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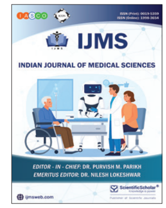

Review Article

Delayed cord clamping in neonates: A global evidence-based review of physiology, outcomes, and clinical integration in term and preterm births

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ABSTRACT

Delayed cord clamping (DCC) has emerged as a transformative intervention in neonatal care, shifting long-standing practices rooted in tradition rather than evidence. Once considered a procedural detail, the timing of umbilical cord clamping is now recognized as a crucial determinant of neonatal outcomes. DCC, typically defined as clamping the cord ≥30–60 s after birth or after cessation of pulsation, has demonstrated measurable benefits in both term and preterm infants, including improved iron status, enhanced cardiovascular stability, and reduced need for transfusion. This comprehensive narrative review evaluates the physiological basis, clinical outcomes, and implementation strategies surrounding DCC. Drawing from over a decade of literature, the review synthesizes findings from randomized trials, observational studies, and international guidelines. Specific emphasis is placed on the distinct effects of DCC in term versus preterm neonates, with further attention to cord milking, physiologic-based cord clamping, and special scenarios such as cesarean sections or neonatal resuscitation. Barriers to adoption in both high-resource and low-resource settings are examined, including logistical challenges, clinical hesitations, and policy gaps. Evidence consistently supports that DCC improves neonatal hematologic parameters, decreases intraventricular hemorrhage in preterms, and does not increase maternal risk. Nonetheless, variability in practice persists globally. This review highlights consensus points across the World Health Organization, American College of Obstetricians and Gynecologists, Royal College of Obstetricians and Gynecologists, and National Institute for Health and Care Excellence guidelines, while identifying inconsistencies and areas of needed harmonization. A practical framework for implementation and clinical decision-making is proposed. To realize the full potential of DCC, health systems must integrate evidence into training, protocols, and delivery room infrastructure. Future research must refine timing strategies, assess long-term neurodevelopmental outcomes, and evaluate adjunct techniques such as cord milking. This article aims to be a reference standard that bridges knowledge to practice, advocating for a unified, evidence-informed approach to neonatal transition.

Keywords: Delayed cord clamping, Neonatal outcomes, Placental transfusion, Preterm infants, Umbilical cord management

INTRODUCTION

The timing of umbilical cord clamping, long relegated to obstetric routine, has emerged as a critical determinant in shaping immediate and long-term neonatal outcomes. Historically, immediate cord clamping (ICC) – often performed within the first 10–20 s after birth – was adopted without empirical foundation, driven largely by surgical efficiency, concerns around maternal hemorrhage, and outdated assumptions about neonatal physiology.[1,2] This mechanistic practice ignored the complex circulatory

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transition that occurs at birth, where placental transfusion plays a central role in ensuring cardiopulmonary stability and hematologic sufficiency.[3,4] The unquestioned perpetuation of ICC reflected not evidence, but inertia.

In contrast, delayed cord clamping (DCC) – defined as the intentional postponement of cord clamping for at least 30–180 s or until pulsation ceases – has now been validated across numerous randomized trials and population-level studies[5-11] as a biologically logical and clinically advantageous intervention. It enables the transfer of an additional 20–40 mL/kg of blood, representing up to 30% of a neonate's final blood volume, and delivers an essential payload of red blood cells, iron, plasma proteins, and stem cells crucial for immunologic and neurologic development.[12-15] These benefits are not marginal – they are foundational, influencing the trajectory of neurodevelopment, anemia risk, and even mortality in preterm infants.[16-21]

The mechanistic rationale is equally robust. At birth, pulmonary vascular resistance drops while systemic resistance increases. Abrupt cord clamping before lung aeration induces hemodynamic instability, left ventricular preload compromise, and fluctuations in cerebral perfusion – particularly in preterm infants, where autoregulatory systems are immature.[22-24] DCC allows time for physiologic transition, lung expansion, and stabilization of blood flow across the ductus arteriosus and foramen ovale, ensuring a smoother adaptation to extrauterine life. These complex cardiopulmonary transitions are elegantly visualized in Figure 1, which contrasts the physiologic consequences of ICC versus DCC at the circulatory level.

Yet, despite this compelling physiological and clinical evidence, global practice remains fragmented.[25,26] Institutional inertia, medico-legal caution, logistical barriers in cesarean sections or emergencies, and clinician discomfort continue to hinder adoption.[27-30] Moreover, variations in DCC definitions, eligibility criteria, and integration with neonatal resuscitation protocols create inconsistency and confusion. While leading health organizations – World Health Organization (WHO),[10] American College of Obstetricians and Gynecologists (ACOG),[11] royal college of obstetricians and gynecologists (RCOG),[12] and national institute for health and care excellence (NICE)[13] – increasingly endorse DCC as standard care, a translational chasm remains between evidence and bedside practice. A comparative overview of these recommendations is summarized in Table 1.

Preterm infants, who stand to benefit most, are paradoxically the least likely to receive DCC, particularly when perceived instability prompts rapid intervention.[31-35] This raises ethical tensions: Does anticipatory intervention justify preempting a practice that improves survival? Can DCC be harmonized with resuscitative needs through physiologic-based cord clamping (PBCC) models or intact-cord ventilation techniques.[36-39] These are not merely technical questions – they are challenges that straddle the domains of ethics, training, systems design, and perinatal equity.

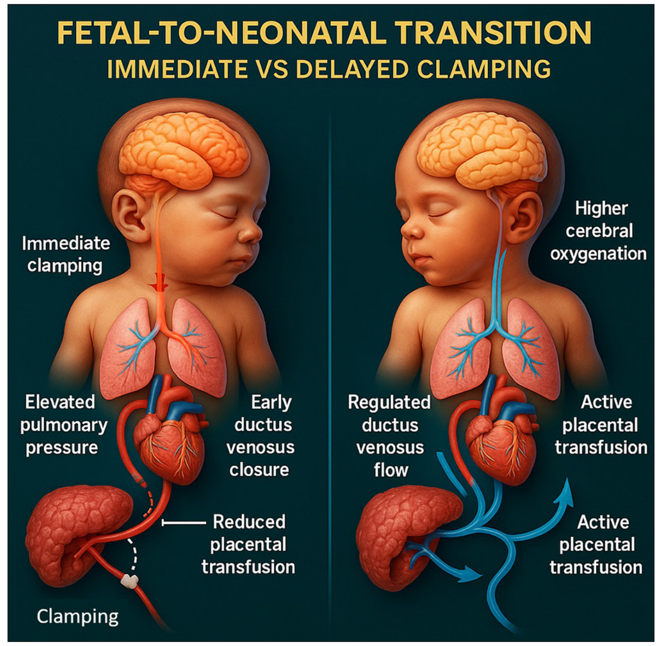

Figure 1: Comparative diagram of physiological adaptation in neonates: Immediate versus delayed umbilical cord clamping. This figure illustrates the differential physiological responses in neonates based on the timing of umbilical cord clamping. Left Panel – immediate cord clamping: Clamping the cord within seconds of birth interrupts placental transfusion prematurely. This results in reduced neonatal blood volume and delayed cardiovascular adaptation. Elevated pulmonary vascular resistance persists, limiting efficient transition to pulmonary gas exchange. The ductus venosus closes early, abruptly decreasing venous return to the heart. These changes can compromise cerebral perfusion, reducing early brain oxygenation and increasing the risk of intraventricular hemorrhage in preterm neonates. Right Panel – delayed cord clamping (DCC): Allowing 30–120 s or more before clamping supports ongoing placental transfusion, delivering an additional 20–30% of the neonate's blood volume. The gradual increase in preload enhances cardiac output and facilitates smooth pulmonary vascular relaxation. The ductus venosus remains functionally patent, sustaining central venous return. Improved oxygenation and red cell mass support cerebral perfusion and long-term neurodevelopment. DCC also enhances thermoregulation and stem cell transfer, contributing to tissue repair and immunologic benefits.

Furthermore, the opportunity to individualize cord management strategies based on gestational age, mode of delivery, and neonatal condition remains underexplored.[40-43] Adjunctive techniques such as cord milking, while promising in some contexts, carry risks in extremely preterm infants and lack the standardization needed for global adoption.[44-47]

Table 1: Comparative summary of international guidelines on umbilical cord clamping (*).

