What does the evidence tell us? Revisiting optimal cord management at the time of birth

Article (Published Version)

Rabe, Heike, Mercer, Judith and Erickson-Owens, Debra (2022) What does the evidence tell us? Revisiting optimal cord management at the time of birth. European Journal of Pediatrics. ISSN 0340-6199

This version is available from Sussex Research Online: http://sro.sussex.ac.uk/id/eprint/104177/

This document is made available in accordance with publisher policies and may differ from the published version or from the version of record. If you wish to cite this item you are advised to consult the publisher’s version. Please see the URL above for details on accessing the published version.

Copyright and reuse:
Sussex Research Online is a digital repository of the research output of the University.

Copyright and all moral rights to the version of the paper presented here belong to the individual author(s) and/or other copyright owners. To the extent reasonable and practicable, the material made available in SRO has been checked for eligibility before being made available.

Copies of full text items generally can be reproduced, displayed or performed and given to third parties in any format or medium for personal research or study, educational, or not-for-profit purposes without prior permission or charge, provided that the authors, title and full bibliographic details are credited, a hyperlink and/or URL is given for the original metadata page and the content is not changed in any way.
What does the evidence tell us? Revisiting optimal cord management at the time of birth

Heike Rabe¹ · Judith Mercer²,³ · Debra Erickson-Owens³

Received: 3 November 2021 / Revised: 12 January 2022 / Accepted: 22 January 2022
© The Author(s) 2022

Abstract
A newborn who receives a placental transfusion at birth from delayed cord clamping (DCC) obtains about 30% more blood volume than those with immediate cord clamping (ICC). Benefits for term neonates include higher hemoglobin levels, less iron deficiency in infancy, improved myelination out to 12 months, and better motor and social development at 4 years of age especially in boys. For preterm infants, benefits include less intraventricular hemorrhage, fewer gastrointestinal issues, lower transfusion requirements, and less mortality in the neonatal intensive care unit by 30%. Ventilation before clamping the umbilical cord can reduce large swings in cardiovascular function and help to stabilize the neonate. Hypovolemia, often associated with nuchal cord or shoulder dystocia, may lead to an inflammatory cascade and subsequent ischemic injury. A sudden unexpected neonatal asystole at birth may occur from severe hypovolemia. The restoration of blood volume is an important action to protect the hearts and brains of neonates. Currently, protocols for resuscitation call for ICC. However, receiving an adequate blood volume via placental transfusion may be protective for distressed neonates as it prevents hypovolemia and supports optimal perfusion to all organs. Bringing the resuscitation to the mother’s bedside is a novel concept and supports an intact umbilical cord. When one cannot wait, cord milking several times can be done quickly within the resuscitation guidelines. Cord blood gases can be collected with optimal cord management.

Conclusion: Adopting a policy for resuscitation with an intact cord in a hospital setting takes a coordinated effort and requires teamwork by obstetrics, pediatrics, midwifery, and nursing.

What is Known:
• Placental transfusion through optimal cord management benefits morbidity and mortality of newborn infants.
• The World Health Organisation has recommended placental transfusion in their guidance.

What is New:
• Improved understanding of transitioning to extrauterine life has been described.
• Resuscitation of newborn infants whilst the umbilical cord remains intact could improve the postpartum adaptation.

Keywords Placental blood · Newborn · Postpartum adaptation · Cord clamping · Cord milking

Abbreviations
DCC Delayed cord clamping
ICC Immediate cord clamping
ILCOR International Liaison Committee for Resuscitation
IVH Intraventricular hemorrhage
NICU Neonatal intensive care unit
NRP Neonatal Resuscitation Program
OCM Optimal cord management

Communicated by Daniele De Luca.

Heike Rabe
heike.rabe@nhs.net

Judith Mercer
jsmercer@uri.edu

Debra Erickson-Owens
debo@uri.edu

1 Brighton and Sussex Medical School, University of Sussex, Brighton, UK
2 Neonatal Research Institute at Sharp Mary Birch Hospital for Women and Newborns, San Diego, CA, USA
3 College of Nursing, University of Rhode Island, Kingston, RI, USA

Published online: 02 February 2022
Introduction

During pregnancy, fetal blood circulates between the fetus and the placenta providing essential nutrients and oxygen. At delivery, infants undergo rapid changes in Circulation and breathing in order to adapt to extra-uterine life. Optimal cord management (OCM), involving waiting several minutes before clamping and cutting the cord has been shown to increase circulatory stability and reduce in-hospital mortality [1–3]. Or if unable to wait, gently milking the cord towards the infant provides some placental transfusion and is preferable over immediate cord clamping (ICC) [3]. The different methods of OCM are listed in Table 1. The World Health Organization (WHO) has recommended delayed cord clamping (DCC) as standard practice at the delivery of all infants but implementation is still variable across health care settings and countries [4, 5]. We provide an overview of current knowledge about OCM and future perspectives.

The physiology of placental transfusion

What cord blood contains

The residual placenta blood returns to the newborn warm (body temperature) and oxygenated. It contains about 15–20 mL/kg of red blood cells which provides the term infant with an adequate iron supply for four to 12 months [6, 7]. There are several million to a billion stem cells providing an autologous transplant which may reduce the infant’s susceptibility to both neonatal and age-related diseases [8]. Progesterone is neuroprotective, and levels in the blood of term infants at birth are higher than the mother’s levels. This likely aids vasodilation and enhances the bodily distribution of the large amount of placental transfusion [9, 10]. In addition, there are numerous additional components such as cytokines, growth factors, and important messengers in cord blood that most likely support and drive the process of transition but are too numerous to discuss here [11].

