

Review

Mapping the Intellectual Structure and Dynamic Hotspots of Post-Cesarean Delivery Modalities: A CiteSpace-Based Scientometric Knowledge Graph Analysis

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Abstract: Background: Trial of labor after cesarean (TOLAC) and vaginal birth after cesarean (VBAC) are important strategies for reducing repeat cesarean delivery. However, the overall development and emerging research trends in this field have not been fully characterized. This study aimed to visualize the knowledge structure, research trends, and emerging hotspots of post-cesarean delivery research. Methods: Publications related to TOLAC and VBAC published between 2005 and 2025 were retrieved from the Web of Science Core Collection. A total of 582 eligible publications were included. CiteSpace (version 6.4.R1) was used to analyze annual publication trends, author and country/region collaboration networks, keyword co-occurrence and clustering, and keyword bursts. Results: The annual number of publications showed an overall increasing trend, with particularly rapid growth in recent years. Several active author groups were identified, while collaboration among different research teams remained relatively limited. China, the United States, and Israel were prominent contributors. Keyword analysis showed that cesarean section, vaginal birth, risk factors, risk, and perinatal outcome were major research topics. Ten keyword clusters were identified, including cesarean scar pregnancy, uterine rupture, labor induction, vaginal delivery, and interdelivery interval. Recent burst keywords included diagnosis, labor induction, placenta accreta spectrum, and postpartum hemorrhage, indicating an increasing focus on risk assessment and prevention of severe scar-related complications. Conclusions: Research on delivery after previous cesarean section has expanded substantially over the past two decades. Risk assessment, uterine rupture, and labor induction remain central themes, while diagnosis, placenta accreta spectrum, and postpartum hemorrhage represent emerging research hotspots. Further multicenter collaboration and individualized risk assessment may contribute to safer TOLAC and VBAC practice.

Keywords: Trial of labor after cesarean; Vaginal birth after cesarean; CiteSpace; Bibliometric analysis; Uterine rupture

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1. Introduction

The global rate of cesarean delivery (CD) has escalated dramatically over the past few decades, far exceeding the World Health Organization's recommended ideal threshold of 10% to 15% [1]. This unprecedented surge has drawn substantial clinical concern due to its strong association with maternal morbidity, healthcare economic burdens, and severe complications in subsequent pregnancies, including uterine rupture and placenta accreta spectrum disorders [2, 3]. In response to these challenges, promoting a Trial of Labor After Cesarean (TOLAC) leading to a successful Vaginal Birth After Cesarean (VBAC) has emerged as a critical, evidence-based obstetric strategy to curtail the repeat cesarean epidemic and optimize perinatal outcomes [4].

Despite clinical guidelines supporting TOLAC for appropriate candidates, its worldwide implementation remains highly variable and fraught with challenges [1, 5]. Obstetricians and pregnant individuals frequently face complex decision-making dilemmas due to the fine balance between the benefits of successful VBAC and the catastrophic risks associated with failed TOLAC, such as emergency hysterectomy or neonatal asphyxia [5, 6]. Consequently, academic efforts in this domain have expanded exponentially, focusing on diverse topics including clinical predictive models, long-term safety evaluation, psychological barriers of patients, and healthcare policy interventions [4, 7]. This rapid growth and diversification of the literature have made it increasingly difficult for researchers to grasp the macro-structural evolution and emerging hotspots within this field.

To synthesize this vast body of knowledge, traditional systematic reviews and meta-analyses provide valuable vertical insights but often struggle to map the broad, horizontal intellectual landscape and dynamic scientific trends over time. Bibliometric analysis stands out as a powerful quantitative tool capable of analyzing large-scale bibliographic data to uncover research networks, institutional collaborations, and landmark papers [8]. In particular, CiteSpace, a widely recognized application developed by Prof. Chaomei Chen, excels at generating co-citation networks and detecting citation bursts, thereby visualizing how the intellectual structure of a specific medical topic has shifted and identifying active front-runner areas [8, 9].

Although research related to post-caesarean delivery modalities is extensive, a comprehensive, visualized bibliometric overview that maps the global evolution of TOLAC and VBAC literature remains sparse. To bridge this knowledge gap, this study systematically retrieved relevant publications indexed in the Web of Science Core Collection (WoSCC) spanning from 2005 to 2025. By utilizing CiteSpace, we aim to delineate the core publication networks, pinpoint influential authors and institutions, track thematic shifts, and unveil prevailing research hotspots. Ultimately, the findings from this visual paradigm will provide clinicians and reproductive health researchers with a clear roadmap of past milestones and future strategic directions in this vital arena of obstetric care.

