Chapter

Vaginal Seeding in Term Cesarean Section Is a Mandatory Condition for Improvement of Neonatal Health

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Abstract

The human vaginal microbiota is an important component of the defense system to fight microbial and viral infections. During pregnancy, a significant decrease in overall diversity is observed in the vaginal flora, and there is an increase in stability as the composition of the vaginal flora changes gradually. These alterations are linked to a decrease in vaginal pH and an augmentation in vaginal secretions. The composition of the vaginal microbiome changes according to gestational age, with its composition in advanced weeks of pregnancy resembling that of nonpregnant women. There is supporting evidence for the existence of differences in the neonate's microbiome between those born *via* C-section and those delivered vaginally. The evidence suggests that this difference is a result of the changes that occur in the mother's microbiome, particularly in the vagina. The vaginal microbiome serves as a crucial barrier between the external environment and the intra-amniotic cavity. The vaginal microbiome appears to play a significant role as an additional defense mechanism of the mother and, consequently, the fetus. Any abnormalities in this microbiome can potentially impact the pregnancy and perinatal outcome.

Keywords: term pregnancies, cesarean section, vaginal delivery vaginal seeding, elective cesarean section with vaginal seeding, perinatal outcome

1. Introduction

Until the beginning of the twentieth century, it was believed that the fetus came into the world free of microbes. Today, there are numerous indications that disprove this hypothesis and suggest that there is already a presence of microbes in the fetal-placental unit. A useful model for examining the causes of numerous disorders and the development of human health is the neonatal microbiome. Multiple studies have described the importance of the first 1000 days of life when basic physiological exposures to microbes can have profound effects on future health. The establishment of a healthy microbiome, comprising trillions of microbial cells and their respective genomes, is critical during this period [1–3]. The neonatal microbiome begins as early as the prenatal period, where many studies suggest that the maternal microbiota colonizes the infant through the *in utero* environment. From here, mode of delivery, breastfeeding, diet, and environment lead to a rapid expansion of bacterial complexity as the microbiome becomes established. This stable trajectory of progressive bacterial colonization becomes critical for immune priming, normal function in multiple organ systems, and lays the foundation for future health. The mode of delivery, whether by cesarean section or vaginal delivery, can influence the neonatal immune system and subsequent susceptibility to infections. Identifying vaginal infections that are dangerous to pregnancy and the fetus from those that are bothersome but harmless and manageable, as well as their precise management, is a challenge for medical experts [4, 5].

The following chapter is the result of a literature review in order to investigate the effects of vaginitis on pregnancy outcomes. This refers to an investigation of the normal microflora of the vagina, its defense mechanisms, and the microorganisms that colonize it. The second part refers to the pathological colonizations of the vagina, the types of vaginitis that cause them, and their diagnosis. Next, the changes that the vagina undergoes during pregnancy, its pathology from the colonization of pathogenic microorganisms, and their treatment are described. Finally, the effects of vaginitis on the outcome of pregnancy are described, with pathologies such as chorioamnionitis, premature birth, and spontaneous abortion.

1.1 Background and context

In recent years, vaginal seeding has drawn interest as a potential strategy to improve the development of the neonatal microbiome. The community of microbes that live in the human body, notably the gut, skin, and mucous membranes, is referred to as the microbiome. It is essential for the development of the immune system, metabolism, and defense against pathogens, among other elements of health. The newborn is exposed to a wide variety of germs in the birth canal during a vaginal birth. This exposure is believed to contribute to the initial colonization of the infant's gut with beneficial bacteria, such as Bifidobacterium and Lactobacillus species. These bacteria are associated with immune system development, regulation of inflammation, and protection against certain diseases.

Cesarean section (C-section) delivery, however, bypasses the vaginal birth canal, resulting in a different microbial exposure for the newborn. Infants born *via* C-section tend to have a microbiome composition that differs from those born vaginally. Research has shown that these differences may have implications for the infant's health as C-section-born infants have been found to have an increased risk of certain health conditions, such as allergies, asthma, atopic disease, obesity, and autoimmune disorders [3–5].

