PHILIPS

General care

Insights

The impact of Early Warning Scoring systems:

Better health outcomes, lower cost of care, and improved staff, patient and family experience

Unmet needs and solutions: Response to the burden of patient deterioration

Sizing the problem of patient deterioration

Patient deterioration is a significant clinical and financial burden for patients, providers, and healthcare systems.[2] (Figure 1) Clinicians are increasingly treating older, sicker populations at risk for complications and in-hospital adverse events.[3] As the volume of hospitalizations for these patients continues to rise, providers are challenged to manage more acute, resource intensive populations in a resource-constrained environment.[3]

Compounded with a scarcity of beds in higher acuity care areas, patient status may be underestimated, and patients may be admitted or transferred to lower acuity care areas while still at risk for deterioration and resulting serious adverse events.

This scenario may be attributable to a relative lack of resources in lower acuity settings, a significant decrease in nurse to patient ratios, and/or a lack of care coordination. However, evidence of the signs of patient deterioration may be present 6-24 hours prior to an event.[5] For example, 66% of cardiac arrest patients show abnormal signs and symptoms up to 6 hours prior to cardiac arrest, but physicians are only notified 25% of the time.[6] Moreover, nursing staff may be unaware of abnormal vital signs in almost 50% of patients in the general [i.e., lower acuity] ward[7] as they struggle to manage time pressures and work interruptions throughout their shift.[8]

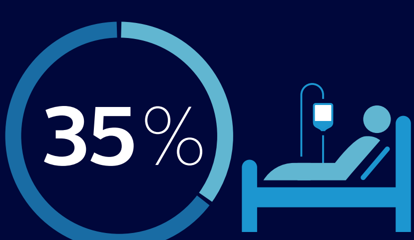
Patient deterioration may also result in a significant direct economic burden for providers. Patients experiencing adverse events are associated with higher direct healthcare costs.[9]

A review of the literature highlights this trend, especially among potentially preventable conditions:

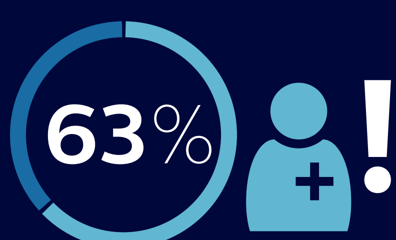
- Surgical complications were associated with a **nearly $20K increase in hospital costs** and a pronounced decrease in contribution margin[10]
- **Median costs associated with sepsis are markedly higher** than in non-septic patients per case ($10K United Kingdom, $23K Germany)[11]
- **$3,580 average cost per day** of hospitalization for recipients of cardio pulmonary resuscitation[12]

Costs related to patient deterioration are also not limited to the direct treatment costs. Patient deterioration may also result in increased operational costs (overhead, capital, nurse turnover) and opportunity costs associated with throughput (unit capacity decreases, missed revenue, contribution margin).

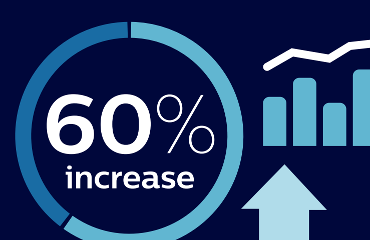
Figure 1: Burden in numbers



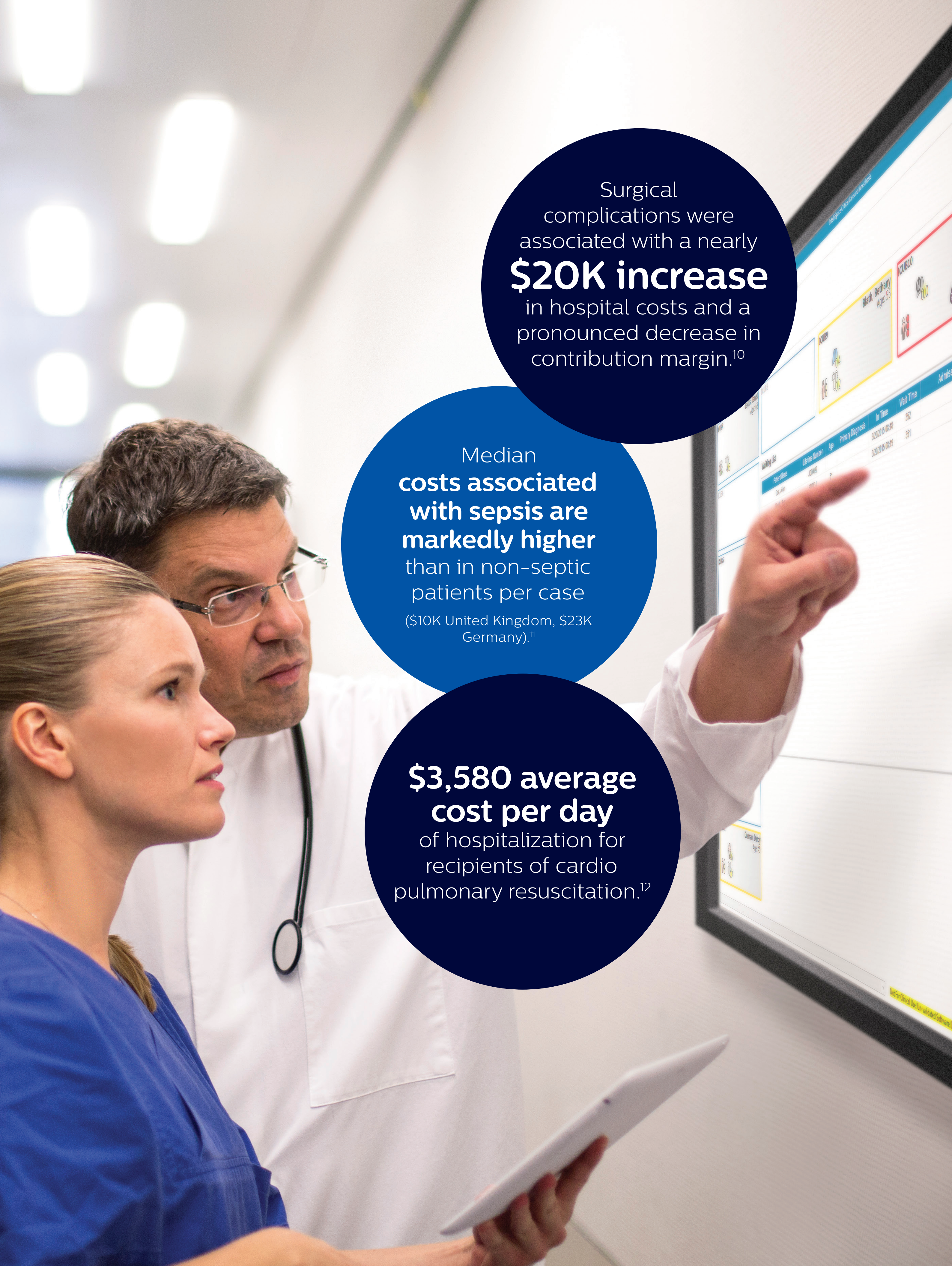
of at-risk patients discharged from the ICU **die on the general ward**.[1]