2. Method

2.1. Data Collection and Search Strategy

Bibliographic data for the current study were exclusively retrieved from the Web of Science Core Collection (WoSCC) database. To ensure search accuracy, the formulated topic (TS) query was applied: TS=("vaginal birth after cesarean" OR "vaginal birth after caesarean" OR VBAC OR "trial of labor after cesarean" OR "trial of labour after caesarean" OR TOLAC OR "labor after cesarean" OR "labour after caesarean" OR "previous cesarean delivery" OR "previous caesarean delivery"). We restricted the publication timespan from January 1, 2005, to December 31, 2025, and limited the document language to English. To prevent biases caused by dynamic daily updates of the database, the data extraction was executed on a single day, July 24, 2026. Two independent investigators meticulously screened the retrieved literature based on predetermined inclusion and exclusion criteria. Only original articles and reviews highly pertinent to continuous labor support were retained. Any disagreements encountered during the screening phase were resolved via consensus or consultation with a third senior reviewer. Ultimately, 582 valid publications were collated and exported for the subsequent bibliometric evaluation.

2.2. Bibliometric Analysis and Visualization

The refined dataset was downloaded from WoSCC as "Plain text files" containing "Full Record and Cited References." These files were then fed into CiteSpace software (version 6.4.R1) to construct visual knowledge maps. The analysis included annual publication trends, author and country/region collaboration networks, and keyword co-occurrence, clustering, and burst analyses. When configuring CiteSpace for mapping collaborative networks, the operational time span was specified as 2005 to 2025 with the

"Years Per Slice" set to 1. "Author" and "Country" were selected as node types to construct collaboration networks. Node selection in each time slice was based on the g-index with $k = 25$. To evaluate thematic trends, the node type was switched to "Keyword," keeping the same slice parameters. We mapped keyword co-occurrences to highlight pivotal research foci and applied clustering algorithms to uncover the fundamental knowledge architecture. The robustness and structural clarity of the generated clusters were assessed using the Modularity (Q) and Mean Silhouette (S) metrics. Keyword burst detection was performed to identify topics that received rapidly increasing research attention during specific periods. All unmentioned parameters were left at their software defaults.

3. Result

3.1. Annual Publication Numbers and Trends over the Past Decade

As illustrated in Figure 1, the annual volume of publications demonstrated an overall upward trajectory between 2005 and 2025, despite intermittent fluctuations. During the initial period (2005–2009), research output remained minimal, hovering below 10 articles per year. A modest increase was observed from 2010 to 2013, with annual numbers ranging between 13 and 19. Publication activity stepped up notably in 2014–2015 to 29 papers, before briefly dipping to 23 in 2016. From 2017 to 2020, output grew steadily from 30 to 36 publications. A sharp escalation occurred in subsequent years: after jumping to 55 in 2021 and 57 in 2022, the count briefly dropped to 42 in 2023 before rebounding strongly to hit an all-time high of 61 in 2025. Overall, these findings reveal a continuous expansion of scholarly focus in this field, with interest intensifying significantly over the last decade.

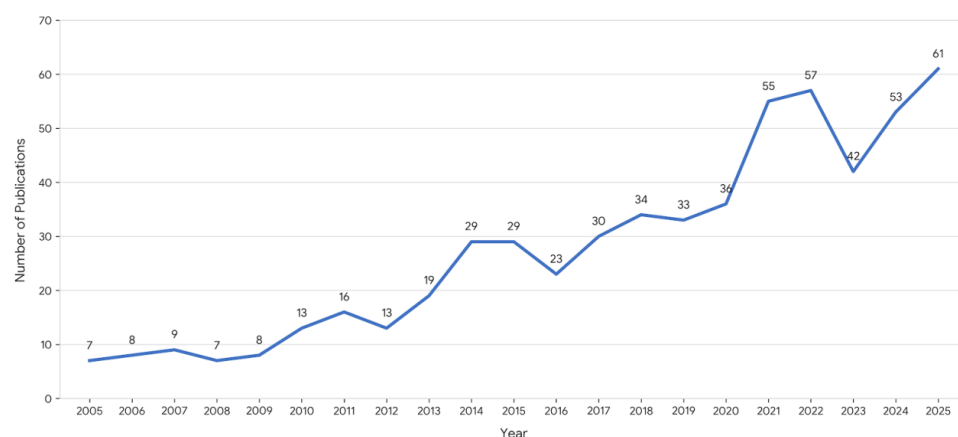


Figure 1. Annual Number of Publications on Vaginal Birth After Cesarean from 2005 to 2025

