositioned by awake patients, resulting in false apnea alerts.

More recently, bed sensors and video cameras have been proposed to monitor heart rate and RR. Bed sensors consist of piezoelectric sensors in plastic pads (contact-free sensor, EarlySense, Israel) to be put under any bed mattress or integrated in modern high-end hospital beds.[42] They "feel" heart beats (using ballistocardiography) and respiratory movements.

Table 1. Large Studies Reporting Clinical Outcome Benefits after the Implementation of Continuous Monitoring on Hospital Wards

Patients, n	Study Type	Monitoring Sensors	Continuous Monitoring	Wireless System	Outcome Benefits	Reference
Postoperative 5,959	Prospective before–after	Pulse oximeter	Spo_2, pulse rate	No	Decrease in rescue events and ICU transfers	Taenzer *et al.*[36]
General 3,747	Prospective before–after	Piezoelectric bed sensor	Heart rate, RR	Yes	Decrease in calls for cardiac arrest and hospital length of stay	Brown *et al.*[37]
Postoperative 128,111	Retrospective before–after	Capnography	RR	No	Decrease in rapid response team events	Stites *et al.*[38]
Medical 4,402	Prospective before–after	Abdominal patch, brachial cuff, pulse oximeter	Heart rate, RR, blood pressure, Spo_2	Yes	Decrease in cardiac arrest, ICU and hospital mortality	Subbe *et al.*[39]
Neurologic and neurosurgical 1,958	Prospective before–after	Electrodes, brachial cuff, pulse oximeter	Heart rate, RR, blood pressure, Spo_2	Yes	Decrease in rapid response team events	Weller *et al.*[40]

ICU, intensive care unit; RR, respiratory rate; Spo_2, oxygen saturation.

They have been used in several clinical studies, including a prospective before–after outcome study[37] showing a significant reduction in calls for cardiac arrest and in hospital length of stay after implementation (table 1). Optical sensors can track chest or abdominal movements to compute RR, as well as subtle changes in skin color (invisible to the human eye) to monitor heart rate (Oxevision, Oxehealth, United Kingdom). However, we are not aware of any published clinical evaluation of such video monitoring systems on medicosurgical wards.

At first sight, bed and optical sensors are appealing because patients are not tied to any device and do not need to wear any sensor. However, they do not follow patients when they leave their bed or their room (*e.g.*, for physiotherapy). We expect most patients to leave their beds as soon and as often as possible to prevent thrombotic complications and bedsores. Early postoperative mobilization is a key element of enhanced recovery after surgery programs. Therefore, mobile monitoring solutions are highly desirable to make continuous monitoring a reality for most inpatients.

Mobile Monitoring Solutions

The ideal mobile monitoring system for ward patients should continuously measure all relevant vital signs, including Spo_2 and blood pressure; should not interfere with daily activities; and should be highly resistant to motion artifact. Such a system does not exist yet. However, several promising monitoring systems have been developed and/or validated over the last decade.[43,44] The combination of a wireless brachial cuff for automatic and intermittent blood pressure measurements, abdominal adhesive patch to capture RR, and finger pulse oximeter to continuously monitor Spo_2 and pulse rate (Intelivue Guardian Solution, Philips Healthcare, USA) has been used with success in a prospective before–after study[39] that reported a significant decrease in cardiac arrests and mortality (table 1). Another monitoring system specifically developed for the wards comprises a finger sensor to measure Spo_2, a wireless brachial cuff for intermittent blood pressure measurements, and chest electrodes for the detection of heart beats (VisiMobile, Sotera, USA). The simultaneous recording of the electrocardiographic and pulse oximetry waveforms enables the calculation of the pulse wave transit time, which is used to continuously estimate blood pressure and/or trigger brachial cuff calibrations. On neurologic and neurosurgical wards, the implementation of this system has been shown to be associated with a significant decrease in the number of rapid response team calls (table 1).[40]

Other "all-in-one" solutions have recently been developed. They include necklaces (CoVa, ToSense, USA; Vitaliti, Cloud DX, Canada), finger sensors (Caretaker4, Caretaker Medical, USA), and adhesive patches (Sensium, The Surgical Company, United Kingdom; LifeTouch, Isansys, United Kingdom; VitalPatch, VitalConnect, USA) integrating accelerometers, photoplethysmographic, piezoelectric, and/or bioimpedance sensors.[43,44,45] They have the advantage of enabling the simultaneous monitoring of several vital signs from a single device. However, none of these sensors is currently able to simultaneously provide all vital signs.[43] In addition, whereas validation studies of wireless adhesive patches showed good results for heart rate monitoring, RR validation has yielded conflicting results, and Spo_2 monitoring from reflective photoplethysmography does not seem ready for prime time.[46–48] Finally, we are not aware of any published outcome study using one of these new "all-in-one" sensors.