of preventable deaths are attributable to **failure to rescue by a registered nurse or physician**.[4]



in hospital cost resulting from slower transfer to ICU due to **late deterioration detection**.[5]



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The evolution of Early Warning Scoring systems

The clinical, economic, and operational burden of patient deterioration has driven providers and payers/governments to seek solutions for early patient identification and proactive interventions. The remaining focus on this whitepaper will be to explore early warning scoring systems as an established approach to addressing patient deterioration.

Prior to the codification of early warning scoring systems, single-parameter variation in key physiological measures were used to identify at-risks patients and trigger intervention.[13] However, in upwards of 40% of cases, calls to rapid response teams were based on a general feeling that "something's just not right" with the patient.[13] Standardized early warning scoring systems were designed to take a multi-parametric approach to identifying the subtle signs of deterioration prior to an event.[13]

A variety of early warning scoring systems have been developed as tools used by hospital care teams to recognize the early signs of clinical deterioration in order to initiate early intervention and management, such as increasing nursing attention, informing the provider, or activating a rapid response or medical emergency team.[14] Early warning scoring systems use a combination of physiological parameters and priority weights to assess the probability that a patient is at risk for deterioration.[14]

Early Warning Scoring system penetration and guidelines adoption

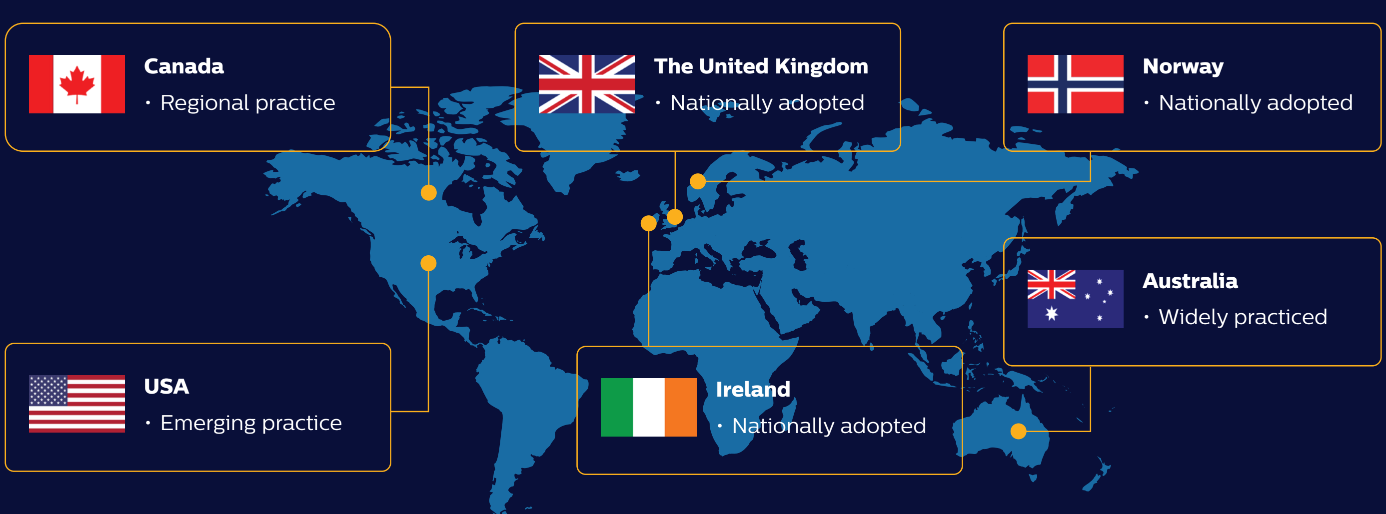
Diffusion and adoption of early warning scoring systems varies based on geography (Figure 2). The United Kingdom has been a leader in the development and implementation of early warning scoring systems. In 2012, the Royal College of Physicians released the National Early Warning Score (updated in 2017), which was endorsed by the NHS England and NHS Improvement.[15] Ireland quickly followed by establishing their own National Early Warning Score in 2013.[16]