3.2. Analysis of Author Collaboration Network

As depicted in Figure 2, the author co-occurrence network generated by CiteSpace consists of 525 nodes and 670 links, yielding a network density of 0.0049. This low density value reflects a relatively loose and decentralized overall structure. Among the mapped researchers, Grisaru-granovsky, Sorina, Rottenstreich, Misgav, Rotem, Reut, Carpenter, Marshall, and Spong, Catherine Y stand out as the most prominent nodes, highlighting their central role and substantial contributions to this domain. In addition, scholars such as Mercer, Brian M, Grobman, William A, Caritis, Steve N, Sela, Hen Y, and Caughey, Aaron B represent other active scientific contributors. Although several small-scale, localized collaborative clusters are observable, the overall sparse connection density (0.0049) suggests that cross-team integration and inter-institutional collaboration remain modest. Building broader collaborative channels across institutions and geographical regions will be essential to propel research in this field forward.

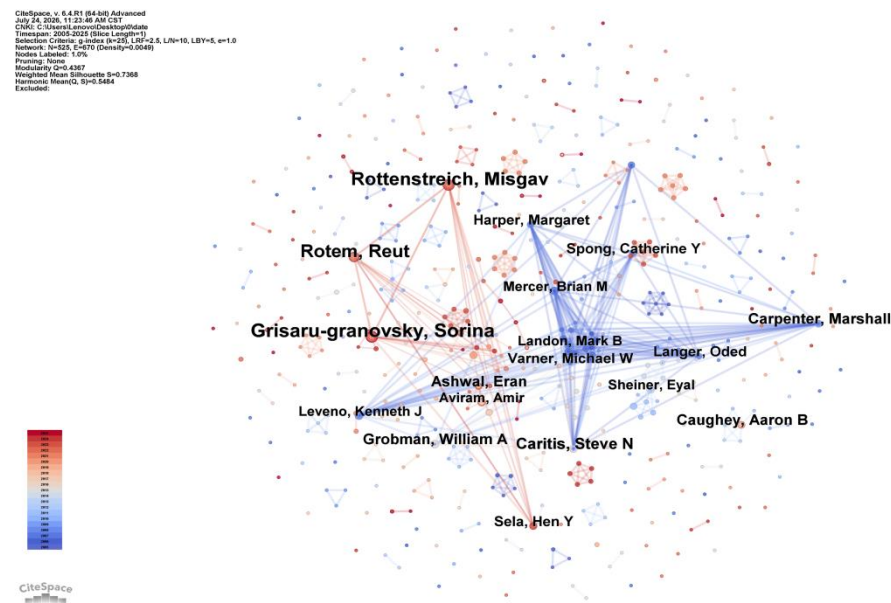


Figure 2. Author Collaboration Network in Vaginal Birth After Cesarean Research

3.3. Country/Region Co-Occurrence Analysis

As depicted in Figure 3, the country/region co-occurrence network generated by CiteSpace consists of 56 nodes and 0 links, yielding a network density of 0.0. This configuration reflects a geographically diverse yet structurally fragmented landscape in post-cesarean delivery modality research. Among the participating entities, PEOPLES R CHINA, the USA, and ISRAEL stand out as the three most prominent nodes with the largest label sizes, underscoring their primary publication volume and influential role in this domain. Other key active contributors include AUSTRALIA, ENGLAND, GERMANY, and the NETHERLANDS, alongside visible presence from FRANCE, SPAIN, TURKEY, CANADA, JAPAN, ITALY, and SAUDI ARABIA. Overall, while academic attention to TOLAC and VBAC draws from nations across multiple continents, the complete absence of network links ($S=0$) indicates that formal cross-border research partnerships remain scarce. Building robust international collaborative frameworks will be vital to propel global advancements in post-cesarean care and obstetric safety.

