

## Bringing Pediatric Early Warning Scores (PEWS) to your hospital

Undetected deterioration of pediatric patients can have serious adverse outcomes, such as morbidity, long-term disability or even death. The medical community agrees that children who deteriorate unexpectedly will usually have observable signs in the period before the seriousness of their condition is recognized.<sup>1</sup> In fact, approximately one in five children who die in hospitals have avoidable factors leading to death, and half of these children have potentially avoidable factors – as shown by a seminal study in the UK.<sup>2</sup> Although cardiopulmonary arrests for in-patient pediatric admissions are generally reported as low (0.7–3%),<sup>3</sup> survival to discharge for these children is poor (11–37%).<sup>3,4</sup> In one review, 61% of pediatric cardiac arrests were caused by respiratory failure and 29% by shock, which are both preventable and potentially reversible causes.<sup>5</sup>

The prevention of these events, which can be done via a systematic assessment of vitals and key symptoms, is a fundamental element of patient safety. The problem is that many children appear relatively unaffected until shortly before respiratory failure or shock. They tend to have a period of physiological compensation for underlying illness or injury. Their vitals appear relatively unchanged between assessments, but change rapidly just before these events

when the compensation mechanisms are overwhelmed. The devastating consequences of cardiopulmonary arrests on these children, their families and their healthcare providers, are well proven.<sup>6</sup> Moreover, the costs of these events are even higher than those reported for adults.<sup>7</sup> In fact, Bonafide et al.<sup>8</sup> estimated that patients who had critical deteriorations cost \$99,773 more during their post-event hospital stay than transfers to the ICU not fulfilling critical deterioration criteria.

## Definition of Pediatric Early Warning Scores (PEWS)

Evidence indicates that prevention of adverse events in pediatrics is possible with early detection, mitigation and escalation. PEWS are track and trigger tools to help alert clinicians to deteriorating children by periodic observation of physiological parameters, calculation of a score (based on aggregate or individual features), and predetermined criteria for escalating urgent assistance. Internationally, PEWS are particularly common throughout the USA, UK,

Ireland, Australia, and Canada. Their application is also gaining momentum in other parts of the world. Initially, PEWS were developed after carefully examining MEWS (Modified Early Warning Scores) for adults, using domain knowledge and incorporating the necessary elements unique to the pediatric populations<sup>5</sup> – shown in **Figure 1**. This is necessary as the anatomy and physiology of children differs widely from adults leading to a higher predisposition for sudden deterioration.<sup>9</sup>

### Pediatric Early Warning Scores

	0	1	2	3	Score
<b>Behavior</b>	Playing, appropriate	Sleeping	Irritable	Lethargic and confused <b>OR</b> reduced response to pain	
<b>Cardiovascular</b>	Pink <b>OR</b> capillary refill 1-2 seconds	Pale or dusky <b>OR</b> capillary refill 3 seconds	Gray or cyanotic <b>OR</b> capillary refill 4 seconds <b>OR</b> tachycardia of 20 above normal rate	Gray or cyanotic AND mottled <b>OR</b> capillary refill 5 seconds or above <b>OR</b> tachycardia of 30 above normal rate <b>OR</b> bradycardia	
<b>Respiratory</b>	Within normal parameters, no retractions	<10 above normal parameters <b>OR</b> using accessory muscles <b>OR</b> 30+%FiO <sup>2</sup> or 3+ liters/min	>20 above normal parameters <b>OR</b> retractions <b>OR</b> 40+%FiO <sup>2</sup> or 6+ liters/min	≥5 below normal parameters with retractions or grunting <b>OR</b> 50+%FiO <sup>2</sup> or 8+ liters/min	

- Score by starting with the most severe parameters first.
- Score 2 extra for every 15-minute nebs (includes continuous nebs) or persistent post-op vomiting.
- Use “liters/minute” to score a regular nasal cannula.
- Use “FiO<sup>2</sup>” to score a high-flow nasal cannula.