Since then, the National Early Warning Score or alternative organization-wide systems to detect and recognize acute patient deterioration, have been has been adapted and adopted to varying degrees by a number of health authorities in systems both on a national level (e.g., Norway) and locally/regionally (Canada, USA, Australia, India). While still an emerging practice in many countries, recognition of the benefits of early warning scoring systems are becoming a reality:

- Inclusion in the Institute of Healthcare Improvement's 5,000,000 Lives Campaign (USA)[13,17]
- Development of the Hamilton Early Warning Score (Canada)[18]
- Piloting of an early warning scoring system (satarkataank) in India[19]

In the following section, the various types of early warning scoring systems will be evaluated, and keys to successful implementation will be addressed.

Figure 2: Uptake of Early Warning Scoring



Early Warning Scoring system implementation: methods, workflow, and conditions for success

Assessment of Early Warning Scoring systems types

Early Warning Scoring Systems have been established to recognize and manage patient deterioration.[21] They are composed of two elements: an Early Warning Scoring System to recognize patient deterioration and a Medical Emergency Team (MET) and/or Rapid Response Team (RRT) to manage deterioration appropriately. "Rapid response systems started as specialized 'cardiac arrest ('code') teams' and progressed to medical emergency teams (MET) and rapid response team models that provide critical care interventions in the presence of unexpected physiological deterioration."[22]

There are over 100 published early warning scoring systems, which can be separated into single-parameter "track and trigger" systems, and multiple-parameter systems.[23] The systems use a scoring table, which assigns a pre-defined risk score to each vital sign measurement.

Other more recent systems use risk-scores based on statistical modelling or are a fully automated implementation of early warning scoring systems, as we will discuss below. Commonly used aggregated scores are the:

- Modified Early Warning Score (MEWS),composed of 5 parameters[24]
- National Early Warning Score (NEWS), composed of 7 parameters[25]
- Electronic Cardiac Arrest Risk Triage (eCART), composed of 30 parameters[26]

NEWS2 is the latest version of the NEWS score, adopted by the UK's NHS, which advocates a system to standardize the assessment and response to acute illness.

The tables presented show the basic composition of the scoring system (Table 1) and resulting clinical responses (Table 2).

Table 1: The NEWS Scoring System[20]

Physiological parameter	Score 3	2	1	0	1	2	3
Respiration rate (per minute)	≤8		9–11	12–20		21–24	≥25
SpO_2 Scale 1 (%)	≤91	92–93	94–95	≥96			
SpO_2 Scale 2 (%)	≤83	84–85	86–87	88–92 ≥93 on air	93–94 on oxygen	95–96 on oxygen	≥97 on oxygen
Air or oxygen?		Oxygen		Air			
Systolic blood pressure (mmHg)	≤90	91–100	101–110	111–219			≥220
Pulse (per minute)	≤40		41–50	51–90	91–110	111–130	≥131
Consciousness				Alert			CVPU
Temperature (°C)	≤35.0		35.1–36.0	36.1–38.0	38.1–39.0	≥39.1	

Table 2: Clinical response to the NEWS trigger thresholds[20]

NEW score	Frequency of monitoring	Clinical response
0	Minimum 12 hourly	• Continue routine NEWS monitoring
Total 1–4	Minimum 4–6 hourly	• Inform registered nurse, who must assess the patient • Registered nurse decides whether increased frequency of monitoring and/or escalation of care is required
3 in single parameter	Minimum 1 hourly	• Registered nurse to inform medical team caring for the patient, who will review and decide whether escalation of care is necessary
Total 5 or more Urgent response threshold	Minimum 1 hourly	• Registered nurse to immediately inform the medical team caring for the patient • Registered nurse to request urgent assessment by a clinician or team with core competencies in the care of acutely ill patients • Provide clinical care in an environment with monitoring facilities
Total 7 or more Emergency response threshold	Continuous monitoring of vital signs	• Registered nurse to immediately inform the medical team caring for the patient – this should be at least at specialist registrar level • Emergency assessment by a team with critical care competencies, including practitioner(s) with advanced airway management skills • Consider transfer of care to a level 2 or 3 clinical care facility, ie higher-dependency unit or ICU • Clinical care in an environment with monitoring facilities

Reproduced from: Royal College of Physicians. National Early Warning Score (NEWS) 2: Standardising the assessment of acute-illness severity in the NHS. Updated report of a working party. London: RCP, 2017.

Some of the existing early warning scores, (MEWS, NEWS, VitalPAC™ Early Warning Score (VIEWS)) were constructed based on expert opinion.[27] Others such as the eCART, an aggregate weighted multi-component early warning score, and the Rothman Index (RI) are derived from statistical modeling.

