Title:

Early warning- and track and trigger systems for newborn infants. A review.

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Abbreviations:

EWS - early warning score

NICU - neonatal intensive care unit

PEWS - paediatric early warning score

NEWS - neonatal early warning score

HR - heart rate

RR - respiratory rate

Keywords: Infant; Neonatal; Paediatric; Emergency Care

**ABSTRACT**

Tools for clinical assessment and escalation of observation and treatment are insufficiently established in the newborn population. We aimed to provide an overview over early warning- and track and trigger systems for newborn infants and performed a non-systematic review based on a search in Medline and Cinahl until November 2015. Search terms included ‘infant, newborn’, ‘early warning score’, and ‘track and trigger’. Experts in the field were contacted for identification of unpublished systems. Outcome measures included reference values for physiological parameters including respiratory rate and heart rate, and ways of quantifying the extent of deviations from the reference. Only four neonatal early warning scores were published in full detail, and one system for infants with cardiac disease was considered as having a more general applicability. Temperature, respiratory rate, heart rate, SpO2, capillary refill time and level of consciousness were parameters commonly included, but the definition and quantification of ‘abnormal’ varied slightly. The available scoring systems were designed for term and near-term infants in postpartum wards, not neonatal intensive care units. In conclusion, there is a limited availability of neonatal early warning scores. Scoring systems for high-risk neonates in neonatal intensive care units and preterm infants were not identified.

**INTRODUCTION**

Early warning scores (EWS) and track and trigger charts are widely used in adult (Ludikhuize et al., 2014) and paediatric (Akre et al., 2010; Solevåg et al., 2013) hospitalised patients to achieve improved patient safety (Royal college of physicians working party, 2012). In theory, such tools can improve the quality of observations, monitoring and documentation, independent of practitioner experience or clinical workload. Less disputable, use of a scoring system will improve recognition of deviations from normal physiology and the measuring and recording of patient data in a systematic and standardized way. EWS may also improve the communication within the multidisciplinary team, and allow for timely stabilisation and treatment including transfer to a higher level of care.

In sick newborn infants, initial subtle and unspecific clinical signs may rapidly progress to cardiorespiratory failure if the infant is not properly recognized as being sick and treated accordingly (Roland, 2010). Despite the challenges in correctly identifying progression of illness severity, the use of EWS and track and trigger charts in neonatal intensive care units (NICU), intermediate care nurseries and postpartum wards is insufficiently established (Roland, 2010). Many available neonatal scoring systems have limited applicability due to requirements for data collection over several hours (e.g. clinical risk index for babies (CRIB) (1993) and score for neonatal acute physiology (SNAP) (Richardson et al., 1993)) and high complexity including a large number of investigations (Gray et al., 1992; Richardson et al., 1993). Many systems are also limited to certain categories of neonates (preterm like the CRIB (1993), hypoxic-ischemic encephalopathy (HIE) like the Thompson score (Thompson et al., 1997) and cardiac disease (McLellan et al., 2014)). Few scoring systems utilize only clinical parameters without including laboratory investigations.

The aim of this review was to provide an updated, but narrative overview of available tools that either have been used as or have the potential for being used as EWS for neonatal patients.

**METHODS**

**Search strategy**

We searched the databases Medline and Cinahl until November 2015 using search terms including ‘newborn’, ‘severity of illness index’, track and trigger’ and ’early warning score’. A manual search of the bibliography of the included studies was also performed.

**Study selection**

Two reviewers (NM and ALS) independently reviewed the retrieved citations for selection. Articles were included in the review if they met the following criteria: infant patients <6 month of age, included reference values for physiological parameters including respiratory rate and heart rate as well as other definitions of deviations from ‘normal’. This was a non-systematic review. Thus, no systematic evaluation of the quality of the identified studies was performed.

**Other sources of information**

Through consultation with clinicians and researchers considered experts in the field, we aimed to identify unpublished systems that could potentially be applicable to EWS for newborn infants.

