# Monitoring of High- and Intermediate-Risk Surgical Patients

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# Monitoring of High- and Intermediate-Risk Surgical Patients

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"Failure to rescue" refers to the observation that factors predicting postoperative complications are different than factors predicting overall in-hospital mortality. Ghaferi et al[1] investigated this concept by analyzing the records of 269,911 patients undergoing high-risk surgical procedures. The authors found that complication rates between hospitals were similar; however, some hospitals had a 2.5-fold higher mortality rate than others (8.0% vs 3.0%), suggesting that adequate rescue of deteriorating patients depends on how well the hospital system is organized to manage postoperative complications.

Rapid Response Systems (RRS) were developed to provide a structured and timely response to deteriorating patients.[2] RRS are subdivided in 2 parts (Figure 1): an afferent and an efferent arm. The goal of the afferent arm is an early recognition of deteriorating patients by monitoring patients on the ward. The purpose of the efferent arm is to provide a coordinated and adequate treatment plan for deteriorating patients by a Rapid Response Team (RRT).

The American Heart Association and the Society of Critical Care Medicine recommend using RRS in every general hospital. However, whether RRS actually improve patient outcome is still debatable and needs further investigation.[2,3] To improve patient outcome, all parts of the RRS should function appropriately. In this review, we discuss all separate elements and respective challenges of the RRS and make suggestions for possible further local improvements for the daily clinical setting.

## AFFERENT ARM OF THE RSS

The afferent arm of the RRS provides a safety net for recognizing deteriorating patients on the ward. Early recognition of a deteriorating patient might provide an opportunity to prevent adverse events (AEs) by establishing a rapid diagnostic and/or treatment plan before the patient deteriorates further. The afferent arm of the RRS consists of several parts: monitoring and surveillance of patients on the ward, understanding how to interpret vital signs, and awareness by the ward staff of the seriousness of physiological instability in postoperative patients. Knowing the criteria for activation of a RRT and its actual activation are also part of the afferent arm.

### Monitoring and Surveillance of Patients

Monitoring means the detection of abnormality by an ongoing assessment of a patient's well-being and acting on it. In contrast, surveillance is the assessment of the patient's well-being, without action in case of deterioration. Monitoring vital signs might improve early detection of patient deterioration because AEs are preceded by changes in vital signs in most patients. Ludikhuize et al[4] investigated changes in vital signs in hospitalized patients before a serious AE (SAE), like cardiopulmonary arrest or an unplanned intensive care unit (ICU) admission, took place. In 81% of the patients, a change in vital signs was seen at least once in the 48 hours before the event; the percentage of deviating vital signs increased closer to the event.

Not all patients can be monitored continuously on a high-care unit because of limited resources. A bedside evaluation tool for monitoring vital signs on the ward is the Early Warning Score (EWS). The EWS was introduced in 1997[5] as a simple scoring system by recording 5 vital variables: blood pressure, heart rate, respiratory rate, temperature, and consciousness. The patient is identified at risk for critical events when his or her vital variables are deranging from predetermined baseline/cutoff scores. Each vital sign that deviates from what is regarded as normal corresponds to specific points of the EWS. By adding these points, a total score is calculated. Since introduction of the EWS, a range of different EWSs has been developed. A widely used EWS is the Modified EWS (MEWS; Table 1). The cutoff points of the MEWS are slightly different from the EWS, and urine production is added to the vital variables.[6]

It is recommended, although seldom practiced, that vital signs/MEWS measurement takes place at least once every 6–12 hours on the ward. Cardona-Morrell et al[7] observed monitoring vital signs practices on the ward and found that measuring all 5 variables on the ward was performed in only 6%–21% of the patients. Conclusively, even though MEWS was elevated, adequate documentation of respiratory rate, diuresis, and oxygen saturation was frequently missing.[4]