Who Should Be Monitored?

A limited number of studies have evaluated the impact of continuous monitoring on hospital wards (table 1). These studies have been performed in heterogeneous medical and surgical populations (receiving opioids or not), so it is still unclear who are the ward patients who may benefit the most from continuous monitoring. A logical approach is the identification of patients at high-risk of postoperative complications. This subset of inpatients could be identified preoperatively using the surgical risk calculator from the American College of Surgeons (riskcalculator.facs.org; accessed February 3,

2021) or scores predicting postoperative morbidity, such as the SORT-morbidity score.[49] Postoperatively, once patients are admitted on the wards, vital sign spot checks and early warning scores are classically used to identify patients at high risk of deterioration.[26] Laboratory data may help as well with the detection of acidosis, dyskalemia, changes in troponin, creatinine and lactate. The recently published PRediction of Opioid-induced respiratory Depression In patients monitored by capnoGraphY (PRODIGY) study[14] focused on patients receiving opioids and identified several factors associated with the occurrence of respiratory depression events. These factors (age, sex, opioid naivety, sleep disorders, and heart failure) were used to develop a score which positive predictive value ranged between 54 and 65%. Overall, the sensitivity and specificity of predicting severe adverse events of the above-mentioned tools and scores are somewhat disappointing. In the future, machine learning–derived scores, such as the eCART or the HAVEN score, may help us to fine-tune the prediction of clinical deterioration and hence to better select patients who should benefit the most from continuous monitoring.[26,35,50]

Challenges Ahead

Although continuous monitoring solutions are emerging and may be the next major opportunity to improve patient safety,[51] there are several challenges ahead.

Sensor Accuracy and Connectivity

The accuracy of sensors used to monitor vital signs is not always demonstrated by peer-reviewed independent clinical studies.[52] Clinical validation studies are scarce, and some have yielded somewhat disappointing results, particularly regarding RR monitoring.[46–48]

Robust connectivity might be an issue as well. Bluetooth and Zigbee require a gateway device as a bridge to the hospital network, and connections are not always as robust as expected, raising safety concerns. Several companies are therefore developing their own connectivity protocols to avoid monitoring disruptions. In the future, machine-to-machine solutions developed for the "Internet of Things" may allow bypassing of hospital networks by enabling data transfer directly from the sensor to cellular (4G/5G) networks. This approach may become indispensable when envisioning home monitoring after hospital discharge.

Nurse Workload and Alarm Management

The impact on nurse workload is another potential issue, particularly during the implementation phase. Nurses may fear that the new technology overwhelms their profession, that their ward will become like an ICU with all the extra displays and alarms but without the high nurse-to-patient ratio and immediate availability of a physician. The development of command centers, centralizing monitoring information from all hospital wards may actually contribute to decrease nurse workload but requires dedicated and trained staff.[44] Nurses may also fear that the availability of continuous monitoring will become an incentive to discharge sooner patients from overcrowded ICUs, resulting in higher workload, thus negating the safety benefits of continuous monitoring. These fears need to be carefully addressed when implementing continuous monitoring systems on the wards.

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%.[53] This would clearly be unacceptable on hospital wards. Several solutions may be considered to decrease false alarms and prevent alarm fatigue. First, motion detection (*e.g.*, with accelerometers) and machine learning algorithms may help to filter artifacts.[54] Second, monitoring could be tailored to the clinical situation and limited to selected vital signs. For example, in patients receiving opioids, we could limit monitoring to respiratory variables (Spo_2 and RR), whereas in patients at high-risk of postoperative bleeding (*e.g.*, patients with coagulation disorders), we could simply monitor heart rate and blood pressure. Third, alarm settings need to be reinvented for ward use. For instance, it has been suggested to personalize thresholds (preoperative vital signs may be very different from one patient to the other) and to use alarms on trends or deviations from baseline values.[55,56] Because physiologic variables may vary throughout the surgical journey, one may also propose to use different thresholds immediately after surgery *versus* a few days later, during the day *versus* during the night, or during physiotherapy *versus* at rest.[56] Increasing annunciation delay intervals may be appropriate in ward settings and can also help to decrease false alarms and prevent alarm fatigue.[40,56] An annunciation delay of 5 min, considered unacceptable in ICU patients, would still provide on the wards 48 to 72 times more vital sign data than spot checks done every 4 to 6 h.