Vaginal seeding is proposed as a method to mimic the microbial exposure of a vaginal birth for infants born *via* C-section. It involves the collection of maternal vaginal fluids, typically using a sterile swab, which is then transferred onto the newborn's skin or mouth within the first moments after birth. The goal is to introduce the mother's vaginal microbiota to the newborn, potentially promoting a microbial colonization pattern similar to that of a vaginal birth. Vaginal seeding is still a contentious issue, despite the fact that it has attracted interest as a potential strategy to affect the newborn microbiota. The possibility for hazardous microbes, such as pathogens and bacteria, resistant to antibiotics, to be transmitted from the mother to the newborn has given rise to safety concerns. The lack of standardized protocols for evaluating the maternal vaginal microbiota and screening for infections poses challenges for implementing this practice. Given the potential impact of the neonatal microbiome on health outcomes and the increasing rates of C-section deliveries, there is a need to better understand the potential benefits and risks associated with vaginal seeding. Ongoing research aims to investigate its effects on the neonatal microbiome composition, immune development, and long-term health outcomes. The findings of these studies have the potential to inform clinical practice, guidelines, and decision-making regarding vaginal seeding [3–7].

1.2 Rationale for studying vaginal seeding

The rationale for studying vaginal seeding lies in the growing interest in understanding the potential impact of this practice on neonatal health outcomes. As the rates of cesarean section deliveries continue to rise globally, there is a need to explore interventions that could mitigate the potential differences in microbial exposure and associated health risks between infants born *via* C-section and those born vaginally [3–7].

1. Enhancement of neonatal microbiome: The neonatal microbiome plays a crucial role in immune development, metabolic processes, and overall health. Vaginal seeding is proposed as a method to introduce the maternal vaginal microbiota to infants born *via* C-section, potentially enhancing the establishment of a more diverse and balanced microbiome. By replicating the microbial exposure of a vaginal birth, vaginal seeding aims to promote the colonization of beneficial bacteria, which may contribute to optimal immune development and reduce the risk of certain health conditions.

2. Potential health benefits: Several studies and anecdotal reports have suggested potential benefits associated with vaginal seeding. These include a reduced risk of allergies, asthma, autoimmune disorders, and metabolic conditions, such as obesity. Exploring the efficacy of vaginal seeding in influencing these health outcomes could provide valuable insights into preventive measures and interventions to optimize neonatal health.

3. Addressing health disparities: Studies have shown that infants born *via* C-section have a higher risk of certain health conditions compared to those born vaginally. By investigating the potential impact of vaginal seeding, researchers aim to address these health disparities and explore strategies to improve the health outcomes of infants born *via* C-section.

4. Clinical decision-making: The growing interest in vaginal seeding has led to varied practices and opinions among healthcare professionals. Conducting research on vaginal seeding can provide evidence-based guidance for healthcare providers, enabling them to make informed decisions and recommendations regarding this practice. Understanding the potential benefits and risks of vaginal seeding is essential for developing standardized protocols, identifying appropriate candidates, and ensuring safe implementation.

5. Ethical considerations: Vaginal seeding raises ethical considerations regarding safety, informed consent, and equitable access to the intervention. Investigating vaginal seeding helps to address these ethical concerns and inform discussions surrounding the risks and benefits of the practice, ensuring that healthcare decisions are made in the best interest of the newborns and their families.

In summary, studying vaginal seeding is important to explore its potential to enhance the neonatal microbiome, mitigate health risks associated with C-section deliveries, and improve neonatal health outcomes. By understanding the rationale behind vaginal seeding and conducting rigorous research, healthcare professionals can make informed decisions and provide evidence-based recommendations to optimize neonatal care [7–9].

2. Literature review

2.1 Overview of the neonatal microbiome and its importance in health

The neonatal microbiome refers to the collection of microorganisms, including bacteria, viruses, fungi, and other microbes, that inhabit the newborn's body, particularly the gut, skin, and mucous membranes. The newborn microbiome experiences rapid development and is essential for many aspects of development and health. During pregnancy, the fetus is believed to be in a relatively sterile environment. However, upon birth, the neonate is rapidly colonized by microorganisms from the surrounding environment, primarily influenced by the mode of delivery, feeding practices, maternal factors, and exposure to the external environment. The early establishment of a diverse and balanced neonatal microbiome is important for multiple physiological processes [7–9].

Immune system development: The neonatal microbiome plays a crucial role in the maturation and development of the immune system. The presence of beneficial bacteria in the gut stimulates the production of specific immune cells and regulatory molecules, promoting immune tolerance and preventing exaggerated immune responses. The interaction between the microbiome and the immune system is essential for the proper functioning of immune defense mechanisms and protection against infections [7–9].

Metabolic processes: The neonatal microbiome is involved in various metabolic processes, including the fermentation of dietary components and the production of essential metabolites. Beneficial bacteria in the gut can break down complex carbohydrates that are indigestible by the host, producing short-chain fatty acids and other metabolites that provide energy to the host cells and contribute to overall metabolic homeostasis [9–11].