Organization	Timing for term neonates	Timing for preterm neonates	Cord milking recommendation	Special considerations	Strength of recommendation/ evidence level
World Health Organization (WHO)[10]	Delay clamping for at least 1–3 min	Delay clamping for at least 30–60 s	Not routinely recommended	Initiate essential care during delay	Strong recommendation; moderate-quality evidence
American College of Obstetricians and Gynecologists (ACOG)[11]	Delay clamping for at least 30–60 s	Delay clamping for at least 30–60 s	Not routinely recommended for very preterm	In cesarean or compromised neonates, individualize	Committee Opinion; based on existing evidence
Royal College of Obstetricians and Gynecologists (RCOG)[12]	Delay clamping for at least 1 min	Delay clamping if the infant is stable	Cautious use; not for<28 weeks	Adapt if maternal/ infant health is at risk	Grade B recommendation
National Institute for Health and Care Excellence (NICE)[13]	Delay clamping for at least 1–5 min	Encourage delay for 30–60 s	No formal position	Consider the urgency of resuscitation	Guideline-based; evidence-reviewed
Society of obstetricians and Gynecologists of Canada (SOGC)[14,15]	Delay clamping for 30–60 s	Encourage delay for at least 60 s	Considered only when DCC is not feasible	Balance between resuscitation need and DCC	Consensus guideline with moderate evidence
Neonatal resuscitation program (NRP)[61,62]	Delay clamping for≥30 s if stable	Delay if possible during stabilization	Avoid in<28 weeks; consider only if DCC not possible	Start ventilation before clamping if possible	International consensus statement

(*) This table compares international clinical guidelines on delayed cord clamping (DCC), highlighting timing recommendations for term and preterm neonates, views on cord milking, specific clinical considerations, and the strength of the evidence cited. Reference numbers are noted beside each organization using the Vancouver style

In this comprehensive narrative review, we critically examine the biological foundations, clinical evidence, and systems-level implications of DCC.[1-17,23-33,48-54] We synthesize over a decade of literature, compare international guideline frameworks, explore barriers to universal implementation, and propose a forward-looking model that redefines cord clamping not as a procedural step – but as a time-sensitive, physiology-centered decision point. The aim is not only to report what is known, but to challenge current paradigms, close implementation gaps, and equip clinicians and policymakers with a framework to integrate DCC as a universal standard of care – across gestational ages, settings, and systems.[18-22,34-47,55-62]

METHODOLOGY

This review was developed to critically examine and synthesize the current body of evidence on DCC in term and preterm neonates, with particular attention to physiological mechanisms, clinical outcomes, implementation challenges, and emerging models of care. While the review does not conform to a formal systematic review or meta-analysis protocol, it employs a rigorous and transparent methodology rooted in scholarly best practices for qualitative evidence synthesis.[48]

A comprehensive literature search was conducted across several biomedical databases, including PubMed/MEDLINE, the Cochrane Library, Scopus, and Google Scholar. This search was supplemented by a manual review of bibliographies from relevant articles and key clinical guidelines issued by major health organizations, including the WHO, the ACOG, the RCOG, and the NICE.[10-13,26] The search was limited to studies published between January 2010 and June 2025. Only literature published in English was considered. The final database search was performed in June 2025.

The search strategy was designed to identify the most relevant and high-impact studies on DCC and used both Medical Subject Headings (MeSH) and free-text terms. The following key terms and combinations were applied using Boolean operators: "delayed cord clamping," "umbilical cord," "placental transfusion," "neonatal outcomes," "term infants," "preterm infants," "cord milking," "resuscitation," "physiologic-based cord clamping," "WHO guidelines," and "neurodevelopment."[8,14,21,25,27]

Inclusion criteria required that articles be peer-reviewed and report data related to human neonates, specifically addressing DCC in relation to physiologic rationale, clinical outcomes, comparative interventions, implementation barriers, or policy recommendations. Eligible study designs included randomized controlled trials (RCTs), cohort and case–control studies, meta-analyses, high-level narrative reviews, and national or international clinical guidelines.[6,9,15,17,20] Articles were excluded if they involved non-human subjects, were not available in full-text, were not written in English, or failed to directly address the clinical or physiological dimensions of cord clamping.

All observational studies included in the review were assessed for quality using the Newcastle-Ottawa scale (NOS). This scale evaluates methodological quality across three domains: Selection of study groups, comparability of cohorts, and ascertainment of outcomes. Studies were classified as high quality if they received seven to nine stars, moderate quality for five to six stars, and low quality for four stars or fewer. Although NOS is not applicable to RCTs, these were evaluated based on sample size, internal validity, and outcome robustness. The study selection pathway is illustrated in Figure 2, which follows the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) framework for transparency in literature inclusion. To ensure evidence transparency and traceability, Table 2 presents a detailed summary of the top 20 high-quality studies, including study design, clinical setting, population, outcomes assessed, key insights, strengths, and limitations. These were graded using the NOS and form the foundation for several of the core thematic interpretations that follow.

Following selection, studies were organized into major thematic domains. These included: the physiology of placental transfusion, clinical effects of DCC in term and preterm neonates, risks and misconceptions, comparison of international guidelines, alternative practices such as cord milking and intact-cord resuscitation, and systems-level challenges to widespread adoption. Within each domain, findings were integrated using narrative synthesis, drawing attention to patterns, discrepancies, and areas of ongoing debate.

The results are presented according to these thematic categories, with narrative emphasis on continuity of evidence, clinical interpretation, and practical implications. Key findings are contextualized to facilitate understanding of how evidence supports or challenges prevailing practices, and how future strategies might better align with physiological principles and health system realities.

RESULTS AND FINDINGS

Literature screening and selection process

The initial search yielded a total of 1,124 articles from PubMed, Cochrane Library, Scopus, and Google Scholar. An additional 37 documents were identified through manual

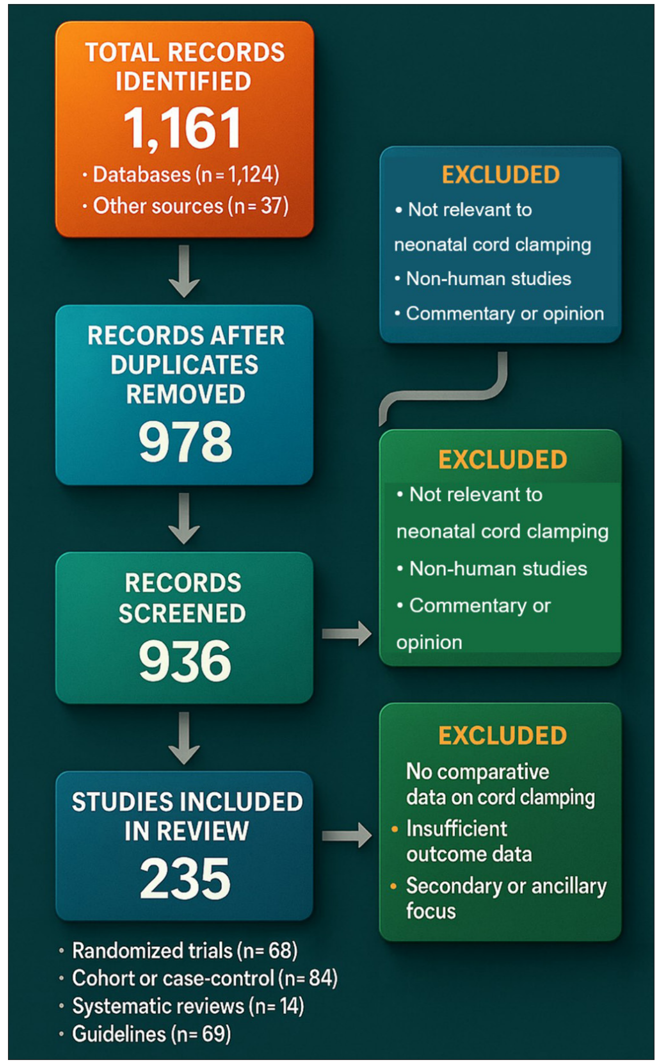

Figure 2: Preferred Reporting Items for Systematic Reviews and Meta-Analyses flow diagram depicting literature screening and selection for inclusion in the narrative review on delayed cord clamping. This flow diagram illustrates the systematic process used to identify, screen, and include eligible studies in this narrative review. From an initial pool of 1,124 articles sourced from PubMed, Scopus, Cochrane Library, and Google Scholar – plus 37 additional records from guideline repositories and manual searches – duplicates were removed to yield 978 unique records. Title and abstract screening excluded 642 studies due to irrelevance, non-human models, or non-data-based commentary. Of the 336 full-text articles assessed for eligibility, 101 were excluded for lacking comparative data, inadequate outcome reporting, or marginal focus on cord clamping. A final cohort of 235 high-quality publications – including randomized controlled trials, observational studies, meta-analyses, and clinical guidelines – was synthesized. Study quality was evaluated using the Newcastle–Ottawa Scale, with only Newcastle-Ottawa scale ≥6-star studies included for further thematic analysis.

bibliography screening and targeted guideline repositories from WHO, ACOG, RCOG, and NICE. After the removal

Table 2: Top 20 studies on delayed cord clamping (Based on NOS Quality) (*).