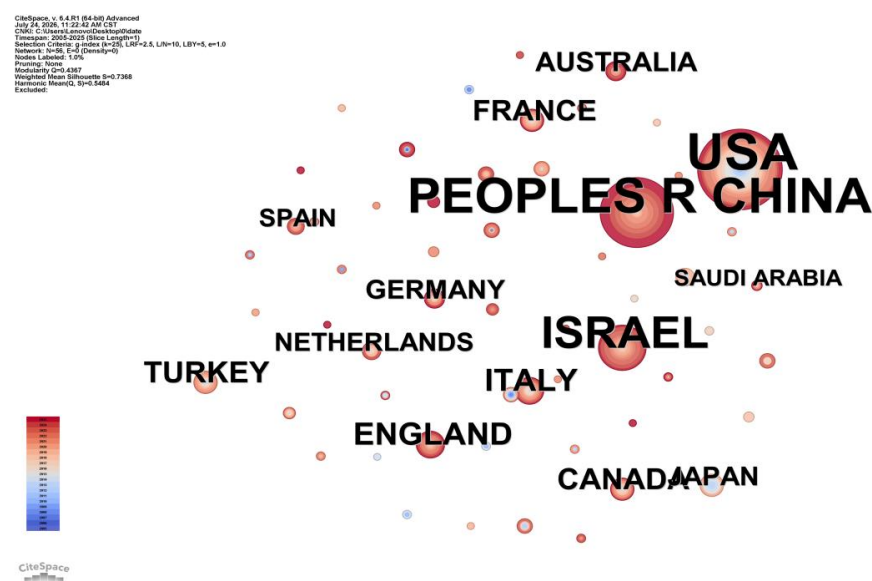


Figure 3. Country/region Collaboration Network in Vaginal Birth After Cesarean Research

3.4. Keyword Co-Occurrence Analysis

As shown in Figure 4, the keyword co-occurrence network generated by CiteSpace contains 459 nodes and 2,625 links, with a network density of 0.025, indicating a tightly interconnected and multifaceted research structure. Among these terms, cesarean section, cesarean delivery, vaginal birth, risk factors, risk, perinatal outcome, and delivery stand out as the most prominent keywords, featuring the largest node sizes and high centrality values (indicated by purple outer rings). These high-frequency terms collectively delineate the core focus of post-cesarean delivery modality research, which revolves around evaluating clinical risk factors, weighing trial of labor (TOLAC) against repeat cesarean section, and optimizing perinatal safety for mothers and neonates. Overall, the centrality of terms such as vaginal birth, risk factors, and perinatal outcome underscores the central paradigm in this field-establishing robust risk prediction models and clinical evidence to safely expand VBAC opportunities and improve maternal-fetal health.