Protection against pathogens: A defense against possible infections is provided by the newborn microbiota. Pathogens are kept from colonizing and overgrowing by beneficial bacteria in the gut and on the skin, which compete with them for nutrition and space. Additionally, they create antimicrobial chemicals that can obstruct the development of viruses and bacteria that cause disease [9–11].

Maturation of organ systems: The neonatal microbiome has been implicated in the maturation and development of various organ systems. It influences the development and integrity of the intestinal epithelial barrier, aiding in nutrient absorption and preventing the translocation of harmful substances into the bloodstream. Additionally, the microbiome can influence the development of the central nervous system and the modulation of neurotransmitters, potentially affecting neurodevelopmental processes.

Association with health and disease: Alterations in the neonatal microbiome have been associated with various health conditions and disease outcomes. Dysbiosis, an imbalance or disruption in the microbial composition, has been linked to an increased risk of allergies, asthma, obesity, autoimmune disorders, gastrointestinal disorders (such as necrotizing enterocolitis), and even neurodevelopmental disorders. Understanding the role of the neonatal microbiome in these health conditions can help develop targeted interventions and strategies for prevention and treatment [9–11].

The neonatal microbiome is a dynamic ecosystem that influences various aspects of health and development. Its establishment and composition in the early stages of life play a crucial role in immune system maturation, metabolic processes, pathogen defense, and the development of organ systems. Understanding the importance of the neonatal microbiome provides insights into the potential impact of interventions, such as vaginal seeding on health outcomes and underscores the need for further research to optimize neonatal health [9–11].

2.2 Exploration of factors influencing the neonatal microbiome, including mode of delivery

The composition and development of the neonatal microbiome are influenced by various factors, including the mode of delivery. Here, we explore the factors that impact the neonatal microbiome, with a specific focus on the influence of delivery mode.

2.2.1 Mode of delivery

Vaginal delivery: During a vaginal birth, the newborn is exposed to the microorganisms present in the birth canal, including bacteria from the maternal vaginal and fecal microbiota. This exposure leads to the colonization of the neonate's gut, skin, and mucosal surfaces with a diverse range of microorganisms, primarily bacteria. Infants born vaginally tend to have a microbiome composition characterized by an abundance of beneficial bacteria, such as Bifidobacterium and Lactobacillus species [9–11].

Cesarean section (C-section): Bypassing the birth canal, a C-section includes the surgical delivery of the infant through an incision in the belly and uterus. Infants delivered by C-section experience a different level of microbial exposure than those delivered vaginally. They are initially colonized by microorganisms present in the surrounding environment, including skin and hospital surfaces. The microbiome of C-section-born infants tends to be less diverse and dominated by bacteria associated with the hospital environment [11–13].

2.2.2 Maternal factors

Maternal microbiota: The composition of the maternal microbiota, particularly the vaginal and gut microbiota, can influence the initial colonization of the neonatal microbiome. The transfer of maternal microorganisms during vaginal birth contributes to the establishment of the neonatal microbiome. Differences in the maternal microbiota, such as bacterial diversity and composition, can impact the microbial transmission to the newborn.

Maternal health and lifestyle: Maternal health conditions, such as obesity, diabetes, and gestational infections, can influence the microbial composition and diversity transferred to the neonate. Maternal lifestyle factors, including diet, antibiotic use, and exposure to environmental factors, may also affect the microbiota and potentially impact the neonatal microbiome [11–13].

2.2.3 Breastfeeding

Breast milk composition: Prebiotics, other bioactive substances, and a wide variety of helpful bacteria are all present in breast milk, which helps some bacteria flourish in the neonatal gut. Lactobacillus and Bifidobacterium, two helpful bacteria that support the development of a healthy microbial community in the infant's gut, are found in breast milk.

Mode of feeding: Neonatal microbiota composition has been linked to breastfeeding vs. formula feeding. In order to encourage the construction of a healthy gut microbiome in the infant, breast milk helps to generate a more diversified and advantageous microbial community [11–13].

2.2.4 Environmental exposures

Early life exposures: Factors, such as the home environment, hygiene practices, and exposure to pets or siblings, can influence the neonatal microbiome. These early life exposures can introduce additional microorganisms and potentially impact the diversity and composition of the neonatal microbiome.

It makes it easier to understand the intricacies of microbial colonization throughout the early stages of life to be aware of the factors that affect the newborn microbiome such as the manner of delivery, maternal factors, nursing, and environmental exposures. It highlights how crucial it is to take these aspects into account when examining how interventions, such as vaginal seeding, affect the newborn microbiota and health consequences [11–13].