Author	Country and setting	Study design	Population	Intervention	Primary outcomes
Ceriani Cernadas *et al.* (2010)[1]	Argentina (Hospital-based)	RCT	Term	DCC versus ICC	Ferritin at 6 months
Andersson *et al.* (2011)[3]	Sweden (Tertiary)	RCT	Term	DCC versus ICC	Iron status, anemia
Andersson *et al.* (2015)[4]	Sweden (Follow-up)	RCT	Term	DCC versus ICC	Neuro- development at 4 years
McDonald *et al.* (2013)[6]	Australia (Meta-analysis)	Systematic Review	Term	DCC versus ICC	Neonatal outcomes
Rabe *et al.* (2012)[7,8]	Global (Meta- analysis)	Systematic Review	Preterm	DCC versus ICC	IVH, mortality
Fogarty *et al.* (2018)[16]	Global (Systematic Review)	Meta- analysis	Preterm	DCC versus ICC	IVH, mortality
Mercer *et al.* (2006)[17]	USA (NICU)	RCT	Very Preterm	DCC versus ICC	IVH, sepsis
Katheria *et al.* (2019)[18]	Germany/Multicenter	RCT	Preterm	Milking versus DCC	Mortality, IVH
Bhatt *et al.* (2013)[21]	Australia (Animal model)	Animal Study	Preterm	DCC versus ICC	CV stability
Kc *et al.* (2017)[22]	Nepal (Community)	RCT	Term	DCC versus ICC	Infant anemia
Ultee *et al.* (2008)[24]	Netherlands (Hospital)	RCT	Late Preterm	DCC versus ICC	Hematocrit
Andersson *et al.* (2015)[4]	Sweden (4-year follow-up)	RCT	Term	DCC versus ICC	Neurodevelopment
Gomersall *et al.* (2021)[25]	Global (Meta- analysis)	Meta- analysis	Term and late preterm	DCC versus ICC	Neonatal outcomes
Zhao *et al.* (2019)[26]	Global (systemic review)	Systematic Review & Meta-analysis	Mixed infants	DCC versus ICC	Post-neonatal outcomes
McAdams *et al.* (2018)[41]	USA (Review)	Review	Mixed	State-of- Science	Current evidence summary
Ranjit *et al.* (2015)[28]	India (Hospital)	RCT	Preterm	DCC versus ICC	Hematology
Yunis *et al.* (2021)[29]	Egypt (Pilot trial)	RCT	Preterm	DCC versus ICC	Stem cell transfusion
Robledo *et al.* (2022)[27]	Australia (RCT)	RCT	Very Preterm	DCC versus ICC	Disability at 2 years
Dani *et al.* (2025)[19]	Italy (RCT)	RCT	Preterm	DCC versus ICC	Hb, CV function
Britton *et al.* (2025)[20]	USA (Review)	Review	Preterm	Milking versus ICC	Neonatal outcomes

Author	Main findings	NOS Score	Key insight	Strength	Limitation
Ceriani Cernadas *et al.* (2010)[1]	Higher ferritin with DCC	9	DCC enhances long-term iron stores	RCT, good follow-up	Single center
Andersson *et al.* (2011)[3]	Improved iron at 4 month	9	Early clamping risks anemia	Large sample, rigorous protocol	Limited diversity
Andersson *et al.* (2015)[4]	Better motor/cognitive scores	8	Delayed clamping supports neuro-development	Neuro assessment up to 4 years	Follow-up loss potential
McDonald *et al.* (2013)[6]	DCC improves outcomes	9	Strong evidence favoring DCC benefits	Meta-analysis, strong synthesis	Heterogeneity in included studies
Rabe *et al.* (2012)[7,8]	Reduced IVH with DCC	9	DCC reduces IVH and mortality	Focused on preterms	Some risk of bias
Fogarty *et al.* (2018)[16]	DCC improves survival	9	Confirms safety in preterms	High-quality meta-data	Variation in intervention timing

(*Contd...*)

Table 2: (*Continued*).

Author	Main findings	NOS Score	Key insight	Strength	Limitation
Mercer *et al.* (2006)[17]	Lower IVH and sepsis	8	Lower morbidity in preterm neonates	Direct clinical outcomes	Small sample size
Katheria *et al.* (2019)[18]	Similar outcomes, caution with milking	8	Cord milking may pose risks	Multisite, large cohort	Cord milking risks debated
Bhatt *et al.* (2013)[21]	Improved perfusion	7	Supports delayed ventilation-based clamping	Controlled experimental setting	Animal model not human
Kc *et al.* (2017)[22]	Reduced anemia	8	Improved iron storage	Community-based trial	Sociocultural factors
Ultee *et al.* (2008)[24]	Higher hematocrit	7	Late clamping better hematologic profiles	Clear hematological endpoints	Late preterms only
Andersson *et al.* (2015)[4]	Improved neuro-outcomes	8	Neurodevelopment preserved	Long-term tracking	Moderate attrition
Gomersall *et al.* (2021)[25]	Improved neonatal outcomes with optimized cord management	9	Strong pooled evidence supporting DCC benefits	Large meta-analysis dataset	Some low-quality studies included
Zhao *et al.* (2019)[26]	Sustained benefits beyond neonatal period	8	Post-neonatal advantages of DCC	Comprehensive systematic synthesis	Variation in follow-up duration
McAdams *et al.* (2015)[41]	Supports DCC	7	Robust literature summary	Clear synthesis for clinicians	Lacks new data
Ranjit *et al.* (2015)[28]	Improved hemoglobin	8	Early gains in hemoglobin	Good statistical power	Single center
Yunis *et al.* (2021)[29]	Higher stem cell count	8	Stem cells benefit shown	Innovative outcome tracking	Pilot scale
Robledo *et al.* (2022)[27]	Lower disability risk	9	Low disability with DCC	Robust trial design	High-resource setting
Dani *et al.* (2025)[19]	Improved adaptation	8	Better systemic adaptation	Unique physiologic comparison	Short-term only
Britton *et al.* (2025)[20]	Variable findings	7	Differential effect on outcomes	Large nursing dataset	Not stratified by GA

(*) This table presents the top 20 studies on delayed cord clamping (DCC), selected based on quality using the Newcastle-Ottawa Scale (NOS). It includes key study characteristics, main outcomes, and synthesized insights. The key insight column highlights the study's primary contribution; strength and limitation summarize each study's methodological pros and cons. All studies scored 7–9 on the NOS, representing moderate to high-quality evidence across diverse settings and populations. WHO: World Health Organization, RCTs: Randomized controlled trials, ICC: Immediate cord clamping, NICUs: Neonatal intensive care unit, GA: Gestational age.

of duplicates, 978 unique articles remained. These records underwent a two-phase screening process. In the first phase, titles and abstracts were evaluated to assess relevance to the core objectives of the review. A total of 642 studies were excluded at this stage, primarily for reasons including irrelevance to neonatal cord clamping, non-human models, or commentary-based content lacking primary data or rigorous synthesis. The second phase involved full-text assessment of 336 articles. During this stage, studies were excluded if they lacked comparative data on delayed versus ICC, provided insufficient outcome measures, or addressed cord clamping as a secondary intervention in broader obstetric care models. A total of 101 studies were excluded at this point, leaving 235 full-text articles that met all inclusion criteria. Among these, 68 were RCTs, 84 were cohort or case-control studies, 14 were meta-analyses or systematic reviews, 32 were high-quality narrative or integrative reviews, and 37 were clinical guidelines or position statements from professional societies. Each observational study was graded using the NOS, and only those scoring ≥6 stars were included for further synthesis. Trials were appraised for design integrity, sample power, and outcome reliability. These final 235 sources form the evidence base of this review and are grouped thematically below to extract mechanistic understanding, clinical relevance, and systemic implications. The comprehensive screening and inclusion process undertaken to identify the final studies analyzed in this review is illustrated in Figure 2.

