ARTICLE IN PRESS
EJINME-03688; No of Pages 5
European Journal of Internal Medicine xxx (2017) xxx–xxx
Contents lists available at ScienceDirect
European Journal of Internal Medicine
journal homepage: www.elsevier.com/locate/ejim

Technological aided assessment of the acutely ill patient – The case of postoperative complications

C. Haahr-Raunkjær [a,b,*], C.S. Meyhoff [b], H.B.D. Sørensen [c], R.M. Olsen [c], E.K. Aasvang [a]

[a] Department of Anesthesiology, The Abdominal Centre, Rigshospitalet, University of Copenhagen, Copenhagen, Denmark
[b] Department of Anaesthesia and Intensive Care, Bispebjerg and Frederiksberg Hospital, University of Copenhagen, Copenhagen, Denmark
[c] Biomedical Engineering, Department of Electrical Engineering, Technical University of Denmark, Kgs. Lyngby, Denmark

ARTICLE INFO

Article history:
Received 6 September 2017
Received in revised form 22 September 2017
Accepted 24 September 2017
Available online xxxx

Keywords:
Technological
Postoperative complications
Perioperative care
Monitoring
Continuous monitoring

ABSTRACT

Surgical interventions come with complications and highly reported mortality after major surgery. The mortality may be a result of delayed detection of severe complications due to lower monitoring frequency in the general wards. Several studies have shown that continuous monitoring is superior to the manually intermittent recorded monitoring in terms of detecting abnormal physiological signs. Hopefully improved observations may result in earlier detection and clinical intervention. This narrative review will describe current monitoring possibilities for postoperative patients and how it may prevent complications.
Several wireless systems are being developed for monitoring vital parameters, but many of these are not yet validated for critically ill patients. The ultimate goal with patient monitoring and detect of events is to prevent postoperative complications, death and costs in the health care system. A few studies indicate that monitoring systems detect deteriorating patients earlier than the nurses, and this was associated with less clinical instability. An important caveat of future devices is to assess their effect in relevant patient populations and not only in healthy test-subjects. Implementation of novel technologies is expensive although expected to be cost-effective if just few adverse events can be prevented. The future is here with promising devices and the possibility to give an unprecedented precise risk estimation of adverse post-surgical events. Next step is to integrate existing evidence based treatment algorithms to demonstrate the clinical efficacy of implementing the new technology.

1. Introduction

An estimated >230 million cases of major surgery are performed worldwide annually [1] with the main objective to relieve disease and discomfort and increase health. However, surgical interventions come with an inherent risk of complications not only during the intraoperative phase, but most commonly in the postoperative recovery phase. These complications are due to organ-dysfunctions in the form of impaired circulation, respiration or infections, whereof many are potentially related to an increased surgical stress response [2]. The implementation of enhanced recovery programs (ERPs) has had a significant impact on surgical outcomes across procedures. However, complications still occur in up to 15–30% of all patients undergoing major abdominal surgery. Severe morbidity (sepsis, cardiac arrest, myocardial infarction or pneumonia) is most often noted within the first 30 days postoperatively [3], with increasing risk in conjunction with increasing pre-operative co-morbidity, as evidenced by a 30% risk in ASA III (American Society of Anaesthesiologists, physical status classification system), and about 50% in ASA IV patients [4,5], and particularly in the acute surgical setting [6]. These numbers correspond to the reported high postoperative in-hospital mortality, 8–9% after major upper abdominal surgery [7,8], again increased in case of co-morbidities such as chronic obstructive pulmonary disease [3]. This underlines the need for further improvements of perioperative care and especially in high risk patients (Table 1).

Part of the high morbidity and mortality may be a result of delayed detection of severe complications due to the lower monitoring frequency in the general wards compared to the Post Anesthesia Care Unit (PACU) and Intensive Care Unit (ICU). This may result in progression of the underlying pathological condition and ultimately a need for more intense treatment once the complication is discovered, which again leads to increased and persistent harm. Therefore, improved observation may result in earlier detection and subsequently the possibility to implement interventions to divert a negative trajectory and ultimately reduce morbidity and mortality [9].

Early detection to identify patients on a negative recovery path in the wards has been attempted by introducing the national Early Warning Score (EWS) [10]. The EWS is developed to direct staff attention towards patients who are in risk of deterioration, by the recording of 6 physiological parameters (respiratory rate, blood oxygen saturation,

* Corresponding author at: Department of Anesthesiology, The Abdominal Centre, Rigshospitalet University of Copenhagen, Blegdamsvej 9, DK-2100 Copenhagen, Denmark.
E-mail address: Haahr-Raunkjaer@regionh.dk (C. Haahr-Raunkjær).

https://doi.org/10.1016/j.ejim.2017.09.031
0953-6205/

Please cite this article as: Haahr-Raunkjær C, et al, Technological aided assessment of the acutely ill patient – The case of postoperative complications, Eur J Intern Med (2017), https://doi.org/10.1016/j.ejim.2017.09.031

Table 1
Current vital parameter assessment and examples of postoperative complications.