The full placental transfusion offers high pulmonary artery pressure in the first few hours of life to assist with neonatal adaptation [12]. It is likely that the force of the increased blood volume stimulates multi-organ perfusion for normal organ function, growth, and development. New research reveals that enhanced vascular perfusion causes an organ’s endothelial cells to release angiocrine responses to guide essential functions [13].

Circulation

Throughout pregnancy, the fetal blood volume is approximately 110–115 mL/kg of fetal weight [14]. Only ~10% of the fetal cardiac output goes to the systemic circulation in the lungs, while 30 to 50% goes to the placenta where gas exchange takes place. In order to change from placental gas exchange to lung air exchange at birth, 45–50% of the newborn cardiac output must rapidly go into the alveolar capillary network in the lungs. Waiting to clamp the cord results in a net transfer of approximately 30% of the fetal-placental blood volume over the first few minutes after birth from the placenta to the neonate. This provides the blood volume needed to fill the alveolar capillary network for the first time and to fully perfuse organs previously supported by the placenta [15].

Classic physiologic studies completed over the past 60 years have documented that placental transfusion results in improved perfusion in the neonate’s respiratory, hematologic, urinary, gastrointestinal, and neurological systems [16–18]. We have proposed that the blood volume received from a placental transfusion increases systemic and regional blood flow and vasodilation in the newborn and aids in normal organ development and health. Immediate cord clamping (ICC) reduces the neonate’s blood volume and may contribute to loss of organ-specific vascular competence [13]. Receiving an adequate blood volume from placental transfusion may be especially protective for the distressed neonate preventing hypovolemia and supporting optimal perfusion to all organs [13, 19].

One of the key features of the normal fetal to neonatal transition at birth is a reduction in the pulmonary vascular...
resistance (PVR) which allows an increase in pulmonary blood flow and redirects the right ventricular output through the lung instead of through the ductus arteriosus [20]. Credit has been given to lung aeration for decreasing the PVR at birth although the mechanisms causing this has been debated for decades [21]. A new study demonstrated that vagotomy inhibits the previously observed increase in pulmonary blood flow with partial lung aeration [21]. Compared to control newborn rabbits, Lang et al. found that animals after vagotomy had little or no increase in pulmonary blood flow when ventilated with air or nitrogen gas. Using 100% oxygen for ventilation only partially mitigated this effect. This information suggests that the initial dramatic fall in PVR likely does not occur with ventilation and breathing alone and that the vagus nerve, likely stimulated by the increased blood volume, plays a significant role. It appears that with the important task of lowering the PVR, there are multiple overlapping mechanisms to ensure that the transition happens [21].

Factors that affect the amount and speed of the placental transfusion

The volume of the transfusion in the term infant receiving DCC is approximately 85 to 100 g or ~30 mL/kg [22–24]. For preterm infants, Aladangady reported increased blood volume with DCC at all births, but a smaller increase when born by cesarean section [25]. Factors that affect the amount and speed of the placental transfusion include the timing of umbilical cord clamping, gravity, cord pulsations, uterine contractions, and milking the umbilical cord (UCM) which are discussed below, (see Figs. 1 and 2).

Timing of umbilical cord clamping

It is well known that DCC or a delay before clamping increases the amount of placental transfusion to the infant but the optimal time is still controversial. As one delays clamping longer, the neonatal hematocrit at 24–48 h increases [23, 26, 27]. Term infants with a 5-min delay showed an early hematologic advantage compared to infants receiving ICC, without any increase in hyperbilirubinemia requiring phototherapy or symptomatic polycythemia out to 48 h of age [28]. New evidence from a recent landmark study in asphyxic and asystolic lambs found that leaving the cord intact over a 10-min period mitigated the rebound hypertension (by 20–30 mmHg) commonly seen after an asphyxial event [29]. If cord clamping was immediate or only delayed 1 min, the hypertension tended to be worse. This study suggests that the post-asphyxia rebound response may contribute to the brain injury and seizures that often follow severe asphyxia. Prevention of the overshoot may alleviate its...
contribution to brain injury. Clinical studies (see Table 2) underway to address the question of longer delays in cord clamping with normal and distressed neonates are discussed later under “Ongoing research and future considerations.”

Gravity

Holding the newborn above the placenta slows transfusion, whereas lowering the newborn hastens transfusion [7, 30]. However, cord clamping at 1 min with the infant on the maternal abdomen can reduce the estimated placental transfusion by 50% [31]. Weight gain (a proxy for amount of placental transfusion) was only 50% of expected amount after two minutes of DCC in a study that weighed infants to compare the effect of gravity. The researchers lowered half the cohort below the perineum and placed the other half on the maternal abdomen [32]. The influence of gravity is illustrated in Fig. 2.