2.3 Introduction to vaginal seeding and its potential benefits and controversies

Vaginal seeding is an emerging practice that aims to mimic the microbial exposure of a vaginal birth for infants born *via* cesarean section (C-section). It involves transferring maternal vaginal fluids, including microorganisms, onto the newborn shortly after birth. The rationale behind vaginal seeding is to introduce beneficial bacteria from the mother's vaginal microbiota to the newborn, potentially influencing the establishment of the neonatal microbiome and promoting optimal immune development [13–17].

The potential benefits associated with vaginal seeding are rooted in the understanding that the early colonization of the neonatal gut with beneficial bacteria plays a crucial role in immune system maturation, metabolic processes, and protection against certain health conditions. Proponents of vaginal seeding hypothesize that by replicating the microbial exposure of a vaginal birth, this intervention may help restore the microbiome composition of C-section-born infants, making it more similar to that of vaginally delivered infants. This, in turn, could potentially lead to a reduced risk of certain health conditions such as allergies, asthma, obesity, and autoimmune disorders.

However, the practice of vaginal seeding is not without controversy and debates. One of the main concerns revolves around the potential transmission of harmful microorganisms from the maternal vaginal canal to the newborn. This includes the risk of transmitting pathogens such as group B Streptococcus, herpes simplex virus, or antibiotic-resistant bacteria. The lack of standardized protocols for evaluating the maternal vaginal microbiota and screening for infections poses challenges in ensuring the safety of vaginal seeding [13–17].

Additionally, the scientific evidence supporting the efficacy and safety of vaginal seeding is limited and often based on small-scale studies or anecdotal reports. The existing studies on vaginal seeding have reported conflicting findings, making it challenging to draw definitive conclusions. There is a need for larger, well-designed studies to evaluate the impact of vaginal seeding on the neonatal microbiome, immune development, and long-term health outcomes. Moreover, the practice of vaginal seeding is not currently recommended by major healthcare organizations, such as the American College of Obstetricians and Gynecologists (ACOG), due to safety concerns and the lack of sufficient evidence. In particular, the ACOG recommends that clinicians and patients avoid this practice, unless as part of an approved research protocol [13–18].

Addressing the controversies and debates surrounding vaginal seeding requires further research and scientific investigation. This includes developing standardized protocols for assessing the maternal vaginal microbiota, screening for infections, and evaluating the short- and long-term effects of vaginal seeding on neonatal health outcomes. The potential benefits and risks of vaginal seeding need to be carefully considered and weighed against each other with a focus on ensuring the safety and well-being of the newborns.

2.4 Review of existing literature on vaginal seeding, including studies on microbiome composition, immune development, and health outcomes

In recent years, several studies have investigated the impact of vaginal seeding on the neonatal microbiome composition, immune development, and various health outcomes. Here, we review the existing literature on vaginal seeding, highlighting key findings and insights in these areas.

Microbiome composition: Studies examining the neonatal microbiome composition following vaginal seeding have reported varying results. Some studies have shown that vaginal seeding leads to an increased abundance of bacteria associated with vaginal birth, such as Lactobacillus and Bifidobacterium species, in the gut and other body sites of C-section-born infants. These findings suggest that vaginal seeding can help establish a microbial community resembling that of infants born vaginally [19–23].

However, other studies have reported inconsistent or limited effects of vaginal seeding on the neonatal microbiome composition. Methodological differences, including variations in the timing and techniques of vaginal fluid transfer, sample collection methods, and analysis techniques, may contribute to the discrepancies in findings. Larger, well-controlled studies with standardized protocols are needed to further elucidate the impact of vaginal seeding on the neonatal microbiome composition [19–23].

Immune development: The influence of vaginal seeding on immune development in newborns has also been explored. Some studies have suggested that vaginal seeding may promote immune maturation such as indicated by changes in immune cell populations, cytokine profiles, and immune markers. These findings indicate that exposure to maternal vaginal microbiota through vaginal seeding may play a role in modulating immune responses and promoting immune tolerance.

However, the clinical significance and long-term implications of these immune changes remain unclear. Further, research is needed to establish a clear link between vaginal seeding and immune development, considering factors such as the timing and frequency of vaginal seeding, potential variations in immune outcomes, and the interplay with other factors influencing immune development [19–23].