The NEWS is one of the most-validated scores.[28] Surveys among staff found that NEWS was easy to use, did not increase workload, and enhanced their ability to identify deteriorating patients.[29] A study published in 2018 showed that NEWS and MEWS are more accurate than a single trigger system for predicting in-hospital cardiac arrest, mortality and ICU transfer in adult ward patients within 24h.[21] In this retrospective study, the eCART risk stratification tool turned out to be most accurate in predicting adverse outcomes, compared to NEWS and MEWS.[21] In addition, the eCART may reduce unnecessary Rapid Response calls. As for the Rothman Index (RI), it provides significantly less false positives than MEWS and NEWS.[30] In addition, more sophisticated recent scores such as the Early Deterioration Indicator (EDI)[31] and the Advanced Alert Monitor model (AAM)[27] show initial promising results and will need further validation. Figure 3 provides an overview of commonly used and emerging systems for generating Early Warning Scores.

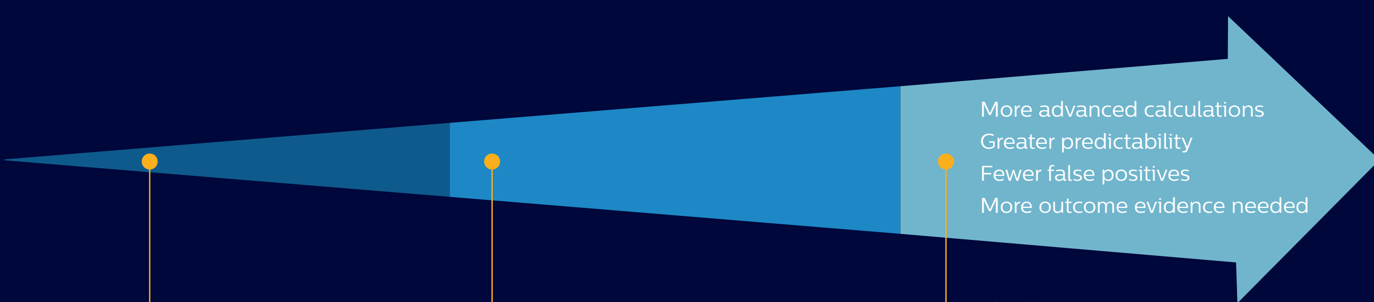
Assessing implementation of Early Warning Scoring systems and workflow integration

Both the recognition and appropriate management of deteriorating patients are essential for improving clinical outcomes. The relationship of EWS to MET or RRT and the inclusion in a caregiver's daily routine are key. In many cases, the combination of nurse-led monitoring with a well-executed protocol for calling RRT is a first step.

A Dutch retrospective record review study did a root cause analysis of unplanned ICU admissions.[32] MEWS had been introduced in the year prior to the study, however, without a clear protocol on how often / when to perform it.

The study showed that almost half of the unplanned ICU admissions from the general ward had healthcare worker related root causes.

Figure 3: Overview of Early Warning Scoring systems



Single parameter track and trigger

Betwen the flags (BTF)[21]
A single parameter will be the trigger (RR, or HR, or SBP, or SpO_2, or unresponsive, or responsive only to pain).

Multiple parameters and scoring tables

Most used

MEWS: 5 parameters (RR, HR, SBP, Temp, level of consciousness).

NEWS: 7 parameters (RR, HR, SBP, Temp, SpO_2, level of consciousness, or confusion).

Assigns a risk score to each vital sign measurement via scoring table.

Multiple parameters and advanced score calculations

Early Deterioration Indicator (EDI): 8 parameters (HR, RR, SBP, DBP, Temp, SpO_2, LOC, age) feeding continuous risk scoring curves. Performed better than NEWS and MEWS but more evidence needed for impact on clinical outcomes.[31]

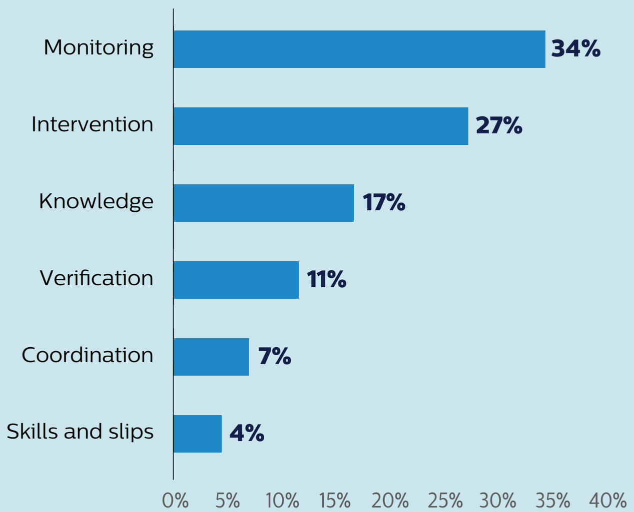
Rothman Index (RI): 26 variables including vital signs, laboratory data, cardiac rhythms, and nursing assessments. Utilizes real-time data to 'calculate new up-to-date RI scores as soon as new entries for any of the input variables are registered in the EMR.[30]

eCART: 30 variables with automatic electronic random forest algorithm combining patient characteristics, observations and laboratory parameters.[21]

Advanced Alert Monitor model (AAM) utilizes machine learning enabled complex modeling tied to the EMR for prediction to increase accuracy.[27]

Of the healthcare worker related root causes, 34% were due to monitoring failures in clinically deteriorating patients. (Figure 4). The study suggests the improvement of the monitoring of patients as a solution.[32]

Figure 4: Health-care worker related root causes for unplanned ICU admission in a Dutch hospital[32]



Human intervention causes were accountable for almost one third (27%) of the healthcare worker related root causes for unplanned ICU admissions. They represent failures resulting from faulty task planning or performance, for example, the case where no intervention was started after the nurse repeatedly mentioned patient's vital signs worsening. Minimizing human interventions where possible can help drive improvements, and evidence suggests that initial RRT alerting may be improved with a real-time electronic dashboard.[33]