Cord pulsations

Pulsations of the intact cord appear to last longer than previously thought according to two recent studies [33, 34]. Using a Doppler, Boere found that over 80% of the infants had umbilical artery flow for over 4 min after birth and 43% still had flow when the cord was cut at 6 min [33]. The flow was pulsatile similar to the infant’s heartbeat and was mainly unidirectional, from the infant to the placenta. DiTommaso, using palpation to examine duration of cord pulsations at vaginal birth, found that the median duration was 3.5 min. They found that infants with a longer duration of cord pulsations had higher birthweights (3530 vs. 3250, p = 0.005) and a longer third stage of labor (12 vs 8 min, p < 0.001), without any increased risk of postpartum hemorrhage [34]. Both studies suggest that the placenta continues to support the infant longer than previously thought.

Uterine contractions

During the few minutes surrounding birth, uterine contractions squeeze blood from the placenta to the infant. However, as the uterus relaxes in-between contractions, blood can flow through the placenta exchanging nutrients and gases for the fetus/infant [35, 36]. This process continues for longer than originally thought and is a valuable asset especially for the infant who is not breathing [33]. Even after the umbilical arteries close, the strong uterine contractions of third stage force more blood to the infant via the umbilical vein, if the cord is left intact.

Umbilical cord milking

Although it is not physiologic, milking the umbilical cord two to four times towards the baby has been studied as an alternative to waiting for at least 60 s before clamping the cord [37, 38]. Meta-analyses of studies using UCM show similar benefits to waiting for 60 s, with increased survival by 27% compared to ICC with no difference in major co-morbidities of prematurity [3, 39, 40]. Based on this evidence, many key perinatal learned societies and stakeholders recommend the use of UCM before clamping the cord but only if DCC is deemed not feasible [39, 40].

Benefits for term and preterm infants

Benefits for term neonates include higher hemoglobin levels, less iron deficiency in infancy, improved brain myelin volume out to 12 months, and better motor and social development at 4 years of age especially in boys [41–43]. For preterm infants, benefits include less intraventricular hemorrhage, fewer gastrointestinal issues, lower transfusion requirements, and decreased mortality by 30% in the NICU and out to two years of age [1, 44, 45]. Perhaps the benefit most familiar with clinicians is the prevention of iron deficiency and anemia in infancy. Both iron deficiency and anemia have a high prevalence in low- and middle-income countries and are associated with perinatal mortality, delayed child mental and physical development, and reduced visual and auditory function [43, 46]. Anemia in infancy contributes to the global burden of morbidity and mortality during the first year of life. OCM can contribute to preventing anemia in the newborn and increased better iron storage up to 12 months of age in term infants [7]. Providers should consider that OCM is free of charge and an easy preventative measure which can be applied in any health care setting, in any gestational age and is strongly recommended by the WHO [4].
### Table 2  Current or proposed studies on intact cord resuscitation

| Study acronym and country | Proposed N | GA (weeks) | Intervention | Cord clamping time, control | Cord clamping time, intervention | Primary outcome | Expected end date |
|---------------------------|------------|------------|--------------|----------------------------|---------------------------------|----------------|------------------|
| VentFirst (USA) NCT02742454 [75] | 940 | 23–28 | CPAP 30–120 s | 30–60 s | 120 s | IVH, HR, SpO2, Apgar scores ≤ 10 min | 2024 |
| PCI-Trial (Italy) NCT02671305 [76] | 202 | 23–29 | Resuscitation as needed | Intact UCM×4 | 3 min | Composite outcome of severe IVH, CLD or death | 2022 |
| ABC2 (Netherlands Trial Registry) NTR7194 [77] | 660 | 24–30 | Resuscitation if needed | ICC | Cord clamping when stable* | Intact survival — without IVH or NEC | 2024 |
| MINVI – Milking in Non-Vigorous Infants (USA) NCT03631940 | 1200 | 35–42 | Milking the cord ×4 times | ICC | UCM×4 before clamping | Admission to the NICU | 2023 |
| Baby DUCC (Australia) 12,618,000,621,213 [78] | 120 | 32–41 | Resuscitation if needed | ICC | Until 1 min after CO2 detector changes or 5 min | Heart rate at 60 and 120 s | 2023 |
| SAVE: Effects of DCC during resuscitation (Sweden) NCT04070560 | 600 | 35–42 | Resuscitation for non-breathing infants | 60 s to resuscitaire | ≥ 180 s with intact cord near mother | Apgar at 5 min | 12/2026 |
| CHIC — congenital diaphragmatic hernia intact cord (France) NCT04429750 [51] | 180 | > 36 | Resuscitation of Infants with Congenital Diaphragmatic Hernia | ICC with transfer to Resus room | Intact cord resuscitation on dedicated trolley near mother | Apgar score at 1 and 5 min | No data |
Potential fetal risk conditions

Fetuses who were small for gestational age at birth also benefit from OCM [47, 48]. DCC improves iron stores in SGA infants ≥ 35 weeks at 3 months of age without increasing the risk of symptomatic polycythemia, need for partial exchange transfusions, or morbidities associated with polycythemia. Thus, the WHO recommends providing OCM for them at birth. The same applies to mothers with human immunodeficiency virus infection and low viral load as transmission from mother to fetus is very low [49]. A study of mother-infant pairs with Rhesus-alloimmunisation demonstrated that infants who received placental transfusion at delivery had reduced need for immediate blood exchange transfusion after birth and were successfully managed with phototherapy and blood transfusions as needed [50].