Health outcomes: The potential impact of vaginal seeding on health outcomes in C-section-born infants has been a topic of interest. Some observational studies have reported associations between vaginal seeding and a reduced risk of certain health conditions, including allergies, asthma, and autoimmune disorders. These findings suggest that vaginal seeding may have long-term health benefits by influencing the neonatal microbiome and immune system [23–25].

However, the evidence on health outcomes and the clinical significance of these associations is limited and often based on small-scale studies or anecdotal reports. Larger, well-designed studies, including randomized controlled trials, are needed to further investigate the potential benefits and long-term effects of vaginal seeding on health outcomes. It is essential to consider potential confounding factors, such as breastfeeding practices and other early life exposures, when assessing the impact of vaginal seeding on health outcomes [23–27].

In summary, the existing literature on vaginal seeding indicates a potential influence on the neonatal microbiome composition, immune development, and health outcomes. While some studies suggest positive associations between vaginal seeding and beneficial outcomes, the evidence is limited, and conflicting results have been reported. Further, research, including larger-scale studies with standardized protocols, is necessary to establish a clearer understanding of the effects of vaginal seeding on the neonatal microbiome, immune development, and long-term health outcomes.

Despite the growing interest in vaginal seeding, there are several gaps in the current knowledge that need to be addressed through further research. These gaps include:

Lack of standardized protocols: There is a lack of standardized protocols for assessing the maternal vaginal microbiota, including methods for sample collection, processing, and analysis. Standardized protocols are crucial for ensuring consistency across studies and facilitating comparisons between different research findings [23–25].

Variations in vaginal seeding practices: Vaginal seeding practices vary widely across studies, including differences in the timing and techniques of vaginal fluid transfer, the selection of participants, and the criteria for determining eligibility. These variations make it difficult to draw definitive conclusions or compare results between studies. Standardized protocols for vaginal seeding are needed to establish consistency in practice and facilitate meaningful comparisons [25–29].

Small sample sizes: Many studies investigating vaginal seeding have relatively small sample sizes, which may limit the generalizability and statistical power of the findings. Larger-scale studies with adequate sample sizes are required to provide more robust evidence regarding the effects of vaginal seeding on the neonatal microbiome, immune development, and health outcomes.

Long-term follow-up studies: There are not enough long-term follow-up studies to evaluate the consequences of vaginal seeding after birth. Longitudinal studies that track infants exposed to vaginal seeding over an extended period are needed to evaluate the persistence of any observed effects and to assess potential health outcomes, including allergies, asthma, autoimmune disorders, and metabolic conditions.

Limited diversity of participants: Many studies on vaginal seeding have primarily focused on populations from developed countries, limiting the generalizability of the findings to other populations and settings. It is essential to include diverse populations, including those from different geographical regions and with varying sociocultural backgrounds, to understand the broader implications of vaginal seeding [25–29].

Safety concerns and screening protocols: Safety concerns regarding the potential transmission of harmful microorganisms during vaginal seeding need to be addressed. Standardized protocols for evaluating the maternal vaginal microbiota, including screening for infections and identification of potential pathogens, are necessary to ensure the safety of vaginal seeding procedures.

Mechanistic understanding: While studies have explored the effects of vaginal seeding on the neonatal microbiome and immune development, the underlying mechanisms are not well understood. Further, research is needed to elucidate the specific pathways through which vaginal seeding influences these processes and to identify the key microbial factors driving any observed effects. Addressing these gaps in the current knowledge will provide a more comprehensive understanding of vaginal seeding and its implications for neonatal health [29–31]. Large-scale, well-controlled studies with standardized protocols, long-term follow-up, diverse populations, and a focus on safety considerations are crucial for advancing our understanding of the potential benefits, risks, and mechanisms of action associated with vaginal seeding.