**RESULTS**

Forty-one articles were identified in Medline and 65 in Cinahl. Most were excluded due to lack of relevance, e.g. paediatric early warning score (PEWS), condition specific including HIE (Horn et al., 2013; Thompson et al., 1997) and preterm (CRIB 1993). Four neonatal early warning scores (NEWS) considered generally applicable were published in full detail (Holme et al., 2013; Roland, 2010; British Association of Perinatal Medicine, 2015; Ahmed et al., 2016), two of them were based on the same chart (British Association of Perinatal Medicine, 2015; Roland, 2010). In addition, one system for infants with cardiac disease was considered as having a more general applicability, i.e. the Cardiac Children’s Hospital Early Warning Score (C-CHEWS) (McLellan et al., 2014). Two sources of reference values for respiratory disease and symptoms were identified through consultation with experts in the field (ACoRN Editorial Board, 2005; Tveiten et al., 2016). Table 1 summarizes the selected studies with relevant reference values.

*The neonatal trigger score (NTS), London UK*

*Holme et al* (Holme et al., 2013) published a retrospective evaluation of the ‘new neonatal trigger score’ (NTS) in ‘unwell’ infants admitted to the NICU (n=193) and ‘well’ infants who remained on the postpartum ward (n=292), all >35 weeks of gestation. The score was developed based on expert consensus, the Neonatal Life Support 2010 guidelines (Richmond, 2010) and the National Institute for Health and Care Excellence (NICE) Postnatal care guideline (NICE, 2014). For charting, they reported to use the charts of Flannigan and Hogan (Flannigan C, 2011) as reference. The resulting neonatal scoring chart consisted of the six elements temperature (even though low temperature was less predictive and unspecific), heart rate (HR), respiratory rate (RR), respiratory distress, level of consciousness (alert-irritable/lethargic/jittery-unresponsive), and pre-feed blood sugar (not compulsory), each of the elements accounting for a score of 0-3. In the NTS, a total score of 0-15 is achievable, with a higher score reflecting a greater deviation from ‘normal’. A score of 2 predicted the need for admission to the NICU with a 79.3% sensitivity and a 93.5% specificity. A score ≥2 was associated with an increased risk of needing intensive care (odds ratio (OR) 48.7, 95% confidence interval (CI) 27.5–86.3), intravenous fluids (OR 48.1, 95% CI 23.9–96.9), and continuous positive airway pressure (CPAP) (OR 29.5, 95% CI 6.9–125.8). Hence, they made the recommendation that a score of 1 should result in review of the baby, and if a score ≥2 transfer to the NICU should be considered. The NTS had a significantly better sensitivity than the Brighton PEWS (Monaghan, 2005), the NHS PEWS, and the Bristol PEWS (Haines et al., 2006), particularly in infants who experienced deterioration within the first 12 hours after birth (p <.001) and in infants with sepsis or respiratory symptoms (p < .001) (Holme et al., 2013).

*The Newborn Early Warning (NEW) system, Plymouth UK*

*Roland et al* (Roland, 2010) developed a Newborn Early Warning (NEW) system based on reference values for HR and RR published in (Rennie, 2005; Taesch, 2004; Davies, 2008; Baston, 2001; Mackway-Jones, 2005) and classified the values as ‘green’ (normal), ‘amber’ (abnormal) or ‘red’(significantly abnormal), with ‘amber’ values corresponding to the upper range of normal physiological measurements. They performed a retrospective evaluation of the charts of infants with a birth weight >2.5 kg admitted to the NICU (n=122), followed by a prospective trial in the labour unit and postpartum wards (n=84). NEW observations were recorded four hourly or more frequently if considered necessary. The study group defined criteria for having a NEW chart based on risk factors including prenatal risk factors such as signs of infection, significant foetal compromise (cardiotocography (CTG), and scalp pH < 7.0). Perinatal risk factors included thick meconium, a cord pH < 7.0, ventilatory support for > 3 min, chest compressions, 5 min Apgar < 8, and grunting/respiratory distress. Postnatal risk factors included grunting, abnormal movements, any other ongoing concerns or ‘at the request of a reviewing advanced neonatal nurse practitioner (ANNP)/senior house officer (SHO)/Registrar’. The NEW chart itself included the parameters temperature, HR, RR, apnoea, oxygen saturation and level of consciousness. The prospective study was pragmatic with a small sample size, and only simple statistics were used to describe the ability of the NEW to identify infants at risk. Similar to the findings in the retrospective study, only about half of the infants that received an intervention, defined as an investigation (blood test or x-ray), treatment (e.g. antibiotics) or transfer to another level of care, were identified by an abnormal NEW in the prospective registration. An increase in retrievable observations from 48% in the retrospective audit to 72% in the prospective audit was demonstrated, and clinical staff commented that the chart made them more aware of the normal parameters for a newborn (Roland, 2010). Following a survey amongst midwifes in the prospective study the NEW chart was revised to increase user-friendliness and avoid over-triggering on the temperature scale.