	Heart rate at rest	Respiratory rate at rest
Newborn (birth – 1 month)	100 – 180	40 – 60
Infant (1 – 12 months)	100 – 180	35 – 40
Toddler (13 months – 3 years)	70 – 110	25 – 30
Preschool (4 – 6 years)	70 – 110	21 – 23
School age (7 – 12 years)	70 – 110	19 – 21
Adolescent (13 – 19 years)	55 – 90	16 – 18

**Figure 1.** The PEWS score calculation sheet by Monaghan et al.<sup>8</sup>

## How well do PEWS perform?

**Table 1** shows a number of the most commonly used PEWS, based on the reviews in References 1, 9 and 10. Note that some of these scores are trigger scores, where an alert is generated whenever one of the parameters crosses a threshold, and others are aggregate scores where an overall score is calculated and used to generate an alert if it crosses a certain value. The table also shows performance results in terms of sensitivity and specificity as measured by different studies.

Key reasons for variations in the performance of different PEWS scores

- Differences in study cohorts (ages and co-morbidities) and settings (general wards or ED and other critical areas)
- Customizations in how these scores were applied in different organizations due to local needs and preferences
- Variations in the definition of clinical deterioration ranging from unplanned ICU admission to cardiopulmonary arrests

PEWS tools	Number of parameters and score range	Sensitivity	Specificity
Brighton PEWS – UK <sup>5</sup>	5 parameters – aggregate score	90% <sup>3</sup> 78% <sup>11</sup> 62% <sup>12</sup> 74% <sup>13</sup>	75% <sup>3</sup> 68% <sup>11</sup> 89% <sup>12</sup> 96% <sup>13</sup>
Bristol PEWS – UK <sup>14</sup>	Single parameter – trigger score	99% <sup>14</sup> 96% <sup>15</sup>	66% <sup>14</sup> 28% <sup>15</sup>
Cardiff and Vale PEWS – UK <sup>16</sup>	8 parameters – trigger score	89% <sup>16</sup> 80% <sup>15</sup>	64% <sup>16</sup> 86% <sup>15</sup>
Melbourne activation criteria (MAC) – Australia <sup>17</sup>	9 parameters – trigger score	68% <sup>18</sup>	83% <sup>18</sup>
Bedside PEWS (BPEWS) – Canada <sup>19,20</sup>	7 parameters – aggregate score	82% <sup>20</sup>	93% <sup>20</sup>
Birmingham Toronto PEWS – UK Canada <sup>21</sup>	16 parameters – aggregate score	78% <sup>21</sup>	95% <sup>21</sup>
Cardiac children’s hospital early warning score (C-CHEWS) – USA <sup>4,22</sup>	5 parameters – aggregate score	67.2% <sup>22</sup>	94% <sup>22</sup>

**Table 1.** Showing some of the most commonly used PEWS scores with their corresponding values of sensitivity and specificity as observed in different studies.

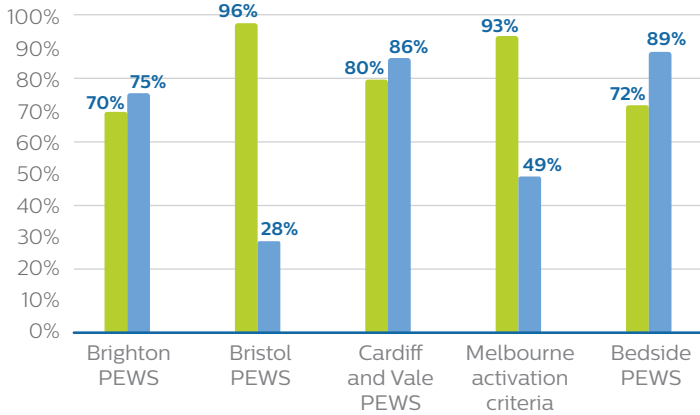
A team from the Great Ormond Street Hospital and UCL (University College London) compared the predictive performance of several PEWS on the same data set.<sup>15</sup> Their motivation was that, despite the multitude of PEWS available, only a minority have been evaluated for their predictive performance. Their data set included patients on pediatric wards collected over two years. All patients who suffered a critical deterioration event were designated “cases” and matched with a control closest in age who was present on the same ward at the same time. The main outcome measures were respiratory and/or cardiac arrest, unplanned transfer to pediatric intensive care, and/or unexpected death.