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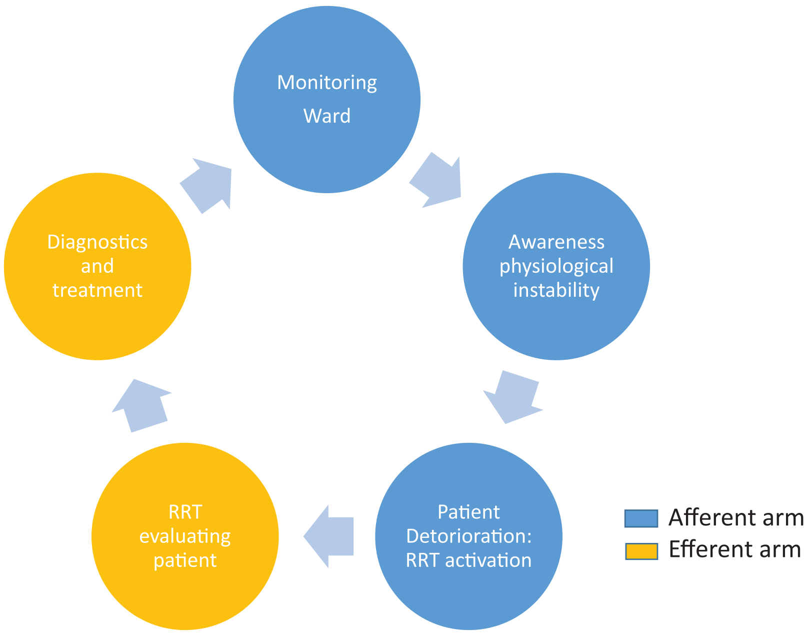


**Figure 1.** Afferent and efferent arm of an RRS. RRS indicates Rapid Response Systems; RRT, Rapid Response Team.

**Table 1. Modified Early Warning Score**

| | Modified Early Warning Score | | | | | | |
|---|---|---|---|---|---|---|---|
| Score | 3 | 2 | 1 | 0 | 1 | 2 | 3 |
| RespR | … | <9 | … | 9–14 | 15–20 | 21–30 | >30 |
| Puls | … | <40 | 40–50 | 51–100 | 101–110 | 111–130 | >130 |
| Syst BP | <70 | 70–80 | 81–100 | 101–200 | | >200 | … |
| Oxygen saturation | <90 | … | … | … | … | … | … |
| CNS | … | … | … | A | V | P | U |
| Urine | … | <75 mL/4 h | … | … | … | … | … |

Abbreviations: A, awake; CNS, central nervous system; P, response to pain stimulus, oxygen saturation (%); Puls: heart rate (beats/min); RespR, respiratory rate (breaths/min); Syst BP, systolic blood pressure (mm Hg); U, unresponsive; V, response to verbal stimulus.

## Awareness of Physiological Instability in Postoperative Patients by Ward Staff

Timely and accurate monitoring of vital signs is a crucial first step in providing adequate input for EWS systems. After the registration of vital signs, nurses need to appropriately interpret deviating vital variables to recognize deteriorating patients. However, the ward staff's limited understanding of the pathophysiology of deteriorating patients hampers adequate interpretation of the recorded observations.

Changes in respiratory rate seem to be the most important predictor of clinical deterioration. Mok et al[8] assessed nurses' attitude toward vital signs monitoring on the ward. They found that respiratory rate was actually regarded as the least important vital sign. To evaluate respiratory function, nurses relied on oxygen saturation only, whereby respiratory rate was just estimated. Nurses have a bias in reporting respiratory rates toward 18–22 breaths/min. These numbers are often estimated or based on previous ratings, rather than actually measured.[9] A change in blood pressure was regarded as the first indicator of patient deterioration. This vital sign is measured most often on the ward.[4] However, blood pressure is often measured with inadequate positioning of the cuff or patients' arm, resulting in inaccurate values. In addition, blood pressure derangement is a late sign of patient deterioration and blood pressure is less useful than other vital signs in predicting AEs.

Furthermore, vital sign measurement by nurses is not always given the priority it deserves. Therefore, this task is often delegated to students or health care assistants that are not trained in interpretation of the respective vital sign values.

## Activation Criteria of a RRT

In literature, the term "Afferent Limb Failure" (ALF) describes a phenomenon whereby a patient presents deviating vital signs for which a RRT should be called, but, in fact, this is not done. The prevalence of ALF is around 22%. Both, nursing and organizational aspects influence RRT activation.