2.5 Consideration of the limitations of the included studies and potential sources of bias

It is important to acknowledge the limitations of the included studies and potential sources of bias as they can influence the interpretation and generalizability of the findings. Some common limitations and potential sources of bias in studies related to neonatal microbial colonization and mode of delivery include: (1). Sample size: Numerous research in this field can have sample sizes that are not very large, which could reduce the statistical power and generalizability of the findings. Small sample sizes might not accurately reflect the population's variety, which could result in selection bias. (2). Selection bias: Studies may recruit participants from specific populations or healthcare settings, leading to selection bias. This can affect the representativeness of the sample and limit the ability to extrapolate the findings to a broader population. (3). Retrospective design: Some studies may use retrospective designs, relying on medical records or previously collected data. Retrospective studies may suffer from incomplete or inaccurate data, and researchers may have limited control over the variables studied. (4). Confounding factors: The association between the technique of delivery and neonatal microbial colonization can be influenced by a number of confounding variables. These elements include nursing habits, gestational age, antibiotic use, maternal microbiome, and mother health. The results may be skewed if these factors are not properly taken into account. (5). Lack of standardization: The methods used to assess microbial colonization can vary between studies, making it challenging to compare results directly. Differences in sampling techniques, DNA extraction, sequencing methods, and data analysis may contribute to variability in findings. (6). Cross-sectional nature: Some studies may have a cross-sectional design, which captures data at a single time point. This design may not allow for the evaluation of changes in microbial colonization over time, limiting the understanding of the dynamics of neonatal microbiota. (7). Lack of long-term follow-up: Long-term follow-up of neonates beyond the immediate postnatal period is essential to assess the potential impact of early-life microbial colonization on later health outcomes. However, many studies may lack long-term follow-up data. (8). Vaginal seeding practice: Studies investigating the impact of vaginal seeding on neonatal microbial colonization are relatively new and may have limited data on the safety and long-term effects of this practice. This area requires further research to establish its clinical efficacy and safety. (9). Publication bias: Published studies may be more likely to report positive or statistically significant results, leading to publication bias. Negative or nonsignificant findings may be underreported, potentially skewing the overall literature on the topic. (10). To mitigate these limitations and potential sources of bias, future studies should aim for larger sample sizes, prospective designs, standardized methods, and rigorous control of confounding factors [31–33]. Additionally, conducting long-term follow-up studies can provide valuable insights into the lasting effects of neonatal microbial colonization on health outcomes. Collaborative efforts and multicenter studies can also enhance the generalizability of the findings and improve our understanding of the complex interactions between mode of delivery, neonatal microbial colonization, and health.

2.6 Addressing the controversies and debates surrounding vaginal seeding

Vaginal seeding is a controversial practice that involves exposing infants born *via* cesarean section to the maternal vaginal microbes shortly after birth. While some proponents of vaginal seeding suggest that it may help promote a more diverse and beneficial microbial colonization in cesarean-born infants, there are significant controversies and debates surrounding its safety, efficacy, and potential risks. Limited Scientific One of the main controversies surrounding vaginal seeding is the lack of robust scientific evidence supporting its safety and long-term benefits. Most studies on the topic have been small, and there is a need for larger, well-designed clinical trials to establish the safety and effectiveness of vaginal seeding. Introducing maternal vaginal microbes to cesarean-born infants carries the risk of transferring harmful bacteria or infections to the newborn. The vaginal microbiome is diverse, and it can include potentially pathogenic microorganisms that may pose health risks to the vulnerable newborns. Vaginal seeding is not a standardized medical procedure, and there is no consensus on the best method for performing it. Different practitioners may use varied techniques, which can lead to inconsistencies and potential risks. While the intent of vaginal seeding is to promote a more diverse and beneficial microbial colonization, there is a concern that it may lead to unintended consequences [33–39]. The introduction of foreign microbes could potentially disrupt the delicate balance of the infant's microbiome and have unknown effects on their health. Vaginal seeding raises ethical concerns as it involves exposing infants to a practice that has not been thoroughly studied for its safety and effectiveness. Inclusion in clinical trials may be complicated due to the need for informed consent and potential risks. Before considering vaginal seeding, the potential benefits must be carefully weighed against the potential risks. Cesarean section is a lifesaving procedure in many cases, and the risks associated with vaginal seeding must be justified by significant potential benefits. Some researchers suggest that breastfeeding and skin-to-skin contact may provide beneficial microbial exposure for cesarean-born infants without the risks associated with vaginal seeding [37–43]. More research is needed to explore alternative approaches to promote a healthy microbiome in cesarean-born infants. In conclusion, while vaginal seeding has gained attention as a potential method to influence neonatal microbial colonization, it remains a controversial and debated practice. The lack of substantial scientific evidence, potential infection risks, and ethical considerations warrant caution and careful consideration before adopting vaginal seeding as a standard practice. Further, research is needed to better understand the safety and long-term effects of vaginal seeding and to explore alternative strategies to promote a healthy microbial colonization in cesarean-born infants. Until then, it is essential for healthcare providers and parents to engage in informed discussions about the potential risks and benefits of vaginal seeding and make decisions based on the best available evidence and individual circumstances [43–49].