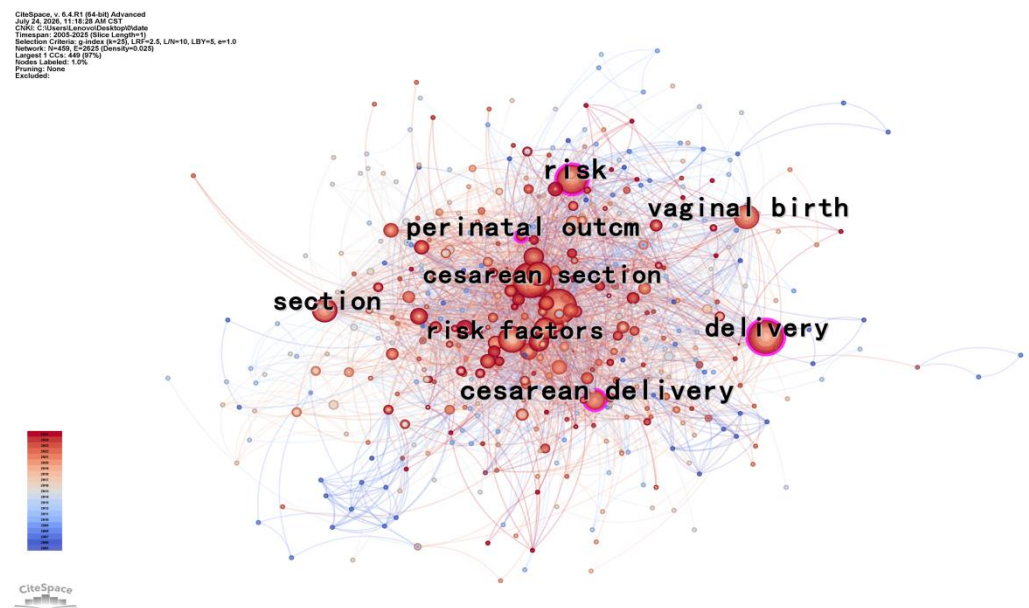


Figure 4. Keyword Co-Occurrence Network in Vaginal Birth After Cesarean Research

3.5. Keyword Clustering Analysis

Figure 5 demonstrates the keyword cluster analysis generated by CiteSpace. A total of 10 distinct major clusters were identified: #0 cesarean scar pregnancy, #1 trial, #2 uterine rupture, #3 cesarean section, #4 labor induction, #5 vaginal delivery, #6 gestational diabetes mellitus, #7 interdelivery interval, #8 infertility, and #9 neonatal outcome. The network yielded a modularity Q value of 0.4367 (exceeding 0.3) and a weighted mean silhouette S value of 0.7368 (surpassing 0.7), confirming a well-defined modular architecture and high clustering credibility. Among these, #0 cesarean scar pregnancy emerged as the largest cluster, underscoring that managing previous uterine surgical scars remains a paramount clinical concern. Taken together, these clusters map out the core research axes in post-cesarean care: delivery decision-making and modalities (#1 trial, #3 cesarean section, #5 vaginal delivery), catastrophic complications (#0 scar pregnancy, #2 uterine rupture), clinical management factors (#4 labor induction, #6 gestational diabetes, #7 interdelivery interval), and long-term reproductive/perinatal outcomes (#8 infertility, #9 neonatal outcome).

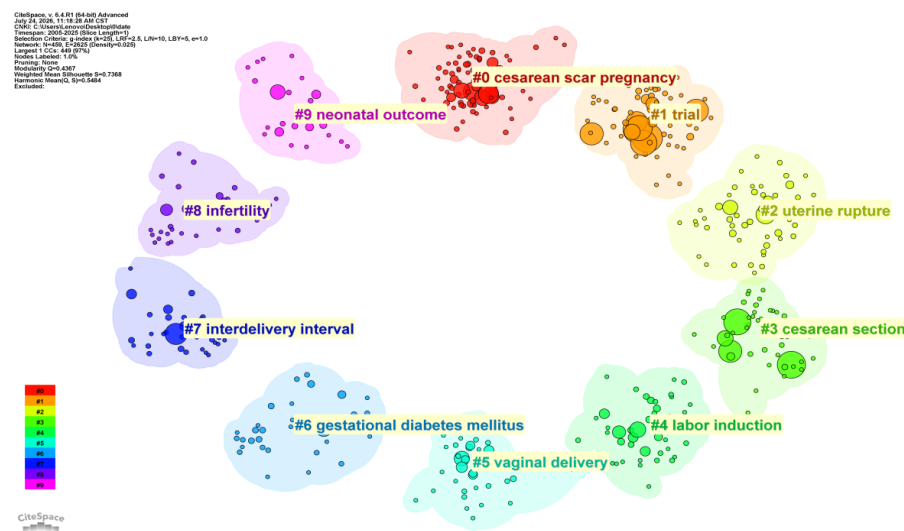


Figure 5. Keyword Clustering Network in Vaginal Birth After Cesarean Research

3.6. Keyword Burst Analysis

As shown in Figure 6, keyword citation burst analysis generated by CiteSpace reveals the dynamic intellectual evolution, shifting priorities, and emerging frontiers of post-cesarean delivery modality research from 2005 to 2025. Among the 25 keywords with significant citation bursts, diagnosis exhibited the strongest burst strength (4.80, 2023–2025), followed by in vitro fertilization (4.57), cesarean section (3.94), impact (3.77), and uterine artery embolization (3.53). Chronologically, the field has evolved across three distinct development phases: an early baseline phase (2009–2015) dominated by fundamental clinical safety evaluations such as perinatal mortality (2.87), trial (2.61), and pregnancy outcome (2.47); a transitional phase (2016–2020) that pivoted toward evidence synthesis, scar pathology, and clinical standardization, as marked by surges in metaanalysis (2.63), accreta (2.36), section scar (2.35), guidelines (2.55), and mechanical induction methods like foley catheter (2.25); and a contemporary frontier phase (2021–2025) characterized by active, interventional management and high-risk obstetric conditions. Crucially, six keywords demonstrate ongoing bursts extending through 2025, including impact (3.77), rupture (2.98), labor induction (2.82), diagnosis (4.80), placenta accreta spectrum (3.10), and postpartum hemorrhage (3.04). Collectively, the persistent focus on uterine rupture, induction protocols, placenta accreta spectrum, and severe hemorrhage underscores that refining diagnostic precision and mitigating catastrophic complications remain the paramount imperatives in advancing safe Trial of Labor After Cesarean (TOLAC) and Vaginal Birth After Cesarean (VBAC) practice.