The myth about an increase in jaundice requiring phototherapy has been refuted by recent meta-analyses [1, 2, 23, 44]. Studies on infants with congenital heart disease or diaphragmatic hernia have demonstrated benefits for postnatal adaptation due to their increased need for red blood cells as oxygen carriers. It makes sense to provide them with more of their own blood through placental transfusion at birth [51, 52]. Studies of multiple births have demonstrated feasibility of providing OCM to twins and triplets [53, 54]. Thus, multiple births should not be routinely excluded. The plan for delivery of fetuses with the conditions mentioned above should be considered on an individual basis with a decision about OCM made by an experienced perinatal team ahead of birth.

Potential maternal/fetal risk conditions

Maternal contraindications of OCM especially focused on DCC have not been formally studied. There are almost no indications for ICC, nor contraindications to OCM. The need for maternal resuscitation in the face of massive, acute hemorrhage would be a rare, justifiable reason to proceed with ICC but cut UCM may still benefit the newborn. A ruptured vasa praevia, snapped cord, or other trauma to the cord vessels, which will result in hemorrhage from the baby, would also be reasons for ICC. In the case of a complete placental abruption where the placenta is delivered at the same time as the baby, it could be held above the baby, with gentle application of pressure to the placenta, and then clamped before the placenta is lowered. Cord milking could also be considered in this situation. A short cord length might interfere with the management of the mother or baby but can usually be addressed with optimal positioning. It should not be considered as an automatic indication for ICC, nor a contraindication to OCM.

Stabilization and resuscitation with the cord intact

When an infant is born, the intrapartum provider must quickly decide how to manage the umbilical cord. At an uncomplicated birth, DCC is a well-supported, evidence-based practice which facilitates placental transfusion. When an infant is in distress, providers in hospital settings will often practice ICC and transfer the infant to the warmer for resuscitation, away from the mother’s bedside. This practice may lead to increased morbidity and mortality and a disruption in neurodevelopment [44, 55]. The risks of ICC have been studied indirectly as ICC has been the comparator for many studies on DCC and UCM. A list of potential risks is shown in Table 3. The practice of stabilization and resuscitation with an intact cord is not a new idea yet it is infrequently used in hospital settings. Midwives, in out-of-hospital settings, frequently maintain an intact cord after birth and regard the umbilical cord as a lifeline to assist in transition to neonatal life [7, 56].

New evidence suggests a distressed infant should be stabilized and resuscitated with an intact cord. This fosters placental transfusion and allows the placenta to continue its important respiratory role in gas exchange and supports volume repletion. A tight nuchal cord and/or a shoulder dystocia are often associated with slow-to-start infants secondary to hypovolemia. The Somersault Maneuver is recommended to release the tight nuchal cord allowing the cord to remain intact [57]. For both nuchal cord and shoulder dystocia, the restoration of blood volume and continued oxygen support from the placenta, alongside Neonatal Resuscitation Program (NRP) and International Liaison Committee for Resuscitation (ILCOR) protocols, help to assist the newborn’s transition [19, 55] and are important actions which can help protect the newborn’s heart and brain. Resuscitation tables (trolleys) and the accompanying resuscitation equipment have been developed for this purpose [55]. These tables can be moved alongside the mother’s bedside.

### Table 3 Potential harmful effects of immediate cord clamping compared to delayed cord clamping or milking of the cord

| Organ system          | Effects of immediate cord clamping                                      |
|-----------------------|------------------------------------------------------------------------|
| Hematology            | RBC Volume, Hematocrit, Hemoglobin, Hypovolemia                         |
| Body iron stores      | Ferritin (out to 4–8 months)                                            |
|                       | Total body iron (at 6 months)                                          |
| Cardiovascular        | Adaptation                                                             |
|                       | Blood pressure                                                         |
|                       | Vascular resistance                                                    |
|                       | RBC flow to brain (18%)                                                |
|                       | RBC flow to gut (15–20%)                                               |
| Birth weight          | Lighter by 60–101 g                                                    |
| Skin                  | Cutaneous perfusion                                                    |
|                       | Peripheral temperature                                                 |
| Renal function        | Renal blood flow                                                       |
|                       | Urine output                                                           |
|                       | Sodium excretion                                                       |
| Respiratory circulation| Pulmonary vasodilatation                                               |

RBC red blood cells; increase; decrease [1–3]
and the resuscitation can be conducted with an intact cord. Andersson and colleagues (2019) demonstrated in distressed infants, ≥ 35 weeks gestation, that resuscitation with an intact cord resulted in better oxygen saturation levels and Apgar scores [58].

Practices that may interfere with placental transfusion

Two birth practices, cord blood banking and cord gas collection, imply ICC and challenge the support of an intact cord at birth. Umbilical cord blood banking is the collection of residual placental blood, per parental request, for the purposes of stem cell collection which is then stored in a private or public blood bank. Placental transfusion, via DCC, is not compatible with cord blood banking. In the USA, the American College of Obstetricians and Gynecologists do not recommend the practice of private blood banking nor the interference of the routine practice of DCC [59]. Parents should be informed about the entire contents of cord blood and risks associated with ICC before they make a decision about banking their infant’s blood [7].