2.7 Suggestions for future research and recommendations for clinical practice

Future research in the field of neonatal microbial colonization and mode of delivery should focus on addressing the existing gaps in knowledge and providing more robust evidence to guide clinical practice. Here are some suggestions for future research and recommendations for clinical practice:

2.7.1 Future research

1. Long-term follow-up: Conduct longitudinal studies with long-term follow-up to understand the lasting effects of neonatal microbial colonization on health outcomes. This will help establish the association between early-life microbial exposure and the development of various health conditions later in life.

2. Randomized controlled trials: To assess the security and effectiveness of vaginal seeding, conduct sizable, and randomized controlled studies. In order to give trustworthy evidence regarding the possible advantages and hazards of the practice, these trials should include a variety of populations and account for confounding variables.

3. Standardization of methods: Develop standardized protocols and methods for vaginal seeding to ensure consistency and reproducibility across different healthcare settings. Standardization will help in comparing results across studies and improve the quality of research in this area.

4. Impact of antibiotics: Investigate the impact of maternal and neonatal antibiotic use on neonatal microbial colonization. Understanding how antibiotics affect the neonatal microbiome can inform strategies to minimize their impact on microbial diversity and balance.

5. Factors influencing microbial transfer: Explore other factors that may influence microbial transfer during vaginal delivery, such as gestational age, mode of onset of labor, and maternal health conditions. Identifying these factors can help in understanding the complexity of neonatal microbial colonization.

6. Microbial analysis techniques: Continue to improve and refine microbial analysis techniques, including advanced sequencing methods and bioinformatic tools. This will enhance our ability to accurately characterize the neonatal microbiome and identify specific microbial patterns associated with delivery mode.

2.7.2 Recommendations for clinical practice

1. Individualized Care: Provide individualized care to neonates based on their specific microbial colonization profile and other clinical factors. Recognize that each infant's microbiome is unique and may require tailored interventions.

2. Promote vaginal delivery: Encourage and promote vaginal delivery when it is safe and appropriate for both the mother and baby. Vaginal delivery exposes the infant to beneficial maternal vaginal microbes, which may positively impact their health.

3. Caution with vaginal seeding: Until more research establishes its safety and efficacy, practitioners should exercise caution when considering vaginal seeding. The potential risks associated with the practice should be weighed against the limited evidence of benefits.

4. Emphasize breastfeeding: As breastfeeding significantly influences the development of the infant's gut flora and general health, promote and support it. Breast milk provides advantageous substances that feed and promote the development of good gut bacteria.

5. Hygiene and infection control: Ensure strict adherence to hygiene and infection control practices during childbirth and neonatal care to minimize the risk of neonatal infections, especially for infants born *via* cesarean section.

6. Educate Parents: Provide expectant parents with balanced and evidence-based information about the potential impact of delivery mode on neonatal microbial colonization. Informed discussions with healthcare providers can help parents make informed decisions about their birth plan.

7. Interdisciplinary collaboration: Foster collaboration between obstetricians, neonatologists, microbiologists, and researchers to advance knowledge in this field. An interdisciplinary approach can lead to more comprehensive and clinically relevant research and recommendations. In summary, future research should focus on filling the gaps in knowledge regarding neonatal microbial colonization and delivery mode. In clinical practice, individualized care, promotion of vaginal delivery, caution with vaginal seeding, emphasis on breastfeeding, and adherence to infection control practices are key recommendations to optimize neonatal health. Collaborative efforts will continue to enhance our understanding of the intricate relationship between the neonatal microbiome and health outcomes [50–55].

This chapter reviews the existing literature on vaginal seeding, a practice aimed at replicating the microbial exposure of a vaginal birth for infants born *via* cesarean section (C-section). The review focuses on the impact of vaginal seeding on the neonatal microbiome composition, immune development, and health outcomes. Several studies have explored these aspects, providing insights into the potential benefits and controversies surrounding vaginal seeding. Studies have reported varying results concerning the impact of vaginal seeding on the neonatal microbiome. Some suggest that vaginal seeding can lead to an increased abundance of beneficial bacteria, similar to those found in infants born vaginally. However, methodological differences among studies may contribute to inconsistencies in findings. More well-controlled studies with standardized protocols are needed to further clarify the effects of vaginal seeding on the neonatal microbiome.

Vaginal seeding has been investigated for its potential role in promoting immune maturation in newborns. Some studies indicate that it may influence immune cell populations and cytokine profiles, contributing to immune tolerance. Nevertheless, the clinical significance and long-term implications of these immune changes remain unclear and require further investigation.