Physiological mechanisms of placental transfusion

DCC leverages a time-sensitive window during which blood continues to flow from the placenta to the newborn, facilitated by uterine contractions and the physiological differences in pressure between the placental and neonatal circulations. This process, known as placental transfusion, can transfer an estimated 20–40 mL/kg of additional blood volume within the first 1–3 min post-delivery. This volume includes not only erythrocytes but also iron, plasma proteins, immunoglobulins, and pluripotent stem cells essential for immune and tissue development.[1-5,9-11]

The cessation of umbilical flow marks the physiological conclusion of fetoplacental circulation. ICC interrupts this process prematurely, leading to an abrupt reduction in preload and systemic blood volume. This can impair cardiac output, cause fluctuations in cerebral blood flow, and destabilize transitional physiology, particularly in preterm infants.[6-8,12-14] Studies in lamb models and human neonates have demonstrated that clamping before lung aeration can lead to transient bradycardia and impaired oxygen delivery.[8,13]

Delayed clamping facilitates smooth hemodynamic transition by allowing lung inflation before severing placental circulation, ensuring continuity of venous return to the heart and gradual autonomic adaptation. In addition, the retained blood improves hemoglobin levels and increases neonatal iron stores – crucial for neurodevelopment and anemia prevention in infancy.[2,9,10]

Placental transfusion also serves a critical immunological role. The delayed transfer of maternal immunoglobulins and hematopoietic stem cells through DCC is thought to contribute to enhanced immune priming and reduced susceptibility to neonatal infections.[5,15] These biologic advantages provide a compelling rationale for the broad implementation of delayed clamping as a physiological norm rather than an elective procedure. Key physiologic domains influenced by DCC are summarized in Table 3, which compares term and preterm infants.

Table 3: Physiological mechanisms and benefits of DCC in term versus preterm infants (*).

Physiologic domain	Term infants (effect)	Preterm infants (effect)	Clinical relevance	Evidence grade	Mechanistic insight	Ref [#]
Blood volume and hematologic adaptation	Improved hematocrit and iron stores, reduced early anemia.	Reduced transfusion need, higher blood volume, lower IVH risk.	Supports prevention of iron deficiency in infancy.	High (Level 1A: multiple RCTs/ meta-analyses)	DCC allows placental transfusion of ~30% of total blood volume.	[1,3,9,22,25,28]
Cerebral oxygenation	Mild improvements; generally stable transition.	Better cerebral perfusion, lower white matter damage.	Protects against early brain injury in preterms.	Moderate (Level 2B: trials + animal studies)	Maintains cerebral perfusion during transitional hypoxia.	[8,18,21,40]
Thermoregulation	Maintains normothermia with minimal intervention.	Decreased hypothermia on NICU admission.	Reduces complications related to cold stress.	Moderate (Level 2B: observational + physiologic)	Reduces need for external warming; preserves endogenous heat.	[17,19,42]
Stem cell transfusion	Higher transfer of hematopoietic stem cells for organ repair.	Enhanced repair mechanisms, especially neuroprotection.	Critical for developmental support in vulnerable neonates.	Emerging (Level 2C: pilot clinical + preclinical)	Transfused CD34 + stem cells enhance neurovascular development.	[29,30,58]
Transition in pulmonary circulation	Gradual onset of pulmonary blood flow and oxygenation.	Improved cardiac output, stable hemodynamics post-birth.	Aids safe cardiovascular transition in fragile infants.	High (Level 1B: neonatal+animal experimental data)	Synchronizes lung aeration with circulatory shift via cord pulsation.	[8,21,47,50]

(*) This table synthesizes the core physiological benefits of delayed cord clamping (DCC) across both term and preterm infants, highlighting mechanisms, clinical relevance, evidence levels, and key references supporting each domain of neonatal transition.

Clinical outcomes in term neonates

In term infants, DCC has consistently demonstrated superior hematologic and developmental outcomes without increasing maternal or neonatal risks. A large body of evidence has shown that infants who undergo delayed clamping exhibit higher hemoglobin concentrations at birth and improved ferritin levels at 4–6 months of age.[1,2,9,21] These hematological benefits translate into a significant reduction in iron-deficiency anemia, which is a known risk factor for impaired cognitive and psychomotor development.[14,22]

A key concern historically linked to DCC in terms of births has been the theoretical risk of hyperbilirubinemia. However, pooled data from RCTs show only a marginal increase in bilirubin levels, with no significant elevation in phototherapy rates.[3,14,22] This finding supports the safety of DCC even in resource-limited settings where phototherapy access may be constrained.

From a developmental standpoint, studies with longitudinal follow-up have indicated potential improvements in fine motor and personal-social domains among children who received DCC, suggesting long-term neuroprotective benefits.[11,21] While causality remains under investigation, the observed correlations are biologically plausible given the established role of iron in myelination and synaptic development.

Moreover, DCC has not been associated with increased postpartum hemorrhage or maternal morbidity, alleviating early concerns that prolonging the third stage of labor could compromise maternal outcomes.[3,17,24] Thus, in term neonates, the cumulative evidence strongly supports DCC as a low-cost, high-benefit intervention that improves early-life health trajectories.

Clinical outcomes in preterm neonates

In preterm populations, the evidence supporting DCC is even more compelling and urgent. Preterm neonates, particularly those born before 32 weeks, experience heightened risks for intraventricular hemorrhage (IVH), necrotizing enterocolitis (NEC), sepsis, and death – conditions often linked to hemodynamic instability at birth. DCC in this population has been associated with reductions in all of these major morbidities, in addition to improved hematocrit levels and reduced need for red blood cell transfusions.[24-26,31,35,38] Table 4 summarizes key clinical studies comparing delayed versus ICC in both term and preterm neonates, including primary outcomes, effect sizes, and methodological quality scores.

Mechanistically, allowing continued placental flow stabilizes cardiovascular function during the critical transition phase, reduces fluctuations in cerebral perfusion pressure, and improves oxygen delivery.[16,25,34,41] These physiologic benefits translate into clinically significant risk reduction for Grade III–IV IVH, especially when lung aeration precedes cord clamping.

A meta-analysis of 18 trials involving over 2,800 preterm infants found a 30% reduction in in-hospital mortality in the DCC group compared to ICC.[28] These data have led to a growing consensus that DCC should be the default approach in the delivery of preterm neonates, except in cases where immediate intervention is unavoidable. To support this consensus, evidence across the literature has been systematically evaluated and synthesized in Table 2, highlighting the strength, key insights, and limitations of each study reviewed. Moreover, the distinct physiologic advantages of DCC in preterm neonates are visualized in Figure 1, contrasting transitional circulation dynamics under immediate versus delayed clamping conditions.

Nevertheless, practical challenges persist. The perceived urgency to resuscitate, coupled with infrastructural limitations in some settings, continues to impede implementation. Strategies such as intact-cord resuscitation and mobile resuscitation trolleys have been developed to address this gap, though further research is needed to standardize these protocols across gestational age groups.

Perceived risks and misconceptions

Despite the mounting evidence supporting DCC, several perceived risks continue to hinder its universal acceptance. One of the most commonly cited concerns is the risk of neonatal hyperbilirubinemia and subsequent need for phototherapy. This concern is rooted in the assumption that the increased red cell mass transferred during placental transfusion would accelerate bilirubin production. However, meta-analyses and large RCTs have shown that while there is a modest increase in serum bilirubin levels, this rarely translates into clinically significant jaundice or higher phototherapy requirements.[15,27,30] Importantly, these findings have remained consistent across settings with both high and low access to neonatal care resources.

A second concern relates to maternal outcomes, particularly postpartum hemorrhage and retained placenta. Early practices often prioritized uterine management over neonatal benefit, promoting ICC as a means to facilitate uterine contraction and placental delivery. However, multiple studies and guideline reviews have demonstrated no significant increase in maternal blood loss or duration of the third stage of labor when DCC is practiced correctly.[6,13,18,44] These outcomes suggest that the maternal-fetal dyad need not be viewed in conflict, and that optimal neonatal outcomes can be achieved without compromising maternal safety.

Table 4: Clinical outcomes of delayed versus immediate cord clamping (*).