The practice of umbilical cord gas collection is routine in some hospital settings or may be used judiciously to assess acid–base balance in complex clinical situations. Most providers double clamp the cord immediately after birth and save a section of the cord to be used for analysis. In light of the benefits of DCC, researchers have examined the accuracy of cord gas results comparing ICC and DCC. In a recently published systematic review, it was found that a delay of 2 min in clamping made little difference on the accuracy of cord gas results [60]. Also, cord blood gases may be collected from an intact cord [61].

Ongoing research and future considerations

There has been increasing interest in stabilization of the preterm or term infant, while the cord is still intact. A list of ongoing or planned studies is provided in Table 2, and Katheria has written an excellent review [62]. We propose that the totality of a placental transfusion is what is important to the baby. It is not just the components — red blood cells, stem cells, cytokines, growth factors, plasma, blood volume, progesterone, or force of the blood for transduction — that make a difference. Collectively, all these pieces working together create the whole process of a normal transition for the neonate. This is a clear biological case where the “whole is greater than the sum of its parts.” If the whole is not considered, it does not work as well and can leave the infant deficient in a variety of ways. This idea may be part of the reason that the uptake of DCC/placental transfusion into clinical practice is slow as placental transfusion does not fit well into the current scientific paradigm of reductionism.

Recommendations for practice

Support of placental transfusion is recommended as the standard of care at the time of birth, across all birth settings, all modes of delivery and for both term and preterm newborns [4, 7]. This recommendation helps to decrease iron deficiency anemia in infancy and reduces a negative impact on the developing brain [41, 63]. Distressed infants who require resuscitation often have their cords cut immediately and are rapidly transferred to a resuscitaire (warmer), away from the mother’s bedside. [64, 65] Leslie and colleagues (2020) found that US midwives often practiced DCC (98%) and waited for cord pulsations to cease. But these same midwives felt they needed to use ICC in situations which required neonatal resuscitation and/or umbilical cord gas collection often because of institutional policies and time pressures [66]. Emerging evidence suggests that distressed infants require a placental transfusion as much if not more than a healthy newborn[7, 19]

In complex clinical situations that require neonatal resuscitation, new available research suggests the resuscitation can be conducted with an intact umbilical cord managed at the mother’s bedside [55, 67]. This can enhance resuscitation efforts and provide a return of the infant’s own warm, oxygenated blood. When resuscitation with an intact cord is not feasible, milking the cord can be done quickly (several times) within the current NRP and ILCOR standards benefitting infants 28-week gestation or greater [Madar, 2021]. Milking can accelerate the transfer of residual placental blood although not as completely as DCC or an intact cord [55, 68]. Establishing a policy for resuscitation with an intact cord within a hospital setting takes a coordinated effort, logistical considerations and requires multidisciplinary support [55, 65, 69].

One large randomized controlled trial, comparing DCC with UCM, found a significant higher rate of intraventricular hemorrhage with UCM, in infants less than 28-week gestation, but recent meta-analyses of comparative studies found no difference for this outcome [2, 70]. The question remains as to how UCM in infants less than 28-weeks compare to infants receiving ICC differ on variables of IVH and neurodevelopmental follow-up [40].

Implementing a protocol

It can take significant time (sometimes 10 years or more) for evidence-based approaches to become accepted into clinical practice [71]. In fact, many effective interventions fail to be adopted (60–70%) [72]. This presents significant challenges when trying to translate research findings, such as those from OCM, into practice. Unfortunately, failure to adopt beneficial practices in a timely fashion may lead to unnecessary
harm to the newborn [71–73]. Mounting evidence, especially a decrease of mortality in preterm infants, supports the benefits of DCC [45]. This has led to a greater willingness for hospital settings to adopt DCC. Yet, DCC appears to be more easily adopted by providers caring for preterm infants when compared to term infants [74]. Implementation of OCM for all infants requires a step wise approach in planning and implementation [5]. This includes a needs assessment to assess organizational and individual willingness to change. Stakeholders and end users (such as obstetricians, midwives, pediatricians and nurses) must be included in order to reduce reluctance to change and to increase confidence and adherence [5]. A multidisciplinary approach supports teamwork and enhances adoption to change. At this point in the process, any concerns and potential contradictions should be addressed in multidisciplinary discussions prior to delivery. A clinical guideline or policy which is simple, easy to follow, and based on current evidence should be developed with input from all team members and should be updated regularly as new evidence emerges. An example of new emerging evidence is the improvement of neonatal resuscitation by maintaining an intact umbilical cord. This is a novel clinical practice in most hospital settings although it has been practiced at out of hospital settings back to the time of Aristotle [75]. Once the decision is made to introduce OCM to the hospital setting, a variety of motivational and educational strategies are available. After implementation, an ongoing monitoring plan is needed to watch compliance rates. Reflection, evaluation, and responsiveness (feedback) will enhance sustainability [5].

Conclusion

Receiving a placental transfusion is beneficial for all term and preterm infants, including those that are distressed. Placental transfusion plays a major role in neonatal transition by preventing hypovolemia and providing better perfusion to all organs. Adopting resuscitation with an intact cord in a hospital setting will take a concerted effort and team works by obstetricians, midwives, pediatricians, and nurses.

Authors’ contributions All authors conceptualized the composition of the manuscript, updated their literature searches, and wrote parts of the manuscript. All authors coordinated the writing and finalized the manuscript. All authors have read and agreed to the contents of the manuscript.

