The impact of cesarean section delivery on intestinal microbiota: mechanisms, consequences, and perspectives: a narrative review

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Abstract

Cesarean section (CS) delivery has become an increasingly prevalent mode of childbirth worldwide. While it is a critical intervention in specific medical scenarios, its impact on neonatal gut microbiota (GM) has raised concerns. Infants born via CS bypass exposure to maternal vaginal and intestinal microbes, resulting in a distinct and often less diverse microbial composition compared to vaginally delivered infants. This disruption, exacerbated by prophylactic antibiotic use, has been linked to long-term health consequences, including an increased risk of immune-mediated disorders such as allergies and asthma, as well as metabolic conditions like obesity and type 2 diabetes. Breastfeeding, probiotics, and synbiotics have emerged as key interventions to mitigate microbial dysbiosis in CS-born infants. Breastfeeding supports GM by delivering human milk oligosaccharides (HMOs) that promote beneficial bacteria, while probiotics and synbiotics restore microbial balance and diversity. Alternative strategies, such as vaginal seeding and targeted dietary modifications, have shown potential but require further research to confirm their efficacy and safety. This narrative review underscores the complex interplay between CS delivery, microbiota, and health, highlighting the need for evidence-based interventions. By addressing microbial disruptions early, healthcare professionals can improve short- and long-term outcomes for CS-born infants, paving the way for healthier generations..

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Introduction

Cesarean section (CS) is increasingly common globally and is a critical medical procedure to prevent complications for both mothers and infants (1–15). However, while it has clear benefits, CS delivery can significantly affect the development of an infant's gut microbiota (GM) (17–26). Establishing GM early in life is crucial for shaping immune function, metabolic health, and overall digestive well-being (27–35). Infants born via CS do not receive the same microbial exposure from the maternal vaginal and intestinal microbiota as those born through vaginal delivery, leading to distinct microbial communities in the gut (36–47). This review delves into the mechanisms, health consequences, and potential strategies to mitigate the microbial alterations associated with CS births (48–58).

The Growing Prevalence of Cesarean Sections

In recent decades, CS delivery rates have surged globally, with many of these procedures performed for non-medical reasons (59–67). This increase has sparked concerns over the overuse of CS and its broader effects on the health of both mothers and infants. Research consistently demonstrates that the mode of delivery plays a pivotal role in the initial microbial colonization of newborns, influencing their health outcomes later in life (68–81). Consequently, understanding the impact of CS on neonatal gut microbiota is critical for developing interventions that can counteract any potential adverse effects (82–96).

How CS Affects Microbial Colonization in Newborns

Birth is the first significant exposure to microorganisms for newborns (97–101). During vaginal delivery, infants are colonized by maternal microbes, such as Lactobacilli and Bifidobacteria, which are essential for establishing a healthy gut microbiota (102–110). These bacteria help modulate immune function and nutrient absorption (111–123). In contrast, CS-born infants are not exposed to these beneficial microbes during birth (124–128). Instead, their microbiota primarily consists of skin-associated microbes and those acquired in hospital environments, leading to less diversity and a predominance of potentially harmful bacteria. (129–131)

The administration of antibiotics during CS birth further disrupts microbial development by inhibiting beneficial bacteria and enabling opportunistic pathogens to thrive (132,133). This microbial imbalance, known as dysbiosis, may affect the infant's health, particularly in the first 1000 days of life (134–148).

Long-Term Health Risks Linked to CS-Induced Microbial Changes

The early microbial changes resulting from CS delivery are associated with various long-term health issues (149–160). For example, CS-born infants are at higher risk of developing immune-related disorders, including allergies, asthma, and type 1 diabetes (160–176). This may be due to delayed colonization by key bacteria like Bacteroides and Bifidobacterium, which play an essential role in immune regulation and gut health (177–190).

Figure 1. Curcumin and its beneficial effects

CS delivery has also been linked to an increased risk of metabolic conditions such as obesity and type 2 diabetes (191–199). The absence of maternal microbial exposure may disrupt the programming of metabolic pathways, potentially increasing the likelihood of metabolic diseases later in life (200–213). Conditions such as inflammatory bowel disease (IBD) and celiac disease are also associated with early-life microbial imbalances, highlighting the importance of GM in overall health (214–221).

Breastfeeding's Role in Balancing Microbial Disruptions

Breastfeeding is crucial for promoting a healthy gut microbiota in infants. Human milk contains beneficial components such as bioactive compounds and human milk oligosaccharides (HMOs), which selectively foster the growth of beneficial bacteria like Bifidobacteria (222–236). For CS-born infants, breastfeeding can partially mitigate the microbial disturbances caused by the lack of maternal vaginal microbiota exposure. Studies indicate that breastfed CS infants have a higher concentration of beneficial bacteria and fewer harmful pathogens than formula-fed infants (237–250).

Beyond its microbial effects, breastfeeding provides immune support by transferring maternal antibodies, immune cells, and antimicrobial peptides to the infant. For CS-born babies, who may have compromised immune defenses due to their altered microbiota, breastfeeding serves as a vital protective factor (251–264).

Probiotics and Synbiotics as Potential Interventions

Probiotics and synbiotics are emerging as potential solutions to restore microbial balance in CS-born infants. Probiotics, which are live beneficial microorganisms, have been shown to encourage the growth of healthy bacteria, reduce inflammation, and support immune system development. Strains like Lactobacillus and Bifidobacterium are commonly used to help restore microbial diversity (265–271).