Regarding the nursing aspect, De Meester et al[10] studied circumstances on the ward before a SAE took place. Frequently, nurses were not aware that their patient was actually deteriorating before the SAE happened. Possible explanations for these findings were an excessive workload and/or inadequate training of nurses.

An organizational aspect that contributes to ALF concerns the availability of multiple EWS systems. These EWS systems use different cutoff points for vital signs and are therefore prone for making mistakes. Table 2 illustrates an example for different cutoff points for respiratory rate. Consequently, the MEWS is often miscalculated, whereby more underscoring than overscoring calculation errors are reported, resulting in ALF and a failure to recognize deteriorating patients.

**Table 2. Early Warning Scores, Different Cutoff Scores for Respiratory Rate**

| Study | EWS System | Points 3 | Points 2 | Points 1 | Points 0 | Points 1 | Points 2 | Points 3 |
|---|---|---|---|---|---|---|---|---|
| Royal College of Physicians[11] | NEWS(2) | ≤8 | … | 9–11 | 12–20 | … | 21–24 | ≥25 |
| Morgan et al,[5] Stenhouse et al,[6] and Subbe et al[12] | (M)EWS | … | <8 | … | 9–14 | 15–20 | 21–29 | >30 |
| Pittard[13] | Modified MEWS | … | <8 | 8–11 | 12–20 | 21–25 | 26–30 | >30 |
| Mathukia et al[14] | Modified MEWS | … | <8 | 8 | 9–17 | 18–20 | 21–29 | ≥30 |
| Day[15] | Derby MEWS | <6 | 6–8 | … | 9–14 | 15–20 | 21–29 | >30 |
| Hodgetts et al[16] | Activation RRT | 8–9<br>4 pt: <8 | 10–11 | … | … | 21–25 | 26–30 | 31–36<br>4 pt: >36 |
| Goldhill et al[17] | PaR EWS | … | <10 | … | 10–19 | 20–29 | 30–39 | ≥40 |

Abbreviations: EWS, Early Warning Score; MEWS, Modified Early Warning Score; NEWS, National Early Warning Score; PaR, Patients at Risk; RRT, Rapid Response Team.

In addition, not all EWS are developed according to established procedures, with little evidence for their reliability, validity, and utility. The original trigger thresholds for each vital sign of the EWS are based on an unknown number of ICU patients.[5] The cutoff points of the MEWS are based on the study by Morgan et al[5] in combination with the vital signs of 206 surgical patients admitted to an ICU. However, how the authors of both studies exactly established the cutoff points and the values regarded as normal is not further described in their articles. Thereafter, the ability of the (M)EWS to identify patients at risk for AEs was evaluated.[12] These studies are mainly based on medical patients and evaluated neither cutoff points nor values regarded as normal. However, it remains to be proven whether normal values of vital variables or the cutoff points of the original ICU patients could be extrapolated to the vital variables of surgical patients in the postoperative period. Many confounding factors in the postsurgical period may influence vital signs. For instance, pain and pain medication might compromise respiratory rate.[18] Normal ranges of vital signs in the postoperative period should be established.

### Afferent Arm Improvement

The afferent arm is a bundle of complex interventions, where each individual part of the bundle has to function properly to early recognize patient deterioration. As highlighted in the previous part, existing shortcomings must urgently be improved: the frequency and accuracy of measuring vital signs, the ward's staff awareness, and knowledge of physiological instability, uniformity of the MEWS, and its validation for perioperative patients.

Education of ward staff is key to improving the afferent arm. A systematic review by Connell et al[19] showed that educational interventions resulted in reduced time to recognize patient deterioration and to activate the RRT. Ward staff training should focus on explaining the RRS, the necessity of adequate vital signs measurement, interpretation of vital signs, determination of clinical urgency, and how and when to activate the RRT. These skills should be practiced in simulation sessions.[19] Changing clinical practice is a long-lasting process, but regular training of ward staff and incorporating their feedback will hopefully increase compliance with the RRS and will eventually lead to improved patient outcome.