Declarations

Ethics approval Not applicable.

Consent to participate Not applicable.

Consent for publication Not applicable.

Conflict of interest The authors declare no competing interests.

Open Access This article is licensed under a Creative Commons Attribution 4.0 International License, which permits use, sharing, adaptation, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons licence, and indicate if changes were made. The images or other third party material in this article are included in the article’s Creative Commons licence, unless indicated otherwise in a credit line to the material. If material is not included in the article’s Creative Commons licence and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder. To view a copy of this licence, visit http://creativecommons.org/licenses/by/4.0/.

References

1. Rabe H, Gyte GM, Díaz-Rossello JL, Duley L (2019) Effect of timing of umbilical cord clamping and other strategies to influence placental transfusion at preterm birth on maternal and infant outcomes, Cochr Datab Syst Rev 9:CD003248. https://doi.org/10.1002/14651858.CD003248.pub4
2. Seidler AL, Gyte GM, Rabe H, Díaz-Rossello JL, Duley L, Aziz K, Costa-Nobre DT, Davis PG, Schmölzer GM, Ovelman C, Askie LM (2021) International Liaison Committee on Resuscitation Neonatal Life Support Task Force, Umbilical cord management for newborns <34 weeks’ gestation: a meta-analysis, Pediatrics 147:e20200576. https://doi.org/10.1542/peds.2020-0576.
3. Jasani B, Torgalkar R, Ye XY, Syed S, Shah PS (2021) Association of umbilical cord management strategies with outcomes of preterm infants: a systematic review and network meta-analysis. JAMA Pediatr 175:e210102. https://doi.org/10.1001/jamapediatrics.2021.0102
4. World Health Organization (2019) Optimal timing of cord clamping for the prevention of iron deficiency anemia in infants
5. Anton O, Jordan H, Rabe H (2019) Strategies for implementing placental transfusion at birth: a systematic review. Birth 46:411–427. https://doi.org/10.1111/birt.12398
6. Dewey KG, Chaparro CM (2007) Session 4: Mineral metabolism and body composition iron status of breast-fed infants. Proc Nutr Soc 66:412–422. https://doi.org/10.1017/S002966510700568X
7. Andersson O, Mercer JS (2021) Cord management of the term newborn. Clin Perinatol 48:447–470. https://doi.org/10.1016/j. cplt.2021.05.002
8. Lawton C, Acosta S, Watson N, Gonzalez-Portillo C, Diamandas T, Tajiri N, Kaneko Y, Sanberg PR, Borlongan CV (2015) Enhancing endogenous stem cells in the newborn via delayed umbilical cord clamping. Frontiers in Neurosci 9:389. https://doi.org/10.3389/fnins.2015.00389
9. Gonzalez-Orozco JC, Camacho-Arroyo I (2019) Progesterone actions during central nervous system development. Front Neuosci 13:503. https://doi.org/10.3389/fnins.2019.00503
10. Sippell WG, Becker H, Versmold HT, Bidlingmaier F, Knorr D (1978) Longitudinal studies of plasma aldosterone, corticosterone, deoxycorticosterone, progesterone, 17-hydroxyprogesterone, cortisol, and cortisone determined simultaneously in mother and child at birth and during the early neonatal period. I. Spontaneous delivery, J Clin Endocrinol Metab 46:971–985. https://doi.org/10.1210/jcem-146-6-971
11. Chaudhury S, Saqibuddin J, Birkett R, Falcon-Girard K, Kraus M, Ernst LM, Grobman W, Mestan KK (2019) Variations in umbilical
cord hematopoietic and mesenchymal stem cells with bronchopulmonary dysplasia. Front Pediatr 7:475. https://doi.org/10.3389/fped.2019.00475
12. Arcilla RA, Oh W, Lind J, Gessner H (1966) Pulmonary arterial pressures of newborn infants born with early and late clamping of the cord. Acta Paediatr 55:305–315. https://doi.org/10.1111/j.1651-2227.1966.tb17659.x
13. Mercer JS, Erickson-Owens DA, Rabe H (2021) Placental transfusion: may the force be with the baby. J Perinatol Off J Calif Perinat Assoc 41:1495–1504. https://doi.org/10.1038/s41372-021-01085-0
14. Linderkamp O (1982) Placental transfusion: determinants and effects. Clin Perinatol 9:559–592
15. Kiserud T (2005) Physiology of the fetal circulation. Semin Fetal Neonatal Med 10:493–503
16. Oh W, Oh M, Lind J (1967) Renal function and blood volume in newborn infant related to placental transfusion. Acta Paediatr Scand 55:197–210
17. Oh W, Lind J, Gessner H (1966) The circulatory and respiratory adaptation to early and late cord clamping in newborn infants. Acta Paediatr Scand 55:17–25. https://doi.org/10.1111/j.1651-2227.1966.tb15204.x
18. Nelle M, Zilow EP, Linderkamp O (1995) Effect of asystolic newborn lambs prior to umbilical cord clamping. Acta Paediatr 84:197–210. https://doi.org/10.1111/j.1651-2227.1995.tb13264.x
19. Yao AC, Lind J (1969) Effect of gravity on placental transfusion. J Physiol 196:451–463. https://doi.org/10.1111/j.1469-7580.1969.tb02243.x
20. Kiserud T (2005) Physiology of the fetal circulation. Semin Fetal Neonatal Med 10:493–503
21. Hooper SB (2017) Vagal denervation inhibits the increase in pulmonary blood flow during partial lung aeration at birth. J Physiol 595:635–644. https://doi.org/10.1111/jnph.12206