However, the topic of health-care related root causes starts with the monitoring of parameters. Indeed, inter-observer-variability can produce inaccurate recordings and user error. Early warning scores were frequently incomplete[34,35] with one or more variables missing in 10% of the cases of a NEWS based system for 168,000 patients.[36] Particularly, for measuring respiratory rate, one of the most significant predictors of deterioration, a prospective observational study showed that electronic measurements are likely to be more reliable.[37] Moreover, the design of implementation strategies needs to be optimized to improve nurse practice.[38]

Burns et al. also show the benefits of enhanced early warning systems for nurses, including an increased awareness of changes in patient condition resulting in earlier response and reassessment times.[39] For the organization, it results in improved communication and collaboration as well as a culture of proactive response (as opposed to reactive).[39] It is key to define and communicate an optimal integration into the workflow of healthcare providers.

Additionally, educational programs may help improve the efficacy of EWS systems. These may include interactive e-learning, on-site, interdisciplinary EWS systems training sessions and simulated scenarios.[40] Research is needed to validate each method.

Conditions for successful implementation of Early Warning Scoring systems

The successful utility of an early warning system in meeting the goal of prediction and early intervention depends on many factors. This is why some the early systematic reviews available on early warning systems have shown ambiguous results (see also section III).

Key elements for a system to be successful are the ability of both the afferent arm (detecting deterioration) and the efferent arm (a fast and appropriate response to deterioration) to perform well together.

This means finding a balance between ease of use, sensitivity of the system to deterioration, low false positive rates[30] on the afferent arm, and ability to see trends of vital signs, to change or suspend a calling criterion and the simplicity of the tool used[21] on the afferent arm. Automation of EWS systems may help to minimize user errors and aid communication between clinical staff.[41]

Clinical staff engagement[41] has been identified as a potentially important element that needs to be researched further. One to one interactions with the patient have also been mentioned as important to capture more subjective aspects about patient well-being, in addition to (continuous) monitoring systems.[42] It has been demonstrated that nurse worry or concern may be more effective than vital parameters monitoring alone.[43]

In addition, ease of use is key to clinical adoption and monitoring systems should be made seamless and intuitive for users.[51] Monitoring should not increase workload at the hospital level but rather redistribute it with more adverse events managed by ward clinicians and less by critical care specialists.[51]

Ideally, every patient would receive ICU-style continuous monitoring rather than intermittent monitoring,[41] particularly for heart and respiratory rates.[52] And yet, it is clearly not feasible to implement continuous monitoring in the general ward due to the need for patients to be mobile and the costs. However, continuous tracking of certain parameters is now possible via wearable wireless devices or contactless sensors.

Finally, another key enabler is to take patient and provider heterogeneity into account.[50]

Optimizing implementation lays the foundation for success. The following section will explore the outcomes and benefits of early warning scoring systems.

Figure 5: Supporting successful implementation

Event detection and trigger
Supporting ease of use
Electronic charting of EWS[44]
Deterioration index, color coding for simplified interpretation[45]
Automatic score computation[46]
Predictive algorithms for risk stratification[46]
Machine learning to filter artifacts and decrease false alarms[46]
EMR based alerting dashboards[47]
Intervention
Optimizing patient management
Pro-active RRT rounding[48]
Inclusion in SOP[49]
Incorporate patient and provider heterogeneity[50]
Management by ward clinicians[51]

Benefits associated with Early Warning Scoring systems

Evaluating clinical outcomes linked to Early Warning Scoring systems

Early warning scoring systems make intuitive sense and have strong validity.[28,53] Early warning scoring systems have also been tested in numerous clinical trials over the past 20 years. Their effectiveness has been examined using a variety of outcome measurements including in-hospital mortality, unanticipated ICU admission, incidence of cardiopulmonary arrest, ICU mortality, and hospital and ICU length of stay (LoS).

Systematic reviews often look at in-hospital mortality and cardiopulmonary arrest as endpoints. Table 3 summarizes the findings of nine systematic reviews. While the slightly older systematic reviews showed rather mixed results, reviews that are more recent conclude that EWS systems are effective at reducing cardiorespiratory arrest and mortality.

More recent individual studies in adult patients confirm these favorable results regarding in-hospital mortality[63,64] and cardiopulmonary arrest.[63,64,65] Among these studies is also a large prospective Dutch multicenter before-after trial involving twelve hospitals with in total 166,569 adult patients representing 1,031,172 hospital admission days.[64]

Some studies have also looked into ICU readmissions. The Dutch multicenter before-after trial found a declining trend for unplanned ICU admissions whereas severity of illness at the moment of ICU admission was not different between periods.[64] A retrospective study in a German university hospital saw a significant reduction in unplanned ICU readmissions.[65]

These positive clinical outcomes typically go hand-in-hand with an increased utilization of the RRT.[63,65]

Electronic systems (like the Philips IntelliVue MP5SC monitor or IntelliVue GuardianSoftware) that automate EWS workflows can help to improve outcomes even further:

- In a large multi-center before-and-after controlled trial (ten hospitals in the United States, Europe, and Australia; a cohort of 18,305 patients in total), Bellomo et al. studied the effects of the deployment of electronic automated advisory vital signs monitors. Intervention was associated with a decrease in median length of hospital stay in all patients (unadjusted $p < .0001$; adjusted $p = .09$) and more so in U.S. patients (from 3.4 to 3.0 days; unadjusted $p < .0001$; adjusted ratio[46] [95% confidence interval] 1.03 [1.00–1.06]; $p = .026$).
- Subbe et al. performed a prospective before-and-after study in all patients admitted to two clinical ward areas in a district general hospital in the UK. They examined the effect on clinical outcomes of deploying an electronic automated advisory vital signs monitoring and notification system, which relayed abnormal vital signs to a RRT. They found significant improvements in key patient-centered clinical outcomes:
  - During the intervention, the number of RRT notifications increased from 405 to 524 (p=0.001) with more notifications triggering fluid therapy, bronchodilators and antibiotics.
  - Moreover, despite an increase in the number of patients with “do not attempt resuscitation” orders (from 99 to 135, p=0.047), mortality decreased from 173 to 147 patients (p=0.042) and cardiac arrests decreased from 14 to 2 events (p=0.002).
  - Finally, the severity of illness in patients admitted to the ICU was reduced (mean APACHE II score: 26 (SD 9) vs. 18 (SD 8)), as was their mortality (from 45% to 24%, p=0.04).
  - The total number of serious adverse events decreased from 268 to 185 (p<0.001). Cases of severe sepsis decreased from 21 to 1 (p<0.001).[44]

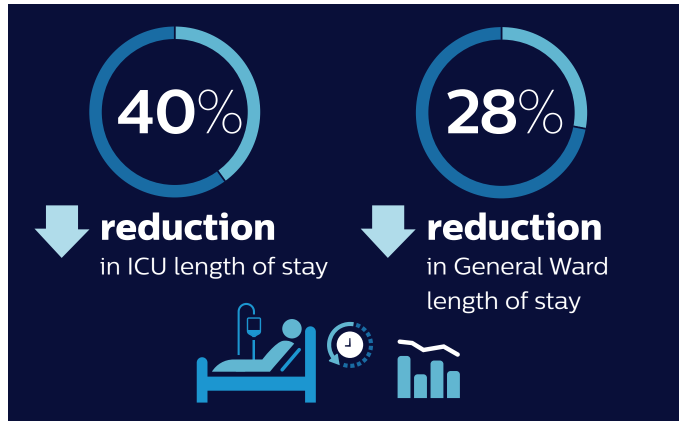
Table 3: Early Warning Scoring Systems literature review

	Number of studies included	Endpoints analyzed	
		In-hospital mortality	**Cardiopulmonary arrest (CPA)**
McGaughey et al. 2007[54] (Cochrane review)	2 cluster-randomized controlled trials: • 1 randomized at hospital level (23 hospitals in Australia) • 1 randomized at ward level (16 wards in UK)	UK study: • Significant reduction (adjusted OR 0.52; 95% CI 0.32 - 0.85)	
		Australian study: • No significant difference in primary endpoint (a composite score comprising incidence of unexpected cardiac arrests, unexpected deaths and unplanned ICU admissions)	
Winters et al. 2007[55]	8 studies • 5 with historical controls • 2 cluster-randomized designs	5 observational studies: • RR 0.87; 95% CI 0.73-1.04 2 randomized studies: • RR 0.76; 95% CI 0.39-1.48	4 observational studies: • RR 0.70; 95% CI 0.56-1.92 1 randomized studies: • RR 0.94; 95% CI 0.79-1.13
Ranji et al 2007[56]	13 studies • 1 cluster randomized controlled trial • 1 interrupted time series • 11 before-after studies	7 observational studies: • RR 0.82; 95% CI 0.74-0.91 1 randomized study: • Intervention: RR 0.65; 95% CI 0.48-0.88 • Control: RR 0.73; 95% CI 0.53-1.02	7 observational studies: • RR 0.73; 95% CI 0.65-0.85 1 randomized study: • Intervention: RR 0.81; 95% CI 0.60-1.10 • Control: RR 0.63; 95% CI 0.48-0.82
Jones et al. 2010[57]	6 studies • 5 single center before-after studies		Reduction in CPA (dose-response relationship)
	• 1 multicenter cluster-randomized study	• Intention-to-treat analysis: no change • Per-protocol analysis: significant improvement	
Chan et al. 2010[58]	18 studies (almost 1.3 million hospital admissions)	Adults: no change • RR 0.96; 95% CI 0.84-1.09 Children: 21.4% reduction • RR 0.79; 95% CI 0.63-0.98	Adults: 33.8% reduction in rates of CPA • RR 0.66; 95% CI 0.54-0.80 Children: 37.7% reduction • RR 0.62; 95% CI 0.46-0.84
Alam et al. 2014[59]	7 studies	Used in 6 out of 7 studies • 2/6: no significant difference • 2/6: significant reduction • 2/6: trend towards improved survival	Used in 2 out of 7 studies: • 1/2: reduced incidence of CPAs and in mortality of patients who underwent CPA • 1/2: increased incidence
Smith et al. 2014[60]	17 studies	Used in 6 out of 17 studies: Trend toward reduction • 1/6: significant reduction • 3/6: non-significant reduction • 1/6: non-significant increase	Used in 3 out of 17 studies: Mixed results • 1/3: reduced rate of CPA calls • 1/3: mixed results depending on EWS score (no difference, significant increase) • 1/3: no difference
Maharaj et al. 2015[61]	29 studies • Mostly before-and-after studies without contemporaneous control	Overall reduction: • Adults: RR 0.87; 95% CI 0.81-0.95 • Children: RR 0.82; 95% CI 0.76-0.89	Overall reduction: • Adults: RR 0.65; 95% CI 0.61-0.70 • Children: RR 0.64; 95% CI 0.55-0.74
Winters et al 2013[62]/2017[53]	• 23 studies on adults • 7 studies on children	Overall reduction: • Adults: RR 0.88; 95% CI 0.82-0.96 • Children: RR 0.82; 95% CI 0.67-1.00	Overall reduction: • Adults: RR 0.62; 95% CI 0.53-0.73 • Children: RR 0.55; 95% CI 0.40-0.75