*The British Association of Perinatal Medicine Newborn Early Warning Trigger and Track (NEWTT)*

The British Association of Perinatal Medicine published in April 2015 a report based on a review of the literature and consensus statement (British Association of Perinatal Medicine, 2015). The literature review was mainly focused on the at-risk identification of infants needing a NEWTT chart, not the chart itself. As the Plymouth chart was the ‘only published work available at the time this group convened’, this was the chart they used. The report included a survey among five clinical sites regarding the ease of use of the chart, but no study was performed to assess the chart’s ability to identify sick infants.

Like the Plymouth NEW (Roland, 2010), the NEWTT defines infants at risk qualifying for having a NEWTT chart: 1) Risk of sepsis as defined by NICE ((NICE), 2012) regardless of gestation, 2) Maternal diabetes mellitus, 3) Maternal hypertension treated with beta blockers, 4) Late preterm, 5) Small for gestational age, 6) Signs of intrapartum compromise (need for resuscitation, 5 min Apgar score ≤ 7, or cord pH ≤ 7.1), and 7) Meconium stained amniotic fluid if combined with Apgar score ≤ 7 at 5 min or requiring intervention at birth. Infants identified as being at risk according to these seven criteria should have their vital signs recorded in a chart that, except for minor differences in reference values (Table 1) is almost identical to the chart used in (Roland, 2010) with the same colour codes, escalation criteria and responses.

*The Burton Newborn Observation Track and Trigger Chart (NOTT)*

The developers of the NOTT (Ahmed et al., 2016) described the development of the chart, including a survey amongst neonatal units in different newborn networks in England. A literature search was then carried out to identify studies related to newborn early warning systems. The resulting NOTT included temperature, RR and oxygen saturation. Babies considered being at risk by the NOTT study group included those with meconium stained amniotic fluid, prolonged rupture of membranes, group B streptococcus risk, 5 min Apgar score <7, arterial cord pH <7.1, scalp pH<7.0, staff concern, abnormal movements, grunting, infant of diabetic mother, ventilatory support >3 min, risk of developing hypoglycemia (according to local guidelines), low (<10th centile) or high (>90th centile) birth weight, maternal medication use, or maternal infection. The sensitivity of the NOTT chart’s ‘medium’ and ‘high’ score was 96% (22/23) and specificity 90% for the outcome urgent medical assessment and intervention. Positive and negative predictive value was 43% and 100% respectively.

*The Cardiac Children’s Hospital Early Warning Score (C-CHEWS)*

At the Children’s hospital of Boston they developed an escalation algorithm including capillary refill time, HR, RR, work of breathing, grunting, oxygen requirement, and level of consciousness. They classified scores 0-2 as ‘green’, 3-4 as ‘yellow’ and >5 as ‘red’ and compared the C-CHEWS with the Brighton PEWS (Monaghan, 2005). They found that the lead-time (i.e. the time until arrest or unplanned transfer to the intensive care unit) for elevated C-CHEWS scores (≥3) was a median of 7 hours longer than elevated PEWS scores (≥3), and the lead-time for critical C-CHEWS scores (≥5) was 2 hours longer than critical PEWS scores (≥5). This increased lead-time should allow for earlier attention to at-risk patients, and earlier treatment and prevention of cardiopulmonary arrests or unplanned transfers.