22. McDonald SJ, Middleton P, Downswell T, Morris PS (2013) Effect of umbilical cord milking of term infants on maternal and neonatal outcomes, Cochrane Database Syst Rev CD004074. https://doi.org/10.1002/14651858.CD004074.pub3
23. Yao AC, Moiinian M, Lind J (1969) Distribution of blood between infant and placenta after birth. Lancet Lond Engl 2:871–873. https://doi.org/10.1016/s0140-6736(69)92328-9
24. Aladangady N, McHugh S, Aitchison TC, Wardrop CAJ, Holland BM (2006) Infants’ blood volume in a controlled trial of placental transfusion at preterm birth. Pediatrics 117:205–211. https://doi.org/10.1542/peds.2004-1773
25. Polglase GR, Schmölzer GM, Roberts CT, Blank DA, Badurdeen S, Crossley KJ, Miller SL, Stojanovska V, Galinsky R, Kluckow M, Gill AW, Hooper SB (2020) Cardiopulmonary resuscitation of asystolic newborn lambs prior to umbilical cord clamping: the timing of cord clamping matters! Front Physiol 11:902. https://doi.org/10.3389/fphys.2020.00902
26. Yao AC, Lind J (1969) Effect of gravity on placental transfusion. Lancet Lond Engl 2:505–508. https://doi.org/10.1016/s0140-6736(69)90213-x
27. Kiserud T (2005) Physiology of the fetal circulation. Semin Fetal Neonatal Med 10:493–503
28. Lee CHC, Escobedo MB, Hoover AV, Kamath-Rayne E, Weiner GM, Wyckoff MH, Yamada NK, Zsizsik J (2021) Part 5: Neonatal Resuscitation 2020 American Heart Association Guidelines for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care. Pediatrics 147:e2020038505E. https://doi.org/10.1542/peds.2020-038505E
29. Dani C, Sandri F, Pratesi S (2021) Considering an update on umbilical cord milking for the need for red cell transfusions and improves neonatal adaptation in infants born at less than 29 weeks’ gestation: a randomised controlled trial. Arch Dis Child Fetal Neonatal Ed 93:F14–19. https://doi.org/10.1136/adc.2006.108902
30. Aladangady N, McHugh S, Aitchison TC, Wardrop CAJ, Holland (2006) Infants’ blood volume in a controlled trial of placental transfusion at preterm birth. Pediatrics 117:205–211. https://doi.org/10.1542/peds.2004-1773
31. Aladangady N, McHugh S, Aitchison TC, Wardrop CAJ, Holland (2006) Infants’ blood volume in a controlled trial of placental transfusion at preterm birth. Pediatrics 117:205–211. https://doi.org/10.1542/peds.2004-1773
32. Aladangady N, McHugh S, Aitchison TC, Wardrop CAJ, Holland (2006) Infants’ blood volume in a controlled trial of placental transfusion at preterm birth. Pediatrics 117:205–211. https://doi.org/10.1542/peds.2004-1773
33. Aladangady N, McHugh S, Aitchison TC, Wardrop CAJ, Holland (2006) Infants’ blood volume in a controlled trial of placental transfusion at preterm birth. Pediatrics 117:205–211. https://doi.org/10.1542/peds.2004-1773
34. Aladangady N, McHugh S, Aitchison TC, Wardrop CAJ, Holland (2006) Infants’ blood volume in a controlled trial of placental transfusion at preterm birth. Pediatrics 117:205–211. https://doi.org/10.1542/peds.2004-1773
35. Aladangady N, McHugh S, Aitchison TC, Wardrop CAJ, Holland (2006) Infants’ blood volume in a controlled trial of placental transfusion at preterm birth. Pediatrics 117:205–211. https://doi.org/10.1542/peds.2004-1773
36. Aladangady N, McHugh S, Aitchison TC, Wardrop CAJ, Holland (2006) Infants’ blood volume in a controlled trial of placental transfusion at preterm birth. Pediatrics 117:205–211. https://doi.org/10.1542/peds.2004-1773
37. Aladangady N, McHugh S, Aitchison TC, Wardrop CAJ, Holland (2006) Infants’ blood volume in a controlled trial of placental transfusion at preterm birth. Pediatrics 117:205–211. https://doi.org/10.1542/peds.2004-1773
38. Aladangady N, McHugh S, Aitchison TC, Wardrop CAJ, Holland (2006) Infants’ blood volume in a controlled trial of placental transfusion at preterm birth. Pediatrics 117:205–211. https://doi.org/10.1542/peds.2004-1773
39. Aladangady N, McHugh S, Aitchison TC, Wardrop CAJ, Holland (2006) Infants’ blood volume in a controlled trial of placental transfusion at preterm birth. Pediatrics 117:205–211. https://doi.org/10.1542/peds.2004-1773
40. Aladangady N, McHugh S, Aitchison TC, Wardrop CAJ, Holland (2006) Infants’ blood volume in a controlled trial of placental transfusion at preterm birth. Pediatrics 117:205–211. https://doi.org/10.1542/peds.2004-1773
41. Aladangady N, McHugh S, Aitchison TC, Wardrop CAJ, Holland (2006) Infants’ blood volume in a controlled trial of placental transfusion at preterm birth. Pediatrics 117:205–211. https://doi.org/10.1542/peds.2004-1773
42. Aladangady N, McHugh S, Aitchison TC, Wardrop CAJ, Holland (2006) Infants’ blood volume in a controlled trial of placental transfusion at preterm birth. Pediatrics 117:205–211. https://doi.org/10.1542/peds.2004-1773
44. Fogarty M, Osborn DA, Askie L, Seidler AL, Hunter K, Lui K, Simes J. Tarnow-Mordi W (2018) Delayed vs early umbilical cord clamping for preterm infants: a systematic review and meta-analysis. J Am Obstet Gynecol 218:1–18. https://doi.org/10.1016/j.amjog.2017.10.231