Remote monitoring is another option to improve the afferent arm. Measuring vital signs using this new technology might support nurses in monitoring patients adequately.[2]

## REMOTE WIRELESS MONITORING

A remote monitoring system is a technology whereby patients wear a noninvasive sensor that measures physiological variables such as heart rate, blood pressure, temperature, respiratory rate, and arterial oxygen saturation continuously. Data detected by the remote monitoring system are transferred to a central receiver connected to the electronic patient record and/or to a pager system to inform nurses whenever vital signs deviate from normal (Figure 2).

A major advantage of remote monitoring is the continuous measurement of vital signs. Even though measurement of vital signs would routinely be done every 6–12 hours, for large parts of the day, patients would remain unmonitored. Given the current intermittent nature of vital signs measurements, patients can deteriorate in between measurements, leading to unprecedented delays in the detection of emergencies. In postoperative patients, Turan et al[20] measured blood pressure continuously on the ward using a remote monitoring system. Fifty-seven of the 302 monitored patients experienced a period of severe hypotension (mean arterial pressure <65 mm Hg for ≥15 minutes). In 47% of patients, this was missed by routine vital sign assessment. Postoperative hypotension is associated with myocardial infarction and death.[21] Continuous measurement of vital signs by a remote monitoring system can significantly reduce the time to detect abnormal vital sings and might allow faster treatment, thereby improving patient outcome.[22]

Worth mentioning, even use of remote monitoring systems does not guarantee for continuous availability of vital signs information since the incorporated software rejects data when, for instance, vital signs measurement is distorted due to severe motion artefacts. Hence, only accurate data are transferred to the caregivers.[23] Accurate vital signs are available 50%–96% of the time, thus far more frequently than when vital signs are measured manually.[23,24] Fewer motion artefacts might be expected while sleeping, so remote monitoring systems allow for almost continuous measurement of vital signs at night. This is particularly advantageous because it prevents sleep disturbance associated with manual measurements of vital signs during sleep time.[25]

Accuracy of vital signs measurement is another advantage of remote monitoring. Remote monitoring systems measure vital signs accurately. However, before remote monitoring systems are installed on the ward, the accuracy of measurements needs to be further validated. In


**Figure 2.** Illustration of the principle concept of remote monitoring system based on SensiumVitals, Sensium Healthcare, London, UK.[23]

these validation studies, patients are monitored by both a remote monitoring system and by standard bedside monitoring and these measurements are compared with each other for overall agreement.[24] Some systems measure vital signs accurately, like the SensiumVitals system (Sensium Healthcare, London, UK).[23] This is a wireless patch measuring respiratory rate, heart rate, and temperature every 2 minutes. Another remote monitoring system measures heart rate accurately, but respiratory rate not according to the accuracy margins set by the authors.[24] These findings deserve further verification.

A major caveat of remote monitoring systems is false alarms. Those can result in alarm fatigue with caregivers and malfunction of the whole response system. To minimize false alarms, "electronic automated advisory vital signs monitors" are deployed. Instead of an alarm for every single variable, these systems generate alarms based on a combination of deviating vital signs, programmed on the basis of local EWSs. These "smart alarms" help medical staff identifying deteriorating patients, resulting in faster RRT activation.

The introduction of a remote monitoring system on the ward requires a thorough implementation. Caregivers need to realize that the system provides for a reduction in workload because vital signs monitoring is time consuming and stressful, particularly at night, when the nurse:patient ratio declines. Acceptance of this new way of monitoring patients is crucial. If the system is regarded as cumbersome and inefficient, implementation will most likely fail.[26] Nurses should be trained properly in using the remote monitoring system adequately before implementation on the ward, and should be encouraged to give feedback on how the system is organized, and how it could be further improved.[27] The fact that the system contributes to an overall safety net yielding at improving patient outcome cannot be stressed enough. Noteworthy, potential fear of caregivers as to being replaced by the remote monitoring system must be addressed carefully.

Systematic reviews and/or large randomized studies assessing the impact of remote monitoring on patient outcome are sparse. In a recent systematic review, the impact of continuous versus intermittent vital signs monitoring on clinical benefit for patients was compared.[22] The authors concluded that remote monitoring is feasible, improves patient outcomes, and is cost efficient. A large multicenter study assessing the effect of continuous wireless monitoring on disability-free survival 3 months after surgery as measured by the World Health Organization Disability free Survival after Surgery (WHODAS) 2.0 questionnaire (12-item version) started last year at the Amsterdam Univeristy Medical Center, location AMC, and University Medical Center Utrecht, the Netherlands, the "surveillance of high-risk early postsurgical patients for real-time detection of complications using wireless monitoring (SHEPHERD) trial" (ClinicalTrials.gov number: NCT02957825).