*Prognostic signs and evaluation*

In an abstract from the 2014 European Academy of Paediatric Societies conference, *Singh et al* (Singh et al., 2014) found that HR, RR, oxygen saturation, capillary refill time, hypo/hypothermia, low birth weight, decreased sensorium level, reduced or no activity, moderate/severe pallor, cyanosis, bleeding, dehydration, respiratory distress, cardiac murmur, and abdominal distension were all independent predictors of mortality in a multiple logistic regression analysis. Hypo-/hypertonia was not independently associated with a poor outcome.

*The ACoRN respiratory score*

In newborn infants, respiratory distress, especially newly acquired distress in previously well babies may be symptoms of other conditions such as infection. Within the Acute Care of at-risk Newborns (ACoRN) framework (ACoRN Editorial Board, 2005), respiratory distress is classified as mild (score <5, starting at birth an lasting <4 hours), moderate (score 5-8 or <5 lasting >4 hours after birth) or severe (score >8) (ACoRN Editorial Board, 2005). Babies with mild distress require ongoing observation, oxygen supplementation if needed and possibly septic work-up. Babies with moderate distress may require respiratory support (CPAP or mechanical ventilation), whereas babies with severe distress require immediate intubation and ventilation.

**DISCUSSION**

As with PEWS, the majority of clinical experience and publications regarding NEWS comes from the UK where early warning systems are in widespread use (Roland et al., 2014). In the systems we identified for this review, temperature, RR, HR, SpO2, capillary refill time and level of consciousness were parameters that were commonly used, but the definitions of ‘abnormal’ varied slightly. This is due to a lack of well-established reference values for biophysical variables in infants of different gestational ages (Roland, 2010). Most systems agree that a respiratory rate of 30-60 min-1 is ‘normal’ and that a SpO2 <90% is abnormal. However, with such a standard set of reference values, (Paliwoda et al., 2016) did a retrospective case control study of three neonatal early warning tools, including (Roland, 2010), and found poor sensitivity and specificity of the tools in a gestational age dependent manner.

The classification of consciousness as either active/wakes to feed, jittery/irritable, floppy/difficult to arouse/seizures is common. Hypothermia was found by (Holme et al., 2013) to be less predictive and unspecific, but is included as a parameter in several of the frameworks. Most of the existing NEWS are colour/‘traffic-light’ coded for visual categorization of acuity, and most systems call for immediate assessment when observations are ‘red’ (Roland, 2010), often synonymous of a score of ≥2 or 3, whereas ‘yellow’ often calls for clinical review. The NTS and the Plymouth NEW (Roland, 2010) were only evaluated in term infants, whereas *Singh et al* (Singh et al., 2014) accounted for an additional risk of being of low birth weight. All identified scoring systems and reference values applied to term infants, except the ACoRN respiratory score. Also, all the scoring systems were developed for use in the postpartum ward. No scoring system for identification of clinical deterioration in the NICU was identified.

The Plymouth NEW and the British Association of Perinatal Medicine NEWTT are both based on the original work by (Roland, 2010) that showed in a small-scale evaluation to have a very limited ability to identify infants that later required a medical intervention. Supported by observational data (Paliwoda et al., 2016), we therefore think that there is a need for developing a validated early warning tool for use in the neonatal population with acceptable sensitivity and specificity in different gestational age groups. The balancing concerns are that a too sensitive tool may devaluate its use (Roland, 2010), whereas on the other hand, determining interventions based on a less sensitive tool may be dangerous. However, ultimately, the chart or the underlying set of observations should not by themselves determine intervention. Abnormal scores should always be followed by a full clinical evaluation, and the score is not meant to replace clinical judgment and experience. The NEWS chart allows for assessing trends in observations, which may potentially be useful, but only one component of a complete clinical assessment.

**CONCLUSION**

Only four early warning scores for newborn infants have been published in full, two of which are based on the same chart, which has been subjected to only limited validation. The little data we have about the ability of available systems to correctly identify infants at risk indicate a rather low sensitivity. We suggest that a modified score, potentially including additional parameters, be developed for use both in postpartum wards and NICUs with both term and preterm infants.

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