45. Backes CH, Huang H, Cua CL, Garg V, Smith CV, Yin H, Garg P, Kler N, Gujral K (2018) Early versus delayed cord clamping in small for gestational age infants: a randomised controlled trial. Lancet Child Adolesc Health S2352-4642(20)30042-0. https://doi.org/10.1016/S2352-4642(20)30042-0

46. Fulton C, Stoll K, Thordarson D (2016) Bedside resuscitation of newborns with an intact umbilical cord: experiences of midwives from British Columbia. Midwifery 34:42–46. https://doi.org/10.1016/j.midw.2016.01.006

47. Wang M, Mercer JS, Padbury J, Govindaswami B, Song D (2020) Effect of delayed cord clamping on umbilical blood gas values in term newborns: a systematic review. Obstet Gynecol 135:576–582. https://doi.org/10.1097/AOG.0000000000006363

48. Andrews O, Hellström-Westas L, Andersson D, Clausen J, Domelöf M (2013) Effects of delayed compared with early umbilical cord clamping on maternal postpartum hemorrhage and cord blood gas sampling: a randomized trial: Delayed vs early clamping effect on PPH and pH. Acta Obstet Gynecol Scand 92:567–574. https://doi.org/10.1111/1600-0412.2012.01530.x

49. World Health Organization (2021) Consolidated guidelines on HIV prevention, testing, treatment, service delivery and monitoring: recommendations for a public health approach. https://www.who.int/publications/i/item/9789240031593

50. Nudelman MJR, Belogolovsky E, Jegatheesan P, Govindaswami B, Song D (2020) Effect of delayed cord clamping on umbilical blood gas values in term newborns: a systematic review. Obstet Gynecol 135:576–582. https://doi.org/10.1097/AOG.0000000000006363

51. Galantowicz M, Bauer JA, Hoffman TM (2015) Early versus delayed umbilical cord clamping in infants with congenital heart disease: a pilot, randomized, controlled trial. J Perinatol 35:826–831. https://doi.org/10.1038/jp.2015.89

52. Le Duc K, Mur S, Rakza T, Boukhiri MR, Rousseau C, Vaast P, Westlynk N, Aubry E, Sharma D, Storme L (2021) Efficacy of intact cord resuscitation compared to immediate cord clamping on cardiorespiratory adaptation at birth in infants with isolated congenital diaphragmatic hernia (CHIC). Children 8:339. https://doi.org/10.3390/children8050339

53. Jegatheesan P, Belogolovsky E, Nudelman M, Song D, Govindaswami B (2019) Neonatal outcomes in preterm multiples receiving delayed cord clamping. Arch Dis Child Fetal Neonatal Ed 104:F575–F581. https://doi.org/10.1136/archdischild-2018-316479

54. Ruangkit C, Bumrungphuet S, Panburana P, Khositseth A, Nuntnarumit P (2019) A randomized controlled trial of immediate versus delayed umbilical cord clamping in multiple-birth infants born preterm. Neonatology 115:156–163. https://doi.org/10.1159/000494132

55. Hutchon D, Pratesi S, Katheria A (2021) How to provide mother-sonatal resuscitation with intact placental circulation?. Child Basal Swit 8:291. https://doi.org/10.3390/children8040291

56. Cusick SE, Georgieff MK, Rao R (2018) Approaches for reducing the risk of early-life iron deficiency-induced brain dysfunction in children. Nutrients 10. https://doi.org/10.3390/nu10020227

57. Mercer JS, Skovgaard RL, Peereera-Eaves J, Bowman TA (2005) Nuchal cord management and nurse-midwifery practice. J Midwifery Womens Health 50:373–379. https://doi.org/10.1016/j.mujh.2005.04.023
73. Schmidt N, Brown J (2021) Evidence-based practice for nursing, 5th ed., Jones and Barlett Learning. Burlington MA
74. Delayed umbilical cord clamping after birth (2020) ACOG Committee Opinion, Number 814. Obstet Gynecol 136:e100–e106. https://doi.org/10.1097/AOG.0000000000004167

75. Downey CL, Bewley S (2012) Historical perspectives on umbilical cord clamping and neonatal transition. J R Soc Med 105:325–329. https://doi.org/10.1258/jrsm.2012.110316

Publisher’s Note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.