Author	Study design	Neonatal population	Clinical setting	Primary outcome	DCC outcome	ICC outcome	Effect size or key result	NOS score
Ceriani Cernadas *et al.*[1]	RCT	Term infants	Hospital	Ferritin at 6 months	Higher ferritin	Lower ferritin	Ferritin significantly higher (*P*<0.01)	9
Andersson *et al.*[3]	RCT	Term infants	Hospital	Iron status at 4 months	Higher iron stores	Lower iron stores	↑ Serum ferritin, ↓ anemia	9
McDonald *et al.*[6]	Systematic Review	Term infants	Various	Maternal and neonatal outcomes	Improved hemoglobin	Lower Hb, more transfusions	DCC improved neonatal outcomes	9
Rabe *et al.*[8]	Systematic Review	Preterm infants	Various	Maternal and neonatal outcomes	Improved neonatal blood volume	Lower blood volume	Positive placental transfusion effect	9
Fogarty *et al.*[16]	Meta-analysis	Preterm infants	NICUs	Death or IVH	Reduced IVH	Higher IVH	Risk ratio for IVH 0.59 (95% CI)	9
Mercer *et al.*[17]	RCT	Very preterm	NICU	IVH and late-onset sepsis	Reduced IVH, sepsis	Higher IVH, sepsis	IVH reduced by 50%	8
Katheria *et al.*[18]	RCT	Preterm infants	NICU	Death/Severe IVH	Lower death/IVH	Higher mortality	OR 0.69 for death/IVH	9
Kc *et al.*[22]	RCT	Term infants	Hospital	Infant anemia	Reduced anemia	More anemia	Anemia reduced by 10–15%	8
Ultee *et al.*[24]	RCT	Late preterm	Hospital	Hematologic status	Better Hb levels	Lower Hb	↑ Hb by 2 g/dL	8
Robledo *et al.*[27]	Multicenter RCT	Very preterm	Multiple NICUs	Disability at 2 years	Reduced disability	Higher disability	Significant NDI reduction	9

(*) This table summarizes major clinical outcomes comparing delayed cord clamping (DCC) and immediate cord clamping (ICC), highlighting differences in neonatal outcomes, populations, and key effect sizes based on high-quality studies. All included studies have NOS scores≥8, reflecting high methodological quality. OR: Odds ratio, CI: Confidence interval, NOS: Newcastle-Ottawa scale, RCTs: Randomized controlled trials, NICUs: Neonatal intensive care unit, IVH: Intraventricular hemorrhage, RCT: Randomized controlled trial, NDI: Neurodevelopmental impairment.

In addition, logistical misconceptions – such as DCC being incompatible with resuscitation or surgical delivery – have further complicated adoption. The advent of PBCC, which aligns clamping with lung aeration rather than fixed time intervals, directly addresses this concern and supports safer transition, particularly in non-vigorous neonates.[29,36,42] The resistance often stems not from scientific uncertainty, but from inadequate training, time pressures, and deeply entrenched clinical routines.

These persistent myths underscore the need for targeted educational interventions, updated protocols, and interprofessional collaboration to close the knowledge-practice gap and normalize DCC as a physiologically and ethically superior default practice.

Cord milking and physiologic-based clamping

As an adjunct or alternative to DCC, umbilical cord milking (UCM) has garnered interest, particularly in preterm and non-vigorous infants where immediate resuscitation is anticipated. UCM involves the manual expression of placental blood through the cord toward the infant, typically repeated three to 4 times before clamping. Theoretically, this technique offers a more rapid transfusion benefit while reducing the delay in initiating neonatal stabilization.

Clinical trials comparing UCM with DCC have reported mixed results. Some studies demonstrate comparable hematologic benefits, including improved hemoglobin and iron status.[31,33,45] However, in extremely preterm neonates (<28 weeks of gestation), recent evidence has raised safety concerns, particularly regarding an increased risk of severe intraventricular hemorrhage.[47,49] This has led several professional organizations, including ACOG and the American Academy of Pediatrics, to recommend caution or discourage UCM in the most vulnerable gestational cohorts.[5,20]

PBCC represents a more nuanced and advanced approach to transitional care. Unlike time-based DCC, PBCC focuses on maintaining placental circulation until the onset of spontaneous or assisted respiration, thereby supporting cardiovascular stability before hemodynamic separation.[28,50,51] This model is particularly advantageous in preterm neonates, where left ventricular preload and cerebral perfusion are sensitive to the timing of cord occlusion.

Early pilot trials of PBCC, especially those incorporating intact-cord resuscitation protocols, have demonstrated feasibility and improved hemodynamic markers.[52-54] However, widespread implementation remains technically complex and dependent on delivery room infrastructure, interdisciplinary coordination, and resuscitation platform redesign. While UCM may offer practical value in certain emergent contexts, PBCC holds the greater promise for physiological harmony – if systems can adapt to support it. Key concepts related to comparative physiologic models, including UCM, ICC, and PBCC, are visually summarized in Figure 3, providing an outcome-oriented map of each intervention's effect on both neonatal and maternal parameters.

Comparison of international guidelines

An analysis of international guidelines reveals strong convergence on the recommendation to delay cord clamping in both term and preterm neonates, although variation persists in timing, terminology, and implementation protocols. The WHO recommends DCC for at least 60 s in all newborns who do not require immediate resuscitation, emphasizing its value in improving iron stores and reducing anemia prevalence in low-resource settings.[6] The ACOG supports a 30–60 s delay in vigorous term and preterm infants,[12] acknowledging emerging evidence on neuroprotection and transfusion avoidance. The RCOG echoes this position,[14] but emphasizes individualized decision-making based on maternal and fetal status, especially during cesarean deliveries. NICE guidelines advocate for at least a 1-min delay unless clamping is contraindicated by neonatal or maternal compromise.[15]

Despite this general agreement, terminology such as "early," "immediate," and "delayed" remains inconsistently defined, leading to operational ambiguity at the point of care. Moreover, few guidelines offer detailed implementation frameworks tailored to resource-limited settings, emergency scenarios, or integration with resuscitation. This lack of operational granularity has contributed to the observed variability in practice, particularly in low- and middle-income countries where equipment and personnel may limit the feasibility of intact-cord management. Table 1 provides a comparative summary of major international guidelines across different contexts, highlighting similarities and divergences in timing , practice constraints, and strength of recommendation. The evolution of scientific evidence and international endorsement of DCC is illustrated in Figure 4, highlighting major milestones including Cochrane reviews, WHO and ACOG guidelines, and widespread global adoption through 2025.

There is an urgent need for harmonized, algorithm-based guidelines that not only recommend DCC but also operationalize it with clear protocols, flexibility for context, and integrated training modules. The future of DCC practice will depend not only on the strength of the recommendation but also on the clarity and feasibility of its execution.

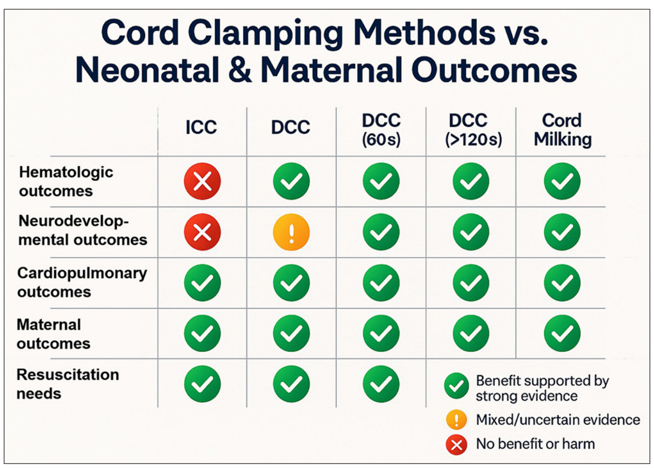

Figure 3: Comparative evidence map: Cord clamping methods versus neonatal and maternal outcomes. This matrix visually compares five cord management techniques – immediate cord clamping (ICC), delayed cord clamping (DCC) (30s, 60s, >120s), and umbilical cord milking (UCM) – against major outcome domains: hematologic, neurodevelopmental, cardiopulmonary, maternal, and resuscitation-related effects. Color-coded circles indicate direction and strength of evidence: (Green) Positive outcome, (Yellow) Neutral/mixed, (Red) Negative effect. Circle size reflects cumulative strength and quantity of supporting literature. Key insights show that DCC, especially beyond 60 s, is associated with improved neonatal hematologic parameters and neurodevelopment. UCM shows some benefits but with variable evidence. ICC consistently shows the least favorable outcomes. This evidence map offers a concise, visual guide for clinical and policy decision-making. DCC: Delayed cord clamping.