In the ideal ward, nurses should be able to focus on deteriorating patients (a minority of patients on hospital wards) and let stable patients recover in a calm environment where priority is given to quality of sleep and interactions with physiotherapists, psychologists, nutritionists, families, and friends to optimize recovery, improve patient satisfaction, and fasten hospital discharge. In this respect, alarms should be banned from patient rooms and received in a command center or/and directly on the pager or smartphone of caregivers. This may require regulatory changes.

Coordinated Response to Clinical Deterioration

To be effective, the early detection of clinical deterioration (also referred to as the "afferent limb" of rapid response systems) must be followed by an early and appropriate intervention (the "efferent limb").[57] Therefore, the transition to using technology for continuous patient monitoring should be combined with dedicated training programs for both nurses and physicians. The structure and organization of ward and rapid response teams often vary from one hospital to another, and, in any case, roles and responsibilities must be clearly defined. Command centers with remote observers may also help to ensure timely and coordinated response to clinical deterioration.

Economic Impact

Very few studies have investigated the economic impact of continuous monitoring on the wards. The cost may vary from one monitoring system to another and from one country to another. In any case, the estimation of the return on investment should take into account potential savings associated with a decrease in serious adverse events and ICU transfers. Moreover, the societal costs of both transient and permanent severe complications may extend well beyond hospital discharge, for example the costs of life-long nursing care for permanent neurologic injury after a cardiac arrest. One study[58] investigated the economic impact of the implementation of a continuous monitoring system in the medical–surgical ward of a U.S. community hospital. Savings were estimated to range between $224 and $710 per patient, with a hospital breaking even on the investment after 6 to 9 months.[58] High-quality studies are warranted to assess the cost-effectiveness of continuous monitoring on the wards.

Conclusions

Too many unexpected deaths still occur on hospital wards. Because of the low nurse-to-patient ratio and the intermittent nature of monitoring, clinical deterioration may be overlooked for hours. More and more solutions become available for continuous monitoring on the wards, and several before–after studies have reported a decrease in the number of ICU admissions, rescue interventions, cardiac arrests, and deaths after implementation. However, which ward patients may benefit the most from continuous monitoring remains to be clarified, and large randomized controlled trials are necessary to confirm the clinical outcome benefits, as well as to assess the impact on patient satisfaction, nurse workload, and hospital finance.

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Competing Interests

Dr. Michard is the founder and managing director of MiCo (Denens, Switzerland), a Swiss consulting and research firm. MiCo does not sell any medical product, and Dr. Michard does not own shares nor receive royalties from any medical device company. Dr. Kalkman received grant funding from the European Commission for a competitive precommercial procurement project (Nightingale, grant No. 727534) to facilitate industry to develop advanced wireless wearable monitoring systems.

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ANESTHESIOLOGY REFLECTIONS FROM THE WOOD LIBRARY-MUSEUM

Vapo-Cresolene: A Dangerous Beauty Redeemed

At the turn of the twentieth century, the attractive kerosene-fueled vaporizer lamp and *cresol* solution known together as Vapo-Cresolene (*center*) caught the public's eye and became famously profitable by capitalizing on fears sparked by the germ theory. British surgeon Joseph Lister had sprayed carbolic acid on his patients and himself to reduce the risk of infection. Since cresol, like carbolic acid, was also a byproduct of coal tar distillation, it was assumed to have similar antiseptic properties. Thus, cresolene was disingenuously marketed as an air purifier and a respiratory cure (*left* and *right*). Recognizing the perils of this phenol-derived puff of smoke, the American Medical Association published a 1908 report exposing Vapo-Cresolene's propensity to cause respiratory distress, muscle weakness, and coma. The Food and Drug Administration similarly cautioned the public in its traveling "Chamber of Horrors" exhibit in 1933. Not tempted to administer Vapo-Cresolene's vapors to their patients, many anesthesiologists repurposed the alluring kerosene lamp and tin tray to sterilize local anesthetic solutions before spinal injection. (Copyright © the American Society of Anesthesiologists' Wood Library-Museum of Anesthesiology.)

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