Although the authors compared more than 12 different PEWS/trigger systems, focus will be on the most commonly used scores given in **Table 1**, which shows results in terms

of sensitivity and specificity. The Birmingham Toronto and C-CHEWS were not used in the comparative study.<sup>15</sup>

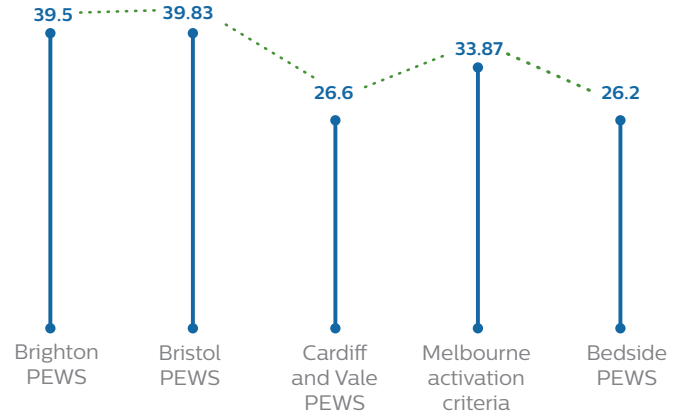
**Figure 2** shows the sensitivity and specificity of five of the PEWS tested on the same data set. The best performer was the Cardiff and Vale PEWS, followed by the Bedside PEWS. The authors concluded that overall trigger systems demonstrated better sensitivity (probability of detection) than aggregate scoring systems, but worse specificity (true negative rates). They also concluded that PEWS demonstrated the ability to detect children at risk of critical deterioration at a significant time before the event (**Figure 3**). Trigger systems showed a longer time to event, reflecting the increased sensitivity. In reality, the selection of PEWS by a clinical team depends on several factors: target sensitivity and specificity, workflow and ease of use, and the ability of the team to record measurements.

## Comparison of different PEWS



**Figure 2.** Retrospective comparison of different PEWS as calculated by Chapman et al.<sup>15</sup> based on the same data set collected in London over two years.