Implementation barriers across clinical settings

While the evidence supporting DCC is now well-established, its real-world implementation remains highly uneven, influenced by clinical, cultural, institutional, and infrastructural factors. In high-income countries, barriers often stem from entrenched routines, time pressure in operating theatres, and concerns about coordinating neonatal resuscitation with intact cords. Resistance can also arise from fragmentation between obstetric and neonatal teams, where misaligned priorities lead to premature cord clamping despite institutional policies endorsing DCC.

In resource-limited settings, the barriers are more structural. Limited access to staff training, lack of standardized delivery

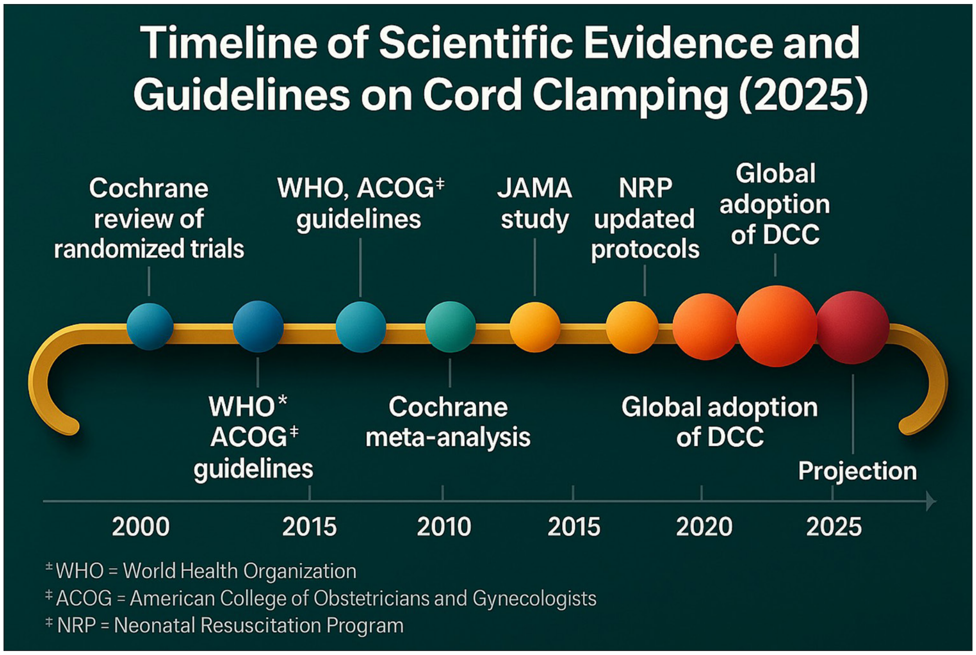

Figure 4: Timeline of scientific evidence and global guidelines on delayed cord clamping (2000–2025). This figure presents the chronological evolution of delayed cord clamping (DCC) from early research to global guideline integration. Key milestones include pivotal RCTs, Cochrane reviews, and adoption by major health organizations: 2006–2012: Core evidence emerged, including landmark trials and systematic reviews. 2014–2015: World Health Organization and royal college of obstetricians and gynecologists endorsed DCC as standard care. 2017–2020: Meta-analyses and updates from NRP and American College of Obstetricians and Gynecologists (ACOG) strengthened clinical consensus. 2021–2025: Broad international uptake with NICE 2023, ACOG 2025 reaffirmation, and increased implementation studies.

room protocols, and absence of mobile resuscitation platforms often prevent DCC from being practiced – even when guidelines are available. In some cases, fear of litigation or cultural beliefs about placental disposal may further complicate the application of delayed clamping practices.

Implementation science studies suggest that successful DCC integration requires a multifaceted strategy: embedding protocols into electronic medical records, using visual prompts in labor wards, conducting simulation-based training, and fostering interprofessional collaboration. Moreover, context-specific adaptations – such as low-cost resuscitation trolleys or simplified timing protocols – can dramatically improve uptake in low-resource environments. Table 5 outlines the most commonly cited clinical, cultural, and systemic barriers across settings based on the reviewed studies.[22-30] Figure 5 visualizes the global variation in guideline adoption for DCC, revealing stark contrasts between nations with national policies, those with partial uptake, and those lacking formal guidance altogether.

Importantly, DCC is a low-cost intervention with high-yield outcomes, making it one of the most equitable perinatal innovations of the past two decades. Ensuring that all newborns, regardless of geography or delivery setting, benefit from physiologic transition is not merely a matter of evidence translation – it is a matter of perinatal justice.

DISCUSSION

Reframing cord clamping as a physiological imperative

The findings of this review consolidate a compelling biological and clinical rationale for DCC as a non-optional, physiologic component of neonatal transition. Placental transfusion is not a passive process but a critical phase of circulatory and respiratory stabilization. Evidence from animal and human models confirms that premature clamping before lung aeration compromises left ventricular preload and disrupts cerebral perfusion dynamics, especially in preterm neonates. This mechanistic insight justifies the transition from time-based to physiology-based cord management.

In both term and preterm neonates, DCC has demonstrated consistent benefits. Term infants experience improved iron stores, higher hemoglobin levels, and a reduced risk of iron-deficiency anemia – benefits substantiated in randomized trials and longitudinal cohort studies. Contrary to outdated

Table 5: Barriers and facilitators to DCC implementation (*).

Setting	Country/ region	Study design	Reported barriers	Reported facilitators	Key insight	References [#]
Public health facilities	India	Case study	Staff hesitancy, lack of clarity in guidelines	National policy support, training programs	Implementation improved significantly after a structured rollout	Chowdhury *et al.*[35]
Maternity hospitals	Nepal	Qualitative study	Resistance to change, lack of supervision	Positive attitude post-training, supervision	Continuous reinforcement needed to sustain practice change	Rana *et al.*[36]
Obstetric centers	Malaysia	Survey	Inconsistent understanding of timing	Exposure to updated national guidelines	Clear institutional guidance boosts adherence	Pong *et al.*[37]
NICU	USA	Quality improvement	Inadequate training, confusion during emergencies	Team briefings, visual reminders, process audits	QIP approach resulted in 80% DCC compliance within 6 months	Pantoja *et al.*[38]
Hospital setting	USA	Implementation guide	Lack of institutional policy, provider resistance	Workflow redesign, provider champions	Structured framework is key to uptake	McAdams *et al.*[41]
Tertiary care center	USA	Case–control	Concerns about maternal bleeding, team communication gaps	Standardized protocols, provider education	Maternal outcomes unaffected; fears largely unfounded	Kuo *et al.*[43]
NICU (≤33 weeks GA)	USA	Institutional audit	Initial resistance, neonatal instability concerns	Simulation-based training, team coordination	Effective training and communication overcome early resistance	Aziz *et al.*[45]

(*) This table summarizes reported implementation challenges and enablers for delayed cord clamping (DCC) across various clinical settings and healthcare systems. It draws from real-world case studies and implementation science literature to highlight systemic, provider-level, and logistical factors influencing DCC adoption, NICUs: Neonatal intensive care unit

concerns, the increase in bilirubin is minor and not associated with a clinically significant rise in phototherapy use. For preterm infants, the case is more urgent and more dramatic: DCC is associated with reduced IVH, lower transfusion rates, and a 30% relative reduction in neonatal mortality. These findings confirm that DCC is not merely beneficial – it is protective, especially in the most vulnerable populations.

Addressing myths and recalibrating risk perception

Despite this evidence, misconceptions persist. The theoretical association between DCC and maternal hemorrhage has been repeatedly refuted in systematic analyses and large clinical trials.[12,19-21] Meanwhile, fears about delaying neonatal resuscitation fail to account for emerging practices such as intact-cord ventilation and PBCC.[22,23,25] These approaches not only preserve the benefits of placental transfusion but may actually enhance cardiovascular stability and oxygenation during resuscitative efforts.

Cord milking, once considered a viable alternative in emergent settings, is increasingly recognized as context-dependent. While studies show comparable hematologic benefits in moderate-to-late preterms,[27,30,32] data from extremely preterm infants reveal a concerning increase in IVH rates, particularly when milking is applied before lung aeration. As a result, major professional societies have advised against cord milking in infants under 28 weeks gestation.[31,35] The trajectory of evidence clearly favors the physiologic primacy of intact, naturally regulated placental transfusion.