Evaluating operational outcomes linked to Early Warning Scoring systems

From an operational perspective, adoption of early warning scoring systems may be associated with improvements in standardization, capacity management, and provider efficiency. While there is scant literature evaluating the operational benefits of early warning scoring systems, available literature has largely focused on efficiency gains from both a provider and system level.[2] On a provider level, evidence suggests clear alignment regarding the need to standardized approaches to early warning scoring and response.

Figure 6: Reduction in LoS by acuity[67]



Given relative high variability in clinical practice, the need for standardization to achieve equity in clinical outcomes, efficiency across unit transfers, and optimized resource utilization has been identified as an unmet need. This is especially true with regard to implementation in smaller hospitals and during after-hours shifts.[66]

Moreover, there are direct time efficiencies to be gained through standardization and automation of vital signs capture. A Health Technology Assessment (HTA) evaluation from Ireland explored the impact of early warning scoring implementation on charting time, finding that implementation resulted in a reduction in vital sign recording time (up to 1.6 times faster than a paper based system).[67] In addition, Bellomo et al. found that the time required to complete and record a set of vital signs decreased from 4.1 ± 1.3 mins to 2.5 ± 0.5 mins (difference [95% confidence interval] 1.6 [1.4–1.8]; $p < .0001$). In aggregate, such efficiency gains may relieve the administrative burden on nurses, improve the accuracy of vitals charting, reduce non-value added activities, and increase the proportion of nursing time associated with direct patient care.

On a systems level, early warning scoring systems may support bed optimization and efficiency/resource gains. Existing health technology assessments and budget impact models looked at efficiency gains associated with a decrease in ICU LoS. For example, the Irish Health Information and Quality Authority estimated that implementation would result in a 28.9% reduction in average LoS in the general ward, translating to over 800,000 general bed days per annum.[67] Similar estimation for the ICU resulted in a 40.3% reduction in LoS and around 30,000 bed days per annum (Figure 6).[67] Additional efficiencies on a systems level also estimated resource gains through avoided follow-up treatments for disability. It should be noted that such benefits are likely to be realized, as net efficiency gains given beds will not be retired.

Evaluating financial outcomes linked to Early Warning Scoring systems

Improvements in clinical and operational Key Performance Indicators (KPIs) may also translate into financial benefits in the form of cost savings and/or additional revenue opportunities. It should be acknowledged from the outset that there is a recognized need for more robust economic assessment of early warning scoring systems. The need for a more robust evidence base has been noted in systematic reviews, citing a lack of cost-effectiveness and budget impact assessments.[2] While direct assessment may be lacking, evidence does suggest that early warnings scoring systems may result in economic benefits post-adoption.[67]

Given that the primary clinical aim of early warning scoring systems is early detection and intervention to prevent patient deterioration and/or adverse events, an area of potential savings is in reducing complications and intervening early to reduce downstream resource utilization and incremental costs. For example, adverse events are common in patients undergoing abdominal surgery and accounted for 44% of total costs of hospital care in a recent Canadian study.[68] Intervening early may have the potential to avoid the downstream costs associated with severe complications.

Early intervention is not without its own costs as RRT/MET activation can be costly and may result in transfers to a higher acuity setting. However, some studies indicate that early referral of less severely ill patients may reduce unplanned ICU costs.[69] Simmes et al. performed a cost analysis within a Dutch hospital to assess whether RRT activation and lowering the APACHE II score threshold for transfer would reduce costs. They found that the costs for extra unplanned ICU days were relatively high but the remaining rapid response system (RRS) costs were relatively low. The 'APACHE II 14' scenario confirmed the hypothesis that costs for the number of unplanned ICU days can be reduced if less severely ill patients are referred to the ICU.[69]

An analysis completed by Moore and Poyton for the New Zealand Health Quality and Safety Commission examined the cost-effectiveness of RRT teams in preventing in-hospital cardiac arrest. Moore and Poyton posited that the cost of standardizing and improving EWS is estimated to be a one off cost of $1.4 million with a majority of cost coming from provider training.[66] Noting that cost-effectiveness is uncertain, Moore and Poyton modeled a conservative and optimistic scenario with a range of cost-effectiveness ratios from no benefit to $3,900 per cardiac arrest. Given the results of pre- and post-studies in New Zealand hospitals, the group felt that the optimistic scenario was more likely. Moreover, the net benefit for

patients (avoided harm) and clinicians (systems and guidance) was deemed worth the moderate cost of implementation.[66]

In an effort to quantify the cost-benefit of early warning scoring systems, Bonafide et al. calculated the cost-benefit within a surgical unit at an United States pediatric hospital. The study found that unplanned transfers that meet critical deterioration (CD) criteria have much costlier post-event ICU and hospital stays than unplanned transfers that do not meet CD criteria.[70] Moreover, the costs of operating a MET can plausibly be recouped with a modest reduction in CD events, based on the makeup of the response team and an absolute reduction in number of CD events. For example, a team consisting of a Registered Nurse + Respiratory Tech + Critical Care Fellow (all with concurrent responsibilities in the ICU) would require a 3.5 reduction in CD events per year to reach the "break even" point.[70]