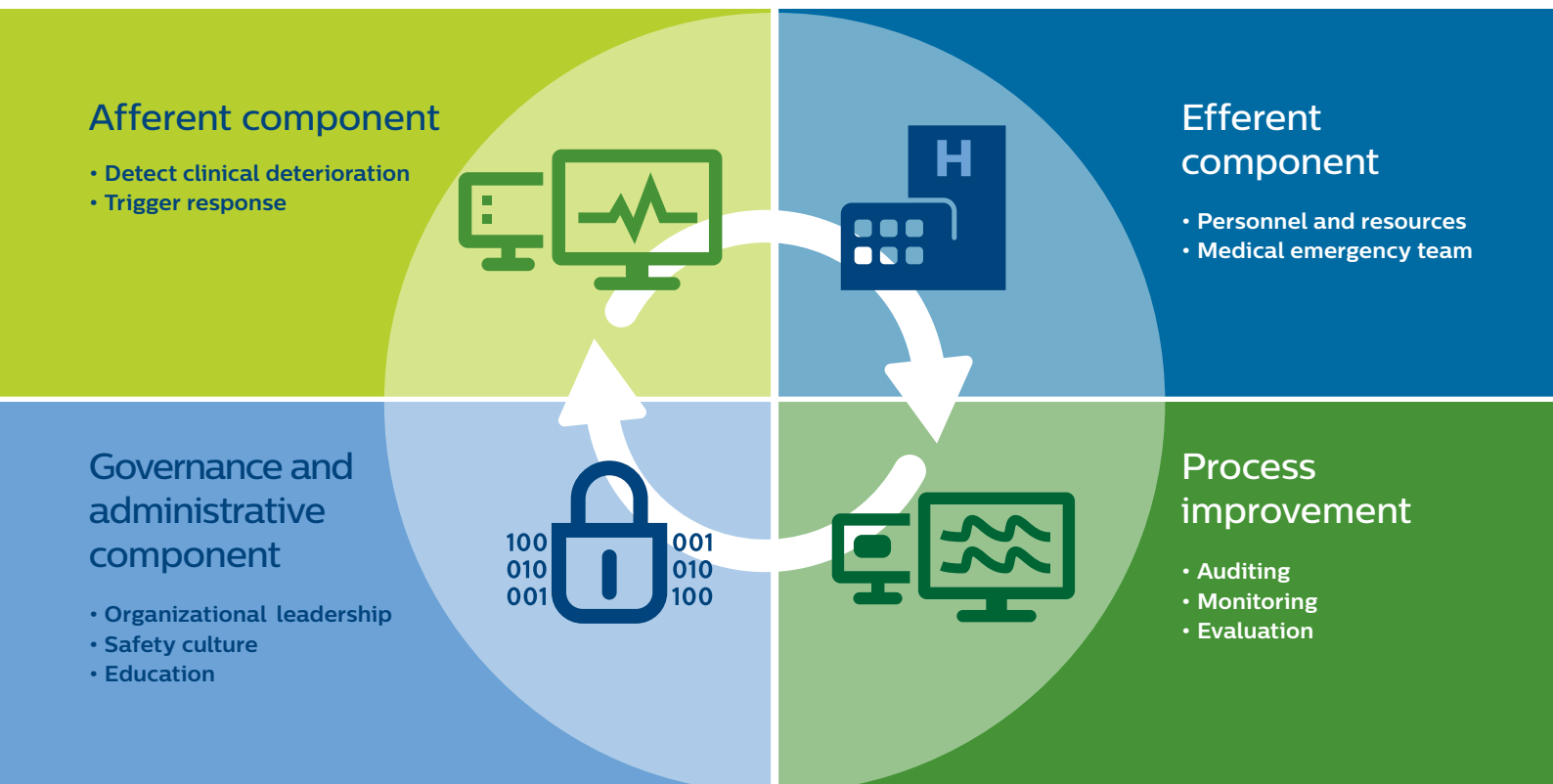
## Time to event



**Figure 3.** Time before an event (in hours) where a particular PEWS can detect deterioration (Chapman et al).<sup>15</sup>

■ Sensitivity      ■ Specificity

## A comprehensive system for detecting deteriorating children



**Figure 4.** Based on the work by EW van der Jagt on identifying the key components for building a comprehensive system for deteriorating patients.<sup>23</sup>

In practice, the key goal in deploying early warning scores is to ensure timely recognition of deteriorating patients combined with a timely and appropriate response from skilled staff.<sup>1</sup> EW van der Jagt highlights four important components that need to go hand-in-hand for a successful implementation of early warning scores.<sup>23</sup>

These components, summarized in **Figure 4**:

- **The afferent component:** This aims to detect clinical deterioration in time, and trigger an appropriate response. **Table 1** showed several PEWS that can perform this task. It is recommended to combine these scores with clear guidance regarding monitoring type and frequency, flagging of diagnostic risk factors as well as a mandatory escalation system.<sup>24</sup>
- **The efferent component:** Ensuring access to a medical emergency team that can respond rapidly, in combination with a network of clinicians that can provide the response. The structure and function of the response limb (or the efferent component) are dependent upon the needs of the institution. A multidisciplinary team with the skills and resources to assess and manage emergencies is recommended.<sup>24</sup> Proactive identification through a rover team or scheduled safety huddles may help with earlier identification of patients at risk.
- **Process improvement:** This summarizes the regular use of auditing, monitoring and evaluation to make sure that the processes around PEWS implementation are efficient. This should be designed around the desired outcomes and identify successes, near misses and failures throughout the process.
- **Governance and administrative component:** This highlights the importance of organizational leadership in addition to maintaining a safety culture in the hospital. Training and education play a crucial role here in bringing all team members on-board and making sure that PEWS are being implemented and sustained for long periods. This component should also be designed around the desired outcomes and key performance indicators.

## PEWS outcomes

The use of PEWS has several benefits. Based on the existing literature, the following are highlighted outcomes:

- Can provide evidence that empowers nurses to overcome barriers to escalating care<sup>25,26</sup>
- Provides less-experienced nurses with vital sign reference ranges<sup>25</sup>
- Increases the proportion of patients seen by a consultant from the time of breach to PICU admission – e.g., in Theilen et al., the proportion increased from 49% to 82%.<sup>27</sup>
- Decreases late ICU transfers – e.g., the time from breach to PICU admission fell from 21 h to 10 h<sup>27</sup>

- Identifies deterioration better than a physician's opinion alone<sup>28</sup>
- Earlier detection (with a time period identified) – i.e., decreasing the time from trigger criteria to clinician response (by 9.25 hours prior to event)<sup>22</sup>
- Decreases PICU length of stay, which would have a positive impact on the children spending less time in critical care, as well as reducing the associated costs. The decrease of length of stay was by around two days.<sup>27</sup>
- Possibly reduces ward cardiac arrests and mortality<sup>29</sup>
- Decreases in code team activations<sup>30</sup>
- Compliance and adherence to guidelines<sup>31</sup>

From a cost-benefit analysis, Bonafide et al. looked into the advantages of having a medical emergency team (MET) in a pediatric ward combined with a deterioration score for over four years.<sup>8</sup> The conclusion was that while having MET teams is costly, the costs are small compared to those of deteriorations in the ward. In fact, the annual cost of having a nurse, respiratory therapist and ICU specialists is equivalent to only a reduction of 3.5 critical deterioration events. The recommendation from that study is that the use of a deterioration score combined with a MET has significant cost reduction benefits to the hospital.