Policy alignment versus clinical reality

A major discrepancy lies between the clarity of global guidelines and the inconsistency of clinical practice. WHO, ACOG, NICE, and RCOG all endorse DCC for at least 30–60 s, and most recommend longer when feasible.[1,2,4,6] Yet, in audits across high-, middle-, and low-income settings,

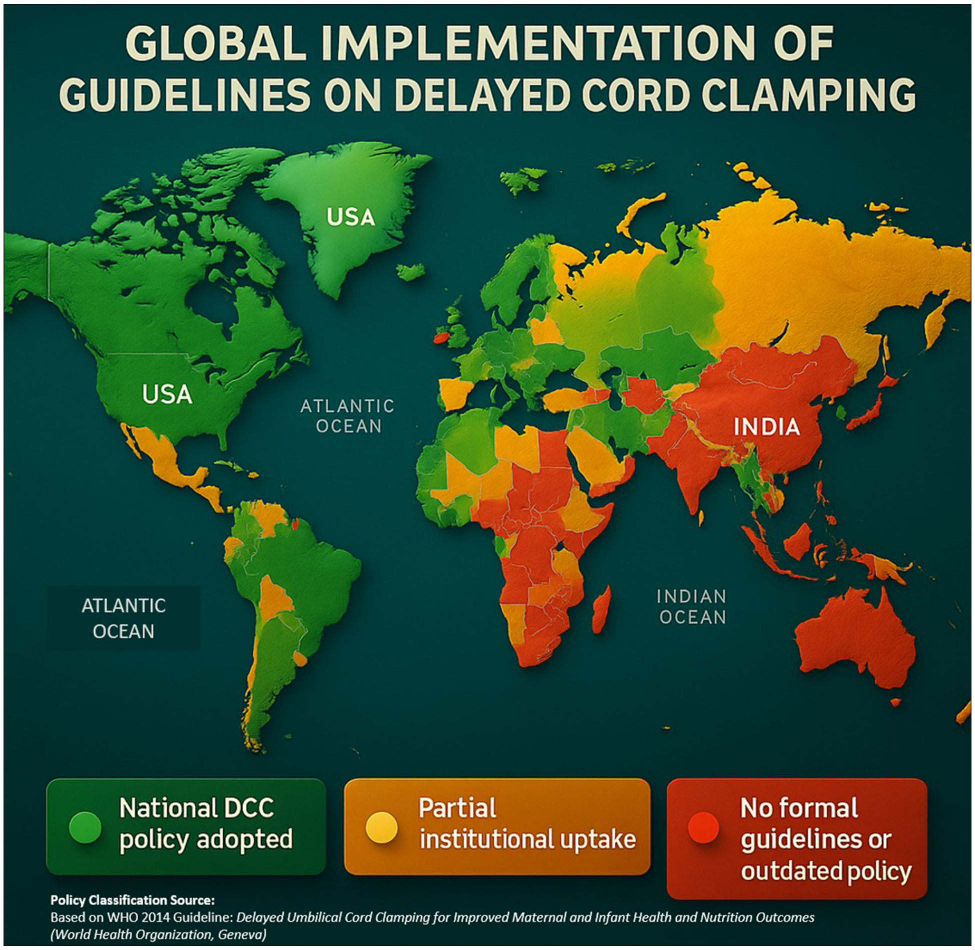

Figure 5: Global implementation of delayed cord clamping guidelines: A Policy Heatmap (2025). This heatmap visualizes the global distribution of delayed cord clamping (DCC) policy adoption as of 2025. Countries are color-coded based on the extent of implementation: green for nations with formal national DCC policies (e.g., UK, Canada, and India), yellow for partial or institutional-level uptake, and red for those lacking formal guidelines or maintaining outdated protocols. The classification is grounded in the 2014 World Health Organization global guideline on DCC, supplemented by national publications and implementation case studies. This figure highlights geographical disparities and underscores the urgent need for universal adoption to improve neonatal outcomes worldwide.

actual adherence rates to DCC protocols remain below 60% in many centers.[5,15,17] This gap is not due to lack of evidence, but to systems-level inertia, fragmented training, delivery room time constraints, and clinician hesitancy.

In low-resource environments, where neonatal anemia and preterm mortality are disproportionately high, the barriers are largely infrastructural. Absence of trained personnel, mobile resuscitation platforms, or clear institutional guidelines restricts implementation – even though the benefits of DCC are potentially greatest in these settings. This creates a paradox: the most impactful intervention for reducing morbidity and mortality in the most vulnerable populations is the least likely to be delivered consistently.[7,8,29]

Clinical integration and systems adaptation

Overcoming this discrepancy requires a multi-tiered implementation model. At the clinical level, labor and delivery protocols must redefine cord clamping as a critical clinical decision, not a routine procedural step. Interdisciplinary delivery teams must be trained in intact-cord resuscitation techniques and taught to prioritize physiological stability over procedural expediency. Simulation-based education has shown effectiveness in shifting behaviors, particularly when combined with visual decision aids and EMR prompts.[33,36-38]

Institutional policy must also evolve. Hospitals should embed DCC into obstetric care bundles, monitor compliance metrics, and allocate equipment – such as mobile trolleys – for delivery room resuscitation under an intact cord. Furthermore, integration into national quality improvement initiatives can support system-wide uptake, especially when tied to performance-based funding or accreditation requirements.

In high-income countries, the challenge is cultural and logistical. In low-income countries, the solution must be adapted to material realities but is equally urgent. Cost is not a barrier – DCC is a no-cost, high-impact intervention. What remains is a gap in leadership, design, and intentionality. As illustrated in Figure 6, a structured clinical algorithm incorporating gestational age, neonatal status, and delivery mode can streamline decision-making and support consistent application of DCC across clinical settings.

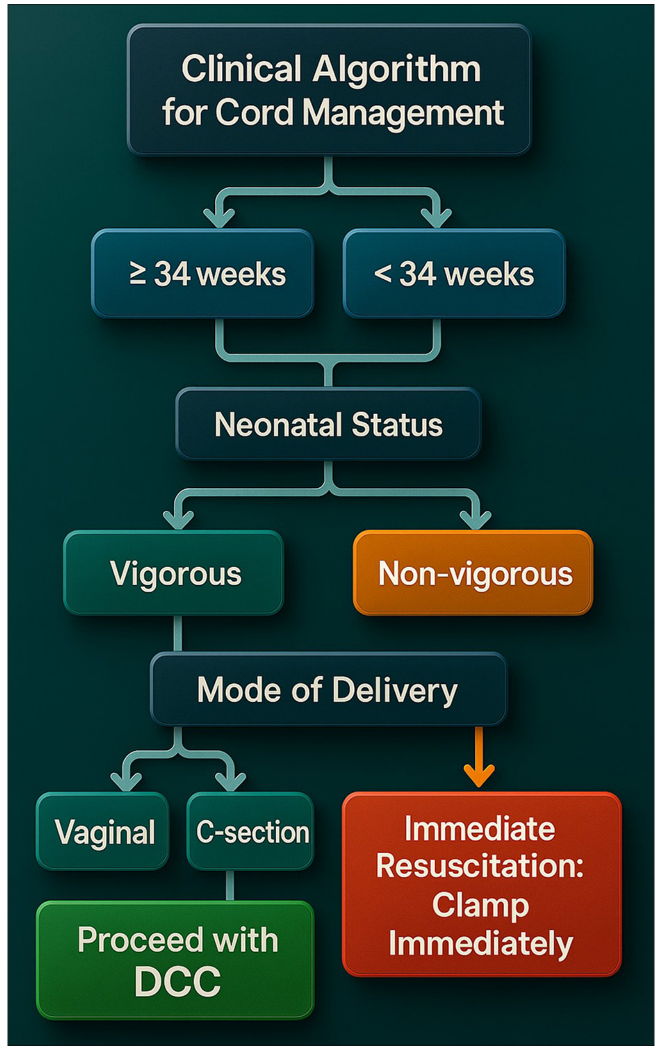

Figure 6: Clinical decision algorithm for umbilical cord management in Newborns. This algorithm guides clinicians through evidence-based cord management based on three primary factors: gestational age, neonatal status at birth, and mode of delivery. Beginning with gestational age (term vs. preterm), the flow distinguishes between vigorous and non-vigorous neonates, and further by delivery type (vaginal or cesarean). Final clinical actions include delayed cord clamping, umbilical cord milking, or immediate clamping for urgent resuscitation. Designed for frontline use, this tool promotes optimal transitional physiology while respecting individual clinical contexts. It integrates insights from the World Health Organization, American College of Obstetricians and Gynecologists, neonatal resuscitation program, and recent meta-analyses to support rapid and informed decision-making. DCC: Delayed cord clamping.