When modeled to a unit with 300 unplanned transfers from ward to ICU per year and a 30% CD proportion, reducing that proportion to 25% (an absolute reduction of 15 CD events per year) by implementing a MET comprised of a nurse, respiratory therapist, and critical care fellow with concurrent clinical responsibilities would result in eliminating $1,496,595 in excess costs per year for a net savings of $1,145,897 annually.[70]

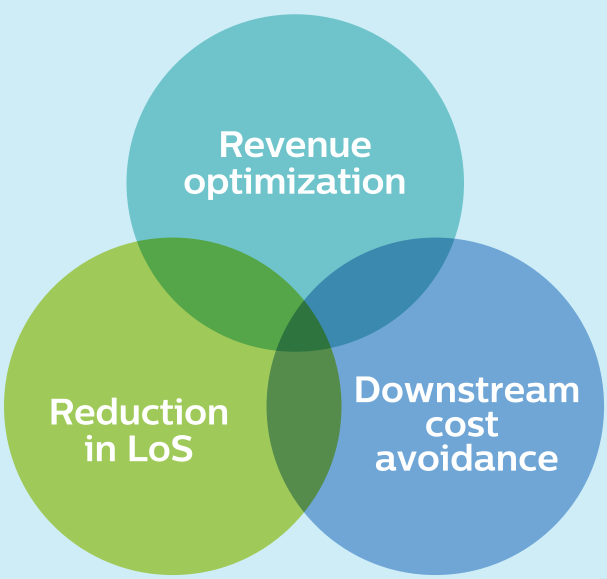
Additional cost savings estimates associated with reduced ICU LoS have also been evaluated at both a national level (Ireland: finding €4.2 million in efficiency savings)[2] and condition level (UK: €4,500 per patient savings associated with NEWS screening for sepsis).[2]

As Ward[71] noted, from a hospital operational and quality perspective, early warning scoring systems may also result in financial benefits from:

- Revenue enhancement through reduction in LoS
- Increased hospital throughput (increased cases, ancillary procedures, etc.).
- Decreased need for capital investments and borrowing

Although limited, available evidence suggests there is "potential for EWS to be cost effective."[2] Such potential is driven by the impact of early warnings scoring system on reducing hospital length of stay and incidence of adverse events.[2] Additionally, the cascading effects of adoption may also drive additional opportunities for revenue generation and an overall positive effect on a hospital's balance sheet. Early warning scoring systems are also well positioned to enable providers to move toward value-based approaches[70] by mitigating risk and enabling success under value-based payment systems (e.g., bundled payments).

Figure 7: Drivers of economic value



Summary and key takeaways

Patient deterioration is a significant clinical and financial burden for patients, providers, and healthcare systems

Economic impact:

- Surgical complications were associated with a **nearly $20K increase in hospital costs** and a pronounced decrease in contribution margin[10]
- **$3,580 average cost per day** of hospitalization for recipients of cardio pulmonary resuscitation[12]
- Increased operational costs (overhead, capital, nurse turnover)
- Opportunity costs associated with throughput (unit capacity decreases, missed revenue, contribution margin)

A variety of early warning scoring systems assess the probability that a patient is at risk for deterioration

- NEWS and MEWS are the most commonly used early warning scoring systems
- The more recent systematic reviews conclude that **EWS systems are effective at reducing cardiorespiratory arrest and mortality**

A successful implementation means finding a balance between ease of use, sensitivity of the system to deterioration, and low false positive rates on the afferent arm.[30] Further, the ability to see vital signs trends, to change or suspend a calling criterion, and the simplicity of the tool used on the efferent arm used are critical for ensure success.[21]

Evidence suggests that early warning scoring systems may result in economic benefits post-adoption and are associated with: reducing hospital length of stay, decreasing incidence of adverse events, improving capacity management, and optimizing provider efficiency

Better health outcome

- Reducing complications and intervening early **reduces downstream resource utilization and incremental costs**.[28]
- RRT/MET activation may be costly but could be offset by the fact that early referral of less severely ill patients may reduce unplanned ICU costs

Increased time efficiencies potentially resulting in improved staff experience

- **Direct time efficiencies are gained** through standardization and automation of vital signs capture.
- Efficiency gains may relieve the administrative burden on nurses, improve the accuracy of vitals charting, reduce non-value added activities, and **increase the proportion of nursing time associated with direct patient care**.

Lower cost of care

- Early warning scoring systems may **support bed optimization and efficiency/resource gains**. For example, the Irish Health Information and Quality Authority estimated that implementation would result in a 28.9% reduction in average LoS in the general ward (>800K general bed days/annum)[67]
- **Additional cost savings estimates associated with reduced ICU LoS** have been evaluated at a national level (Ireland: finding €4.2 million in efficiency savings) and condition level (€4,500 per patient savings associated with NEWS screening for sepsis).[2]

Improved patient and family experience

Additional efficiencies on a systems level also estimated resource gains through **avoided follow-up treatments for disability**.

Early warning scoring systems are well positioned to enable providers to move toward value-based approaches by mitigating risk and enabling success under value-based payment systems (e.g., bundled payments).[70]

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