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## Editorial

# The beating heart of newborn resuscitation



Heart rate has long been recognised as a valuable indicator of an infants' well-being in the minutes after birth. Virginia Apgar described it as "the most important diagnostic and prognostic of the five signs" in the Apgar score.<sup>1</sup>

The reputation of the heart rate as an indicator has prevailed. Even without a timing device and using only a stethoscope, an experienced clinician can usually assign the heart rate within the broad categories needed for clinical decisions. Dr Apgar discussed why "Color . . . is by far the most unsatisfactory sign . . .".<sup>1</sup> Pulse oximetry solves some of the difficulties in assessing oxygenation and also presents pulse rate, but it requires the equipment and a latency of a minute or more for application and then to acquire and interpret a signal. Furthermore, when using oximeters, poor signal is a common and important source of error, particularly the underestimation of heart rate.<sup>2</sup>

During neonatal hypoxia and acidosis, vagal reflexes slow the sinoatrial node, so bradycardia can be an important indicator of inadequate gas exchange.<sup>3</sup> Secondly, heart rate is an important determinant of cardiac output. However, heart rate response is also mediated by timing of cord clamping and environmental factors<sup>4-6</sup> and the relationship with cardiac output may differ between infants, so other clinical signs remain important in deciding whether and what type of resuscitation is needed. Reports of pulseless electrical activity in newborns<sup>7,8</sup> mean that while ECG detection of heart rate has some advantages over pulse oximetry or physical examination, methods that detect the pulse in arteries or perfusion of tissues can be expected to provide complementary information.

The responsiveness of heart rate to changes in the newborn's condition and the now proven limitations of palpation and intermittent auscultation have led to commendable research to find better measurement methods. This interest is highlighted by three recent systematic reviews comparing existing methods for heart rate measurement (palpation or auscultation, pulse oximetry and ECG), enhancements of these methods (e.g. phone apps or digital stethoscopes for timing) or novel methods (sensor- or camera-based reflectance photoplethysmography, doppler ultrasound and capacitance or piezoelectric devices).<sup>9-11</sup> Johnson et al. included 46 studies (11 used for a quantitative comparison) while Anton et al. and Kevat et al. included fewer because they excluded studies that did not compare each technology with pulse oximetry or ECG. Using the Cochrane Risk of Bias and the ROBINS-I tools, Johnson et al. concluded that the evidence was generally of low quality. Anton et al. and Kevat et al. used the QUADAS-2 tool for diagnostic accuracy studies and concluded that many of the studies are at risk of bias, with frequent issues related to patient selection, differences in the time at

which results were measured for the index and reference tests, and selective data analysis. All three reviews comment on indirectness of the evidence; many of the study participants were infants in neonatal units, or infants at birth who were not expected to need resuscitation. All three reviews conclude that while the new devices show potential, the low certainty of the evidence and the diverse experimental designs yield results insufficient to recommend particular new methods for widespread use. Nevertheless, it is encouraging to see new approaches being developed to address this important clinical need.

Too few neonatal devices are designed and tested "from the ground up" with the needs of neonates and their caregivers foremost. In designing future studies, we should consider in which infants is the measurement of heart rate most critical, and the specific challenges in some cases. Examples include circumstances where signal strength may be low, (e.g. low cardiac output or hydrops), or where there are risks or difficulties of sensor attachment, such as in very preterm infants or those with limb malformations. When is it critical to know the heart rate? Is it important to measure the latency in acquiring a measurement from birth, from decision to measure (often after initial steps or commencement of respiratory support), or from sensor application? Some technologies and devices might be better suited to certain time intervals and situations than others.

Which device characteristic is more important: accuracy or precision? Measurements that are precise but inaccurate at some or all heart rates may be correctable using software algorithms, whereas imprecise results can be much less useful, even if accurate in the summation of measurements on many infants.

Johnson et al. acknowledge that human factors should be considered in the validation of these devices.<sup>10</sup> As is evident in all three systematic reviews, however, an explicit consideration of human factors is unacceptably rare, whether in the design of technology for assessing neonatal heart rate after birth or in the evaluation of these technologies.<sup>9-11</sup>

Most commonly, consideration is given to human factors only after device designs are finalised—to evaluate the end user's experience and performance of tasks using the device. Adopting human factors principles and heavily involving end users from early in the conceptualisation and initial design through to final design and testing is more likely to produce devices that accommodate diverse potential end users and their complex information needs during newborn resuscitation.<sup>12-16</sup> Newborn resuscitation is a complex, time-pressured task. Leveraging end user feedback is more likely to produce a device capable of supporting cognitive load, decision-making, situation-awareness, and teamwork, thus supporting resuscitation teams' adaptation to both typical and atypical responses

during resuscitation, and to potentially discrepant cues from the baby and from various monitors.

Ultimately, the design and evaluation of future technology for assessing neonatal heart rate after birth should go beyond characteristics such as accuracy, precision and latency, and give equal consideration to human factors principles. Is the display accessible to and interpretable by all resuscitation team-members who need it? What does attachment and use of the device demand of the user? Does the display support eyes-free heart rate monitoring, or will it require visual attention, or even computation? Does the display support user awareness, preferably background awareness, without distracting from other cognitive tasks?<sup>17</sup>

The value of human factors input to design of medical devices for adults is being increasingly recognised<sup>12–16</sup>, but its application to neonatal devices is just starting to emerge. Very recently, Pickup et al.<sup>18</sup> have combined a user-centred design approach with an applied cognitive task analysis to develop a hands free, wireless monitoring system for neonatal resuscitation that focused on user requirements. The human factors approach can also go beyond individual devices. For example, a decision-centred design process, involving relevant practitioners at every stage of the process was used to create a decision support tool for challenging airway management situations in anaesthesia.<sup>19</sup> These studies demonstrate the potential of incorporating human factors principles in the development of technology and tools to improve clinical performance and outcomes.

In conclusion, we encourage medical device designers and researchers to engage with human factors professionals for both the design and evaluation of new devices for neonatal resuscitation. With a new tool-kit of devices, we may be better equipped to address whether the current heart rate thresholds for interventions (decades-old and never rigorously tested) are correct, whether the same thresholds should apply in each minute after birth, and which thresholds and which measurement devices produce the best infant outcomes.

## Conflicts of interest

None.

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