

Evolution of neonatal resuscitation with intact placental circulation

This article considers the rationale and evidence for resuscitation while the placental circulation remains intact. The history and evolution of the approach and necessary equipment are described, detailing initial development of the BASICS trolley followed by the LifeStart trolley. The initial clinical evaluation of the equipment is presented along with a discussion of future development.

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In recent times, the idea of initiating resuscitation before clamping the umbilical cord has often been disregarded and considered unimportant. Aristototele had described resuscitation of the neonate by milking the intact cord¹. Then, in the 15th century, there was one of the first documentations of neonatal resuscitation by initiating ventilation². Clamping the cord before ventilation was not considered.

“When a baby is born by the Grace of God, the midwife shall have at hand a linen cloth not harsh but old and soft and swaddle the infant and keep it on her lap. She will watch if the newborn infant is alive or not and has black or white or vivid red spots, and if the infant is breathing or not. If the infant does not breathe she shall insufflate (blow air) into his mouth.”

Paolo Bagellardo da Fiume, Padova 1472.

Five hundred years later Virginia Apgar, an obstetric anaesthetist, published her work on a method of assessing the condition of the neonate at birth to determine those infants needing resuscitation, essentially in the form of ventilation. As there was considerable concern that general anaesthetic agents were reaching the infant, the umbilical cord was clamped as soon as possible after birth in all infants born under anaesthesia. Ten years later, Brady et al showed that early clamping caused a marked bradycardia, but since all Apgar's infants had early clamping, the scoring system had already taken this into account. Over the next 30 years the advantage of placental transfusion was investigated and debated for both term and preterm infants but consideration was restricted to those not requiring assisted ventilation. The need for ventilation has always been considered

Keywords

resuscitation; delayed cord clamping; BASICS trolley

Key points

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1. Delayed cord clamping benefits healthy newborn infants and is likely to provide even more benefit to the asphyxiated neonate.
2. Recent developments permit resuscitation to be carried out at the mother's side while the placental circulation remains intact.

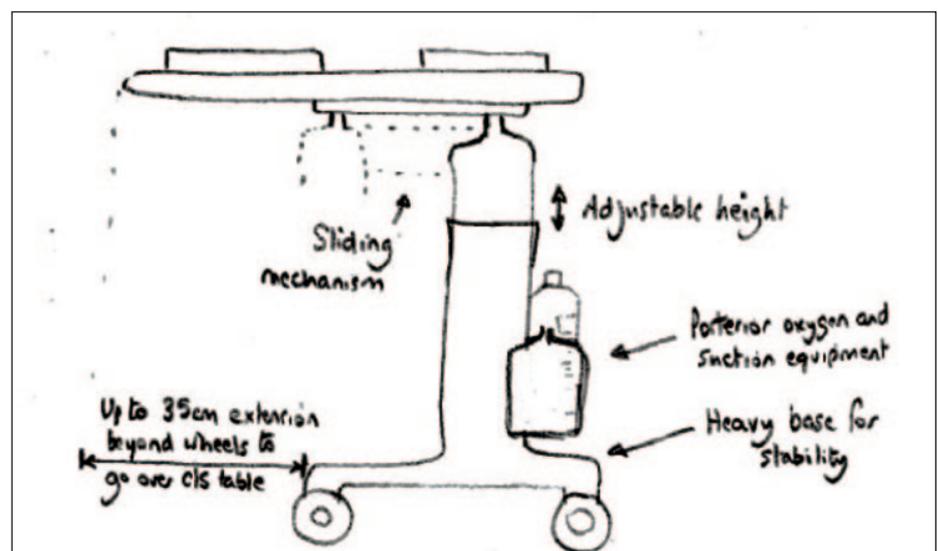


FIGURE 1 The initial concept: a sketch of the mobile resuscitation trolley drawn by Andrew Weeks at the Worcestershire Royal Hospital meeting in 2009.

more important than that of placental transfusion. The conflict between early clamping and successful resuscitation was considered in the Newborn Life Support (NLS) guideline in 2006³. The effects of early cord clamping include hypovolaemia, especially when there has been cord compression, and there was general agreement that neonatal resuscitation could be ineffective with a significant degree of hypovolaemia or the failure of an adequate placental transfusion⁴.