Synbiotics, a combination of probiotics and prebiotics (non-digestible food components that support the growth of beneficial bacteria), offer an integrated approach to improving gut health. Research has shown that synbiotics can help CS-born infants achieve a microbiota composition more similar to that of vaginally delivered infants. For example, synbiotic formulas containing Bifidobacterium breve and galactooligosaccharides have been found to promote beneficial bacteria and reduce pathogenic microorganisms (272–277).

Exploring Vaginal Seeding and Other Approaches

Vaginal seeding, a practice where maternal vaginal microbiota is transferred to CS-born infants, has been proposed as a way to mimic vaginal birth microbial exposure. While early studies suggest vaginal seeding can improve microbial profiles in CS-born infants, concerns about safety and inconsistent results have limited its widespread use. Rigorous screening of maternal pathogens is necessary, and more research is needed to establish standardized protocols and assess long-term outcomes (278–283).

Other strategies, such as delaying antibiotic administration and providing prebiotic or probiotic-enriched formulas, may also help mitigate microbial imbalances in CS-born infants. For instance, delaying antibiotics until after the initial microbial colonization may allow the infant to benefit from exposure to beneficial microbes. Similarly, supplementing the formula with HMOs or prebiotics could support the development of a healthy microbiota (284–286).

Oral Microbiota and Its Relationship with Gut Microbiota

Although often overlooked, the oral microbiota is essential in establishing the gut microbiota. The mouth serves as an entry point for microorganisms, and oral microbiota composition can influence the gut microbiota (287). In CS-born infants, disrupted oral microbiota may further contribute to the challenges of gut microbiota development. Understanding the connection between oral and gut microbiota is critical for developing comprehensive approaches to neonatal microbiota health (288).

For example, breastfeeding promotes gut health and influences oral microbiota, helping beneficial bacteria flourish. Similarly, oral probiotics can impact oral and gut microbial communities, highlighting the interconnected nature of these microbial ecosystems (289–293).

Microbiota's Role in Oral Health

Establishing a healthy microbiota during infancy is essential for gut health and preventing oral diseases like dental caries and periodontal disease. Beneficial bacteria such as Bifidobacterium and Lactobacillus, commonly found in the gut, also help protect the oral cavity by inhibiting harmful bacteria. CS-born infants who experience disrupted microbial development may be at higher risk of oral health issues, which may require targeted interventions (292,293).

Emerging research suggests that incorporating probiotics into oral care routines could offer dual oral and gut health benefits. For example, probiotic lozenges and chewable tablets may reduce oral pathogens while supporting gut health. This underscores the need for interdisciplinary collaboration between medical and dental professionals to optimize health outcomes for CS-born infants (294,295).

Figure 1.

Materials and Methods

Literature Search

A narrative review was conducted to explore the impact of precision medicine on oral health and the infant microbiota. A literature search was performed using PubMed, Scopus, and Web of Science, covering articles published between January 1, 2013, and July 1, 2023. Keywords such as "cesarean delivery," "infant gut microbiota," and "infant oral microbiota" were combined using Boolean operators to identify relevant studies.

Inclusion and Exclusion Criteria

The inclusion criteria were as follows:

1. Studies published in English that investigated the relationship between cesarean delivery (C-section) and the infant gut microbiota (GM).
2. Studies discussing the administration of vaginal microbiota to newborns.
3. Randomized clinical trials, observational, or retrospective studies with full-text access.

The exclusion criteria were:

1. Animal or in vitro studies.
2. Off-topic studies.
3. Systematic reviews, case reports, case series, or commentary articles.

Selection Process

The selection process did not follow the rigid protocols of systematic reviews. Instead, the narrative approach allowed for a broader scope of studies, emphasizing qualitative interpretation and clinical implications. Identified articles were thematically analyzed to synthesize key findings and future perspectives.

Study Selection and Characteristics:

The database search yielded approximately 484 articles, primarily from PubMed, Scopus, and Web of Science. The selection process focused on studies exploring the correlation between precision medicine, genomics, and oral health. After an initial screening of titles and abstracts, irrelevant studies, such as those addressing unrelated topics, in vitro research, and review articles, were excluded. Ultimately, 10 studies were selected for qualitative analysis, focusing on clinical implications and practical applications.

Discussion

The relationship between CS delivery and gut microbiota underscores the significance of early microbial exposures in shaping health outcomes. While CS is often medically necessary, its impact on microbial colonization requires careful attention. Understanding these mechanisms will guide the development of strategies to mitigate adverse effects (296).

Probiotics and synbiotics provide a promising way to restore microbial balance in CS-born infants. These interventions support the growth of beneficial bacteria, enhance immune function, and reduce inflammation. Breastfeeding remains a fundamental intervention for counteracting microbial disruptions caused by CS (297).

Although vaginal seeding and dietary supplementation show promise, more research is needed to assess their safety and long-term effectiveness fully (298–301). Large-scale studies will be crucial in understanding how these interventions influence microbial composition and health outcomes (302).

Conclusion

Cesarean section delivery presents unique challenges for developing a healthy gut microbiota. The lack of exposure to maternal vaginal microbiota during birth can lead to disruptions in microbial colonization, with significant implications for immune function, metabolic health, and overall well-being. However, targeted interventions, including probiotics, synbiotics, and breastfeeding, offer practical strategies to mitigate these effects. As CS rates continue to rise, addressing the microbial consequences of this delivery method will be critical to optimizing neonatal and long-term health outcomes.

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Conflicts of Interest

The authors declare no conflicts of interest.

Abbreviations:

CS	Cesarean Section
GM	Gut Microbiota
IBD	Inflammatory Bowel Disease
HMOs	Human Milk Oligosaccharides

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