## PEWS challenges

Despite showing positive impacts in many studies, the application of PEWS scores in practice can have many challenges. Some of these include:

- Compared to adult EWS (Early Warning Score), PEWS needs a variation in age-specific thresholds.<sup>1</sup>
- Some children are unable to articulate their level of pain or discomfort, which makes it more difficult for the clinical team to document these levels.
- Staff training issues and adherence to new protocols.
- Incomplete measurement of some of the required vital signs. A Danish study by Jensen et al. proposed a multicenter randomized trial using Bedside PEWS, deducing that all seven items in Bedside PEWS are complete in only 5% of the time.<sup>19,32</sup> In particular, the study showed that clinicians had difficulty in measuring blood pressure and consciousness levels.
- The fact that there are many available PEWS scores can be confusing for hospitals. The lack of large-scale validation and comparison studies can also be problematic. Unlike MEWS for adults, there are currently no government or medical guidelines recommending one score over another.
- As the previous section highlighted, deterioration detection and response require a comprehensive change management framework that embodies processes and education as well as communication. If any of these elements were missing, hospitals would definitely find it challenging to implement PEWS and maintain results over time.

## How can Philips bring PEWS to your hospital?

Philips Early Warning Scoring System IntelliVue Guardian Solution (IGS) offers a comprehensive solution to help address clinical deterioration and patient care. It allows caregivers to automatically acquire vital signs, automate early warning scoring (EWS) calculations, aid in identifying early signs of deterioration, and can inform responsible clinicians for an efficient intervention. Philips Guardian Software can be embedded in clinical workflows and automatically incorporated in electronic health records. For surveying an adult population, Guardian prospective evaluation in two general wards of a hospital in the United Kingdom has shown a 52% increase of rapid response team notifications that triggered interventions. In addition to that, the evaluation showed a 20% decrease in mortality, an 86% decrease in cardiac arrests, a 24% reduction in ICU admission, and a 31% reduction in the severity of patients admitted to the ICU.<sup>33</sup>

IGS provides a means of addressing many of the challenges in deploying PEWS scores, and notifying rapid response teams when needed:

- **Pediatric-specific deterioration detection:** Philips offers an EWS system that recognizes the fundamental physiological differences between adults and children. Our Pediatric Early Warning System (PEWS) calculates early warning scores that take into account the unique patterns of deterioration in children, placing a greater emphasis on nursing observations in determining the level of risk.<sup>33</sup>
- **Bringing PEWS scoring to the child's bedside:** This can simplify workflows by directly uploading the vital signs data into the EHR to reduce the vital signs collection time and provide an early patient deterioration score and direction

on the monitor. The Philips infrastructure allows the calculation of PEWS in spot-check or continuous mode using the Philips Patient Information Center (PIC iX), if the patient is on continuous monitoring.

- **Highly configurable:** IGS is highly configurable and able to accommodate different PEWS such as trigger and aggregate scores, given in **Table 1**. The Guardian solution can also be accessed from different devices and screens to match the hospital's workflow.
- **Facilitating communication:** The Care Event event management system can be configured to deliver notifications to the care team's mobile devices of choice, aiming to improve communication between care teams regardless of caregiver location.<sup>33</sup>
- **Running multiple algorithms at once:** Guardian supports more than one scoring algorithm for a single patient at the same time. This allows clinicians to combine PEWS with other scores (such as sepsis screening scores) that can be used on long and short time windows simultaneously to assess patient risk from multiple points of view.
- **Support in workflow integration:** As the previous section highlighted, deterioration detection and efficient response require a comprehensive change management framework that embodies processes and education as well as communication. Philips clinical specialists are trained to assess current workflows and practices, then collaborate with clinical teams to identify process changes that can positively affect RRT activation within customized configurations. They will plan, validate and test the solution to facilitate successful workflow transitions.

## IntelliVue GuardianSoftware – a comprehensive solution to help address clinical deterioration and patient care



**Figure 5.** Overview of the components of the Philips General Care solution.

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