Observational studies have suggested associations between vaginal seeding and reduced risks of certain health conditions such as allergies, asthma, and autoimmune disorders. However, evidence in this area is limited and based on small-scale studies or anecdotal reports. Large-scale and well-designed studies, including randomized controlled trials, are necessary to evaluate the potential benefits and long-term effects of vaginal seeding on health outcomes [56–63].

The review identifies several gaps in the current knowledge about vaginal seeding. These include the lack of standardized protocols, variations in vaginal seeding practices, small sample sizes, limited long-term follow-up studies, and insufficient diversity among study populations. Safety concerns, mechanistic understanding, and the need for broader well-controlled research are also highlighted as areas that require attention..

In conclusion, while the existing literature provides some evidence suggesting the potential benefits of vaginal seeding, it also underscores the need for further research. Standardized protocols, larger sample sizes, diverse study populations, and extended follow-up periods are essential to establish a clearer understanding of vaginal seeding's impact on the neonatal microbiome, immune development, and health outcomes. Addressing these gaps will help healthcare professionals make more informed decisions about the use of vaginal seeding and its potential role in promoting neonatal health and well-being.

2.8 Recapitulation of the importance and implications of the research

The research on vaginal seeding holds significant importance in the field of neonatal health and microbial development. Recapitulating the key findings and implications of the research sheds light on the potential impact and controversies surrounding this practice [56–63].

The neonatal microbiome plays a crucial role in immune development, metabolic processes, and overall health outcomes. Understanding how vaginal seeding influences the neonatal microbiome composition can have far-reaching implications for neonatal health and disease prevention. With an increasing number of births occurring *via* cesarean section, exploring interventions such as vaginal seeding becomes crucial to promote microbial diversity and mimic the benefits of vaginal delivery. This research addresses the potential differences in the microbiome between infants, born *via* C-section and those delivered vaginally. Investigating the impact of vaginal seeding on immune development provides insights into potential strategies to promote immune tolerance and reduce the risk of immune-related disorders in later life. Exploring associations between vaginal seeding and reduced risks of allergies, asthma, and autoimmune disorders highlights the potential long-term health benefits of this practice. However, due to limited evidence, further research is necessary to draw definitive conclusions [56–63].

The findings of this research may influence clinical practice by encouraging healthcare professionals to consider vaginal seeding as an option for infants born *via* C-section. However, due to safety concerns and the need for more robust evidence, further research and standardized protocols are necessary before widespread adoption. The research underscores the importance of educating pregnant women about the potential benefits and risks of vaginal seeding. Clear communication with expectant mothers can help them make informed decisions about their birth plan and understand the implications of various delivery methods.

Identifying gaps in the current knowledge highlights the need for future research priorities. Larger-scale studies with diverse populations, long-term follow-up, and standardized protocols will contribute to a more comprehensive understanding of vaginal seeding's effects [56–63].

2.9 Final remarks and closing thoughts

In conclusion, the research on vaginal seeding represents a compelling area of investigation with potential implications for neonatal health and development. The neonatal microbiome and immune system are critical factors in shaping an infant's health and well-being and understanding how vaginal seeding influences these aspects is of utmost importance.

The conclusions drawn from the body of material already in existence indicate the potential advantages of vaginal seeding in promoting a microbiome composition that is similar to that of vaginally delivered children. Such a procedure may promote immunological development and maybe lower the risk of developing certain diseases in later life. However, it is essential to recognize that the evidence is currently limited and often inconsistent, necessitating further research with standardized protocols and larger sample sizes to validate these findings [56–63].

The research also emphasizes the importance of addressing gaps in our current knowledge. Long-term follow-up studies, inclusion of diverse populations, and standardized procedures are necessary to draw definitive conclusions about the safety and effectiveness of vaginal seeding. Moreover, ethical considerations surrounding informed consent, safety protocols, and potential risks should remain at the forefront of any research or clinical implementation [56–63].

The idea of vaginal seeding has potential, but caution must be used to prevent oversimplifying results until more conclusive data are available. The medical community should collaborate to prioritize research efforts in this field to ensure that decisions concerning vaginal seeding are evidence-based and prioritize the well-being of newborns and their mothers [55–63]. In closing, the exploration of vaginal seeding represents a fascinating avenue of research that has the potential to impact the future of neonatal care positively. By advancing our understanding of the neonatal microbiome and immune development, we can pave the way for more personalized and effective interventions. Continued investigation, collaboration, and critical evaluation will be crucial in unlocking the full potential of vaginal seeding and its implications for neonatal health and long-term outcomes. Ultimately, with evidence-based knowledge, we can strive to provide the best possible start in life for every newborn and support their journey toward a healthy and thriving future.

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