By the 1970s there was increasing concern about the care of preterm infants. Professor Peter Dunn working in Bristol understood the importance of a physiological transition for these infants. For preterm infants born by caesarean section, he described how the infant and placenta could be delivered together and then resuscitation of the neonate carried out *before* clamping the cord, maintaining the placenta above the level of the infant. This approach resulted in a fourfold reduction in neonatal mortality⁵.

By 2003 there was still little understanding or concern about the timing of



FIGURE 2 The trolley used in the Glasgow trial¹¹ in 2006 and debated at the Worcestershire Royal Hospital meeting in 2009. Photograph courtesy of Anne Marie Heuchan, Consultant Neonatologist, Queen Mother's Hospital, Glasgow.

cord clamping even in preterm infants. It was not a standard of care in the 27-28 weeks' gestation CESDI (confidential

enquiry into stillbirths and deaths in infancy) audit⁶. A survey of obstetricians showed that it was considered impractical as many of these infants needed resuscitation⁷. While working in New Zealand in 2005, the author noticed how midwives would bring tubing from the wall-mounted resuscitation unit to the delivery table, to provide a facility to initiate resuscitation of the newborn infant without leaving the mother and without clamping and cutting the umbilical cord. This provided a solution to the failure of obstetricians to apply the evidence from the Cochrane review that delayed cord clamping benefited preterm infants⁸.

The conflict between resuscitation and cord clamping was highlighted in a review article by van Rhee in 2004⁹ and a simple solution was offered. Initiation of ventilation with a bag valve mask resuscitator (an 'Ambu bag') with the neonate lying under the mother's legs was advised. However this method did not attract the attention of neonatologists who, by this time, were favouring more

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A way had to be found to provide the standard resuscitation equipment close enough to the mother to allow the placental circulation to remain intact. By moving a resuscitation platform (the Resuscitaire®) right up to the side of the operating table, with appropriate drapes to maintain the sterile field, it was shown that it was possible to resuscitate the neonate with the cord intact¹⁰. However, with this approach there was no room for the operating surgeon and the procedure was clumsy and did not inspire the obstetricians or neonatologists. Although the theory that resuscitation would be much more effective if a physiological transition was permitted was strong, without clinical evidence it would not be considered seriously.

In 2009, a team of interested obstetricians and neonatologists – formed by the author and hosted by Dr Andrew Gallagher at the Worcestershire Royal Hospital – met to discuss ways of initiating resuscitation with the cord intact. Various approaches were presented and, by the end of the meeting, enthusiasm and the stirred imagination of the team led to the development of a small mobile resuscitation trolley – the BASICS (bedside assessment stabilisation, immediate cardio-



FIGURE 3 The winning concept BASICS trolley, built by Peter Watt of Liverpool University.

respiratory support) trolley (**FIGURE 1**). Development by the University of Liverpool was accepted and funding sought through the National Institute for Health Research (NIHR). The trolley was based on a modified mobile height-adjustable, over-bed table that had been used in the trial of delayed cord clamping in preterm infants in Glasgow in 2006 (**FIGURE 2**)¹¹. The development team advised design changes that were tested to meet the requirements of normal delivery, caesarean section and assisted vaginal delivery in the lithotomy position. The final first prototype (**FIGURE 3**) was awarded ‘Best Redesign in Cardiovascular Medicine’ at the Medical Futures Awards 2011¹².

Development

Winning the innovations competition gave the project a considerable boost. However the majority of obstetricians and neonatologists did not fully accept the advantages of delayed cord clamping and no further enthusiasm for using the approach in infants needing resuscitation was seen. Furthermore, the concept trolley was still a long way off from being capable of clinical use. How could a manufacturer be persuaded to develop and market equipment that did not have the support of the majority of the profession?

The development team identified a number of features deemed necessary for a functional trolley (**FIGURE 4**). The traditional overhead heat system was clearly going to interfere with access and it was rapidly realised that heating on the resuscitation surface was the only solution. While searching for a heating solution the author discovered the Inditherm CosyCrib, which had a very similar frame to the BASICS trolley but included an electric motor for height adjustment. Through the generous understanding of the chief executive officer, Inditherm agreed to modify its CosyCrib and provided the first prototype after a few months. The team met again in Liverpool Women’s Hospital and tested the Inditherm prototype (**FIGURE 5**) and the BASICS trolley in a variety of mock clinical scenarios. It was found that the size of the wheels, necessary for trolley stability and mobility, was too high to run under the base of many delivery beds... back to the drawing board for the trolley frame!