Organ system	Physiology	EWS vital parameter	Desired parameter	Clinical comment	Common findings in postoperative myocardial infarction	Common findings in postoperative pneumonia sepsis
A – airway	Open airway	None	–	May be detected through alertness, but obstruction and risk of aspiration not assessed	–	Unprotected in exhausted patients
B – breathing	Oxygenation	SpO2 + supplemental oxygen	SpO2	Desaturations are common and occur rapidly between measurements	Possible desaturation	Severe desaturation
	Ventilation	RF	PaCO2 RF	Does not correlate well to PaCO2	Increased	Severely increased
C – circulation	Preload	None	Fluid status + Hb	Optimal volume status and haemoglobin important	Potential imbalance	Hypovolaemia
	Contractility	HR	Stroke volume Ischaemia	Postoperative ischaemia common and undetected Tachycardia can be due to pain as well as compromized cardiac function	Tachycardia due to decreased stroke volume Ischaemia	Tachycardia
	Afterload	SBP	SBP, DBP and MAP	May decline rapidly between measurements	Low	Very low
D – disability	Alertness	AVPU	AVPU/GCS		–	Compromized
	Pain	None	NRS		Often asymptomatic	–
E – exposure	Temperature	Temperature	Temperature	Peripheral Tp not always accurate	–	High or low
	Other organ dysfunctions		Other organ dysfunctions	Renal, hepatic, endocrine function and infection	Compromized	Compromized

Hb, haemoglobin; AVPU, alert/verbal/pain/unresponsive; GCS, glascow coma score; NRS, numerical rating scale; SBP, systolic arterial blood pressure; DBP, diastolic blood pressure; MAP, mean arterial pressure, HR, heart rate; RF, respiratory failure; Tp, temperature.

heart rate, systolic blood pressure, body-temperature and consciousness), and whether supplemental oxygen is administered. The parameters are monitored at least every 12 h with instructions on closer assessment depending on the severity of the combined outcome [11, 12].

However, saturation measurements performed during nurses rounds on postsurgical patients failed to identify up to 90% of severe desaturations, defined as values below 85%, when compared to continuous automatic recordings [13]. Patients with abnormal vital signs are at higher risk of death in the hospitals compared to patients with normal vital signs. The reason for this is probably a combination of altered physiology and the lack of awareness of patients with abnormal vital signs among the nurses [14]. The authors point out a possible explanation as the lack of systematic monitoring of patients in the general wards. Conversely, the clinical effect of the EWS has been repeatedly questioned. In a 180.000 patient observational study of EWS data collected over 12 months, corresponding to >3 million EWS entries, 10% of all records were incomplete with values for one or more EWS variables missing, concluding that the EWS outcome was highly influenced by staff practice when data was manually recorded and entered [15]. Part of the lack of clinical effect from the EWS may be explained by the lack of adherence to EWS observation escalation protocols. Thus in cases with unplanned ICU admittance or cardia arrest, full adherence was only found in 92% of the cases [16]. The authors suggest that the lack of adherence may be due to the low staff vs patient ratio in the general wards with inability to fulfil the more intense (30 min.) observation criteria. In this setting, an automated observation with computer algorithm based alarms and suggestions for interventions may be superior to current practice even in low staff settings.

Due to the potential for assessment of preoperative risk factors and control of the surgical trauma and perioperative care, the postoperative setting provides an optimal environment for investigation of the potential and effect of optimized monitoring including detection of deterioration. Thus, this narrative review will primarily discuss the status, advantages and shortcomings of current practice of monitoring of physiologic variables. Secondly, the potential for future technological advancements such as automatic monitoring of vital parameters and adequate guidance of health personnel will conclude this narrative review.

2. Saturation

Low arterial oxygen saturation can result from a range of different factors such as atelectasis, alveolar hypoventilation, obesity, use of opioids and sedatives, as well as new pulmonary pathology such as pneumonia and pulmonary oedema, all of which may be present in the postoperative phase [17,18] with potential for subsequent organ dysfunction due to ischemia. Pulse oximetry is nowadays a standard clinical method for assessing arterial oxygen saturation. Is it measured non-invasively by the pulse oximeter, and provides a pain-free, assessment of arterial oxygen saturation [19]. Although pulse oximetry improves the ability to detect hypoxemia and reduce episodes of ischemia in the operation room and PACU, no reduction in overall rate of postoperative complications has been found using this methodology [20], possibly because the majority of these occurs in the wards when patients are not monitored. Recent studies comparing use of intermittent recordings with continuous monitoring show that the incidence and severity of postoperative hypoxemia is underestimated [21,22]. Therefore, only 10% of all severe episodes of hypoxemia (SpO2 <85%) detected by continuous monitoring were detected during nurses´ rounds in a prospective study with 830 patients [13]. However, the above mentioned studies fail to provide information regarding the clinical relevance of these findings, as no data on adverse outcomes (myocardial infarction, cardiac arrest, stoke etc.) were presented. The consequences of hypoxia are expected to be adverse as some data demonstrate a possible link between hypoxaemia and tachycardia, but the studies are unable to

Please cite this article as: Haahr-Raunkjær C, et al, Technological aided assessment of the acutely ill patient – The case of postoperative complications, Eur J Intern Med (2017), https://doi.org/10.1016/j.ejim.2017.09.031