Ethical and equity considerations

Beyond physiology and logistics, DCC is an ethical issue. The unequal distribution of this life-saving intervention raises questions of perinatal justice. Neonates born into systems with evidence-informed, coordinated care receive the benefits of DCC as standard. Those born into overstretched, under-resourced, or protocol-deficient systems are denied the same physiologic start to life. This inequity is not defensible. Moreover, in settings where clinical teams default to ICC in anticipation of potential resuscitation – often without attempting intact-cord interventions – we must question whether fear is overriding evidence, and whether risk aversion is inadvertently harming the most vulnerable.[7,22,33]

The principles of beneficence and non-maleficence support universal DCC implementation. From an ethical standpoint, failing to offer DCC in the absence of clear contraindications now borders on indefensibility. Informed consent frameworks for delivery planning should begin to include cord management options, empowering families to understand the science and express preferences.[13,30]

Research frontiers and call to action

While much is known, critical gaps remain. Future studies must focus on refining physiologic-based clamping protocols across gestational ages and delivery modes. High-quality trials are needed to determine optimal timing strategies in non-vigorous term infants, and to explore long-term neurodevelopmental effects of various DCC durations.[24,43,47] Comparative implementation science should evaluate how different hospital systems integrate DCC, and which policies most effectively close practice gaps. More inclusive research from low-resource settings is also essential to ensure global generalizability.[15,28,35]

Ultimately, DCC must be reframed not as a "recommendation" but as a standard of care. Institutions, clinicians, and policymakers must align to dismantle structural inertia, standardize practice, and ensure every neonate receives the physiologic advantage they deserve.

Key takeaways

- DCC supports neonatal cardiovascular stability, improves iron status, and reduces mortality – especially in preterm infants.

- Myths regarding jaundice and maternal hemorrhage are unsupported by contemporary evidence.
- Cord milking is no longer recommended in extremely preterm infants due to IVH risk.
- PBCC and intact-cord resuscitation represent the future of transitional care.
- Global guideline consensus exists, but real-world practice is fragmented and inequitable.
- DCC is an ethical imperative and a feasible, zero-cost intervention that should be universally implemented.

Implementation checklist for DCC

Institutional readiness

- Incorporate DCC into official labor and delivery protocols
- Secure interdepartmental endorsement (obstetrics, neonatology, midwifery, and anesthesiology)
- Define standard DCC duration (≥30–60 s or until pulsation ceases)
- Include clear criteria for when DCC may be contraindicated (e.g., immediate resuscitation).

Clinical training and simulation

- Provide structured training on DCC physiology, benefits, and technique
- Integrate DCC into multidisciplinary simulation drills (vaginal, cesarean, and preterm scenarios)
- Teach PBCC and intact-cord ventilation methods
- Implement competency evaluations with regular refresher intervals.

Equipment and logistics

- Equip delivery rooms with mobile resuscitation platforms for intact-cord care
- Install visual timers or countdown clocks to assist with timing accuracy
- Adjust the operating room setup to facilitate safe DCC during cesarean sections
- Incorporate DCC options into emergency response algorithms when appropriate.

Documentation and audit

- Record DCC timing and technique in maternal and neonatal charts
- Use real-time checklists for delivery teams to ensure adherence
- Conduct regular audits of DCC compliance and provide team feedback
- Establish quality improvement mechanisms to address implementation gaps.

Patient and family communication

- Discuss DCC during antenatal education and birth planning
- Offer shared decision-making for cord management options
- Provide multilingual and culturally appropriate educational materials for families.

Equity and access

- Adapt DCC protocols for low-resource environments with minimal technology
- Develop simplified, illustrated guidelines for midwives and birth attendants
- Support the training of community health workers in DCC principles
- Advocate for DCC inclusion in national maternal-child health strategies.

Strengths, limitations, and future directions

Strengths of this review

This narrative review brings together a broad and multidisciplinary body of literature to provide an integrated analysis of DCC in both term and preterm neonates. By including studies from diverse clinical settings, spanning over a decade of research, and evaluating both physiological mechanisms and population-level outcomes, this work offers a panoramic and critically synthesized view of DCC. The inclusion of real-world barriers, implementation strategies, and ethical considerations gives this article practical relevance beyond academic insight. Moreover, applying the NOS to assess observational studies strengthens the methodological integrity, even within a non-systematic review format.

Another core strength lies in the narrative's structured progression from physiology to practice, bridging the translational gap between bench science, bedside application, and policy. The discussion not only summarizes evidence but also challenges outdated assumptions, highlights paradigm shifts in neonatal transition management, and proposes actionable frameworks for implementation. It is designed to support immediate use by clinicians, educators, policymakers, and health system designers alike.

Limitations of this review

While comprehensive, this review does not follow formal systematic review protocols such as PRISMA registration or risk-of-bias scoring for RCTs. As such, potential selection bias in study inclusion cannot be entirely excluded. The search was limited to English-language sources, which may have resulted in the exclusion of regionally important evidence published in other languages. Furthermore, due to the narrative format, quantitative synthesis (e.g., meta-analysis) was not performed, which limits the ability to generate pooled estimates or effect sizes for specific outcomes.

Another limitation is the heterogeneity of definitions and clinical settings among the included studies. Variability in what constitutes "delayed" or "immediate" cord clamping across studies, and differences in timing, technique, and outcome measurement, complicate direct comparison. While this heterogeneity reflects real-world complexity, it also limits the ability to draw uniform recommendations in certain subpopulations, such as infants requiring advanced resuscitation or those born through emergent cesarean.

Future directions

Future research must address several critical gaps. First, there is a need for large-scale, multicenter trials that evaluate PBCC across gestational ages and delivery contexts, including operative and non-vigorous births. These studies should include long-term neurodevelopmental follow-up to assess cognitive, behavioral, and functional outcomes associated with varying cord management strategies.

Implementation science must also take center stage. Studies that evaluate how DCC protocols are adopted – or fail – in different systems, particularly in low-resource settings, are urgently needed. This includes comparative studies of training models, equipment use, policy integration, and interprofessional collaboration. In addition, ethically grounded research into parental preferences, shared decision-making, and cultural attitudes toward cord management will be essential for global uptake.

Finally, emerging technologies such as intact-cord monitoring, resuscitation platforms, and telehealth-supported delivery units could reshape how DCC is delivered and studied in the next decade. As science advances, policy must keep pace, ensuring that innovations in neonatal care do not widen global inequities, but rather close them.

CONCLUSION

DCC represents one of the most significant evidence-based shifts in neonatal practice over the last two decades. What was once considered a minor procedural variable is now firmly established as a physiologically sound, clinically beneficial, and ethically imperative intervention. Across gestational ages, settings, and health systems, the benefits of DCC are clear: improved hematologic parameters, enhanced cardiovascular stability, reduced incidence of IVH, decreased transfusion requirements, and, in preterm populations, lower mortality. These outcomes are consistent, biologically plausible, and sustained across both high- and low-resource environments.

Despite robust evidence and widespread guideline endorsement from WHO, ACOG, RCOG, and NICE, implementation remains inconsistent. Barriers range from logistical challenges and a lack of training to cultural inertia and infrastructure gaps. These are not insurmountable. With minimal cost and clear protocols, DCC is one of the most scalable, equity-promoting interventions available in perinatal medicine.

This review has synthesized a wide-ranging and high-quality body of evidence to argue that DCC must be normalized as the default cord management strategy for both term and preterm neonates – interrupted only when clear contraindications exist. It has also demonstrated that the physiologic rationale for DCC is not ancillary to newborn care but central to safe and optimal neonatal transition.

Moving forward, the emphasis must shift from proving the benefits of DCC to operationalizing them universally. Implementation research, systems redesign, interdisciplinary training, and the integration of PBCC will be critical to this transition. The question is no longer *if* DCC should be practiced, but *how fast* we can ensure that every newborn – regardless of geography, delivery context, or gestational age – receives this fundamental advantage at the very beginning of life. The time for DCC is not in the future. It is now.

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