Now, armed with a better understanding of requirements, Inditherm redesigned the trolley. The base was made smaller and

- Easy mobility
- Access for all modes of delivery
- Height adjustment
- A stable surface for the neonate
- Access for the resuscitation team
- An Appgar timer
- Suction
- PEEP
- Oxygen blender
- Heating

FIGURE 4 The features required for a mobile resuscitation trolley.



FIGURE 5 The first Inditherm prototype trolley.

rotation of the resuscitation platform was achieved through rotation of the whole equipment. Ancillary equipment for ventilation etc, was incorporated onto medical rail systems, which allowed equipment to be customised to each hospital’s requirements. The new trolley was again tested in a number of scenarios and proved to meet clinical requirements. With an agreement to use the trolley in the UK preterm birth study¹³, Inditherm completed CE marking of the equipment and donated a trolley to Liverpool Women’s Hospital. The trolley was marketed under the name of LifeStart in April 2012 (**FIGURE 6**).

Clinical evaluation

Clinical evaluation at the Liverpool Women’s Hospital included initial training of the staff who were already delaying cord clamping routinely at normal births. Results from the first 48 infants managed on the trolley, including seven infants of less than 33 weeks’ gestation and three of less than 1kg in weight, were presented at a conference in Birmingham in 2013¹⁴. Temperature maintenance and airway management were both good, with mask ventilation in 16 infants and intubation in six infants achieved. The anticipated

advantages of resuscitation with the cord intact appeared to be realised and, in particular, positive reaction was received from the mothers who were spared the normal separation from their infant¹⁴. Further development of the trolley is anticipated to allow a stand-alone air, oxygen and suction supply¹⁵. The approach is not limited to high resource countries and can be applied using more basic equipment in low resource settings¹⁶.

The future: heart rate monitoring

When there is doubt about the health of an adult one of the first things a doctor will do is feel for the pulse to check the heart rate. During labour, when the fetus cannot be observed, healthcare professionals depend on the heart rate almost exclusively to determine its health. In high-risk pregnancies the fetal heart is continuously monitored and documented and a record is available for future scrutiny, if necessary. However as soon as the infant is born this 'state of the art' monitoring ceases and currently, for the first few minutes after birth, healthcare professionals rely largely on clinical judgement and auscultation until it is clear that the infant has either transitioned successfully or needs continued care. There is no real-time documentation, which cannot be satisfactory for providing the appropriate intervention for the infant nor for any potential audit or review of management.

By its nature, resuscitation with the cord intact at the side of the mother may be limited in its sophistication due to lack of access. From a purely technical aspect, there is unlikely to be any advantage in cardiorespiratory function after, perhaps, five minutes with the cord intact. It is essential in any resuscitation to see improvements in the condition of the neonate until it has obviously transitioned successfully and is breathing well with a normal heart rate and oxygen saturation. Meeting the criteria for determining improvement requires accurate assessment of heart rate and oxygen saturation at every stage of the resuscitation.

The heart rate is generally considered the most important parameter of health in the newborn infant and there is no reason why the method used during labour cannot be continued postpartum. The commonest method is using Doppler ultrasound with computer analysis to extract the heart rate. Once the infant is born, a specially designed and much smaller and lighter



FIGURE 6 The final production model – the LifeStart trolley.

transducer can be placed on the neonate's chest to pick up heart movement. Ideally this would be transmitted wirelessly to the electronic fetal monitor providing an almost continuous tracing of fetal and neonatal heart rate. If cardiocography tracing is via fetal electrocardiography (ECG), the ECG signal can be picked up from between the neonate's shoulders using non-contact electrodes. The ECG may be a more appropriate and reliable method for providing a heart rate in the severely compromised neonate.

Until now, monitoring of the neonatal heart rate in this way has not been developed, not because of a lack of technological ability, rather a failure to appreciate the importance of the placental circulation during transition and the weakness of clinical assessment of the neonatal heart rate during this critical period. Once the importance of maintaining the placental circulation and keeping the infant close to its mother is fully proven, it will be a minor step to ensure that monitoring and documentation of the condition of the fetus and neonate are seamlessly continuous.

Acknowledgements

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