## EFFERENT ARM

The efferent arm consists of a quick evaluation of the patient by a medical emergency team and setting up an adequate diagnostic research and/or treatment plan. The efferent arm of the RRS compared with the afferent arm is sparsely studied, probably explained by the challenge to define clinical deterioration end points. For instance, ICU admission can be considered as an undesired event; however, it can also prevent patients from further harm. Also, more deaths after cardiac arrest occur in patients with agreements on "do not attempt resuscitation" and the RRT is a key player in making these arrangements, not resulting in fewer deaths but in a more dignified end-of-life.

The largest randomized trial studying the effectiveness of RRT is the Medical Emergency Response Improvement Team (MERIT) study.[3] Twenty-three hospitals participated in this study. In 12 hospitals, a Medical Emergency Team was introduced and these hospitals were compared to another 11 hospitals with standard care without a RRT. The authors found no overall effect on unplanned ICU admissions, cardiac arrest, or unexpected death. However, this study had major limitations, for example, lack of a uniform implementation of RRTs and a severe lack of statistical power. Thus, this study should be interpreted as a lack of evidence, rather than evidence for a lack of effect of RRT to improve patient outcome.

McNeill and Bryden[28] performed a systematic review to evaluate the effectiveness of medical emergency teams. The authors concluded that a RRT might reduce ICU admission, might reduce cardiac arrest rates, and might improve patient survival. With the exception of the MERIT trial, this systematic review is largely based on before-and-after studies of single centers, so a large part of the scientific evidence is based on moderate- to low-quality studies. More randomized controlled trials are needed; however, because a RRS or RRT is nowadays standard of care in most hospitals, it would be unethical to remove these systems for scientific purposes.

## FURTHER IMPROVEMENTS

Zegers et al[29] reported a 5.7% incidence of AEs in hospitalized patients in the Netherlands. Forty percent of the AEs were preventable. More than half of these AEs were related to surgical procedures. To prevent AEs, the authors recommended a multidisciplinary management related to the diagnostic process and interventions to optimize health care procedures.

Multidisciplinary management implies that a surgeon together with an anesthesiologist, intensivist, or internist is responsible for the postoperative treatment of patients. Traditionally, a surgeon consults the appropriate medical specialist with specific requests. However, often consultations are done with substantial delays, and follow-up of the consultant's recommendations is even more deferred. Communication between the surgeon and the consultant is often minimal. Multidisciplinary management relies on the active role of the complementary specialist. Continuous availability of the surgical counterpart, allowing for minimal treatment delays and substantially reduced communication errors, is essential.

The concept of multidisciplinary management involving an internist or intensivist in a specific surgical patient group has been assessed with promising results.[30,31] In the Netherlands, the "Routine postsurgical anesthesia visit to improve patient outcome" (TRACE) trial addresses the question whether the implementation of a routine postsurgical anesthesia visit to high-risk surgical patients reduces postoperative 30-day mortality.[32] Anesthesiologists are trained to identify deterioration of vital functions in an early phase and are used to work with surgical patients. This study is not restricted to patients of a specific surgical specialty. Study results are expected later this year.

## CONCLUSIONS

Postoperative complications form a major burden to patient outcome and health care. The RRS is developed to offer a structured approach in managing deteriorating patients. All elements of the system should be implemented adequately enabling the system to function appropriately. However, most elements of the system need further improvement, whereby education and training are essential. Remote monitoring systems can support caregivers in the afferent arm of the system by measuring vital signs continuously and most importantly in an accurate manner. Multidisciplinary teams might improve the efferent arm and thus patient outcome. Further research is necessary to more generally evaluate these hypotheses.


## DISCLOSURES

**Name:** Linda Maria Posthuma, MD.
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**Name:** Benedikt Preckel, MD, PhD.
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