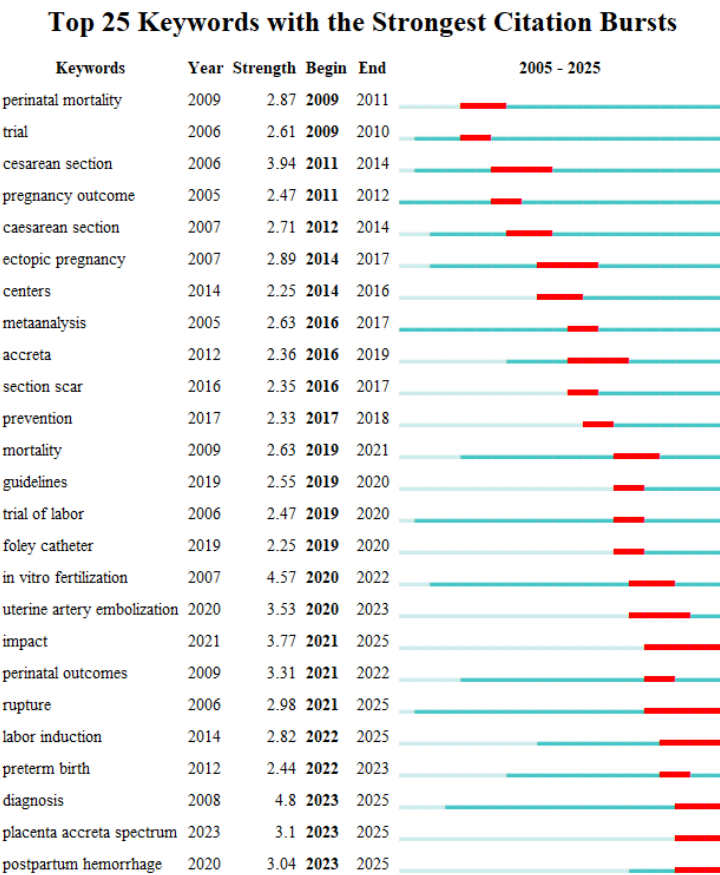


Figure 6. Top 25 Burst Keywords and Dynamic Research Hotspots in Vaginal Birth After Cesarean Research

4. Discussion

This study used CiteSpace to visualize the research trends and hotspots of post-cesarean delivery modalities from 2005 to 2025. Overall, the number of publications showed an increasing trend, particularly in recent years, indicating growing academic interest in the management of delivery after previous cesarean section. The author collaboration network showed several active research groups, whereas the relatively low network density suggested that cooperation among different research teams remains limited. Similarly, the country/region analysis demonstrated contributions from multiple countries, with China, the United States, and Israel being prominent contributors. These findings suggest that although this field has attracted increasing international attention, broader collaboration among institutions and countries may still be beneficial.

Keyword analysis showed that cesarean section, vaginal birth, risk factors, risk, and perinatal outcome were among the most important terms. This indicates that the central concern of this research field remains the balance between the potential benefits of vaginal birth after cesarean (VBAC) and the risks associated with trial of labor after cesarean (TOLAC). Previous studies have shown that TOLAC can provide an opportunity to avoid repeated cesarean delivery, but uterine rupture remains an important safety concern [10]. Therefore, accurate identification of suitable candidates is essential. Several prediction models have been developed to estimate the probability of successful VBAC using maternal and obstetric characteristics [11,12], reflecting the increasing emphasis on individualized risk assessment.

The clustering and burst analyses further showed that uterine rupture and labor induction remain major research themes. Uterine rupture is uncommon but potentially serious and therefore has been continuously investigated in women undergoing TOLAC. Sonographic assessment of lower uterine segment thickness has been proposed as a

potential method for evaluating scar integrity, although differences in measurement methods and cutoff values limit its routine application [13]. Labor induction is another important clinical issue. A meta-analysis reported that women undergoing induced labor had a lower VBAC rate and a higher rate of uterine rupture than those with spontaneous labor, and oxytocin use was also associated with increased rupture risk [14]. These findings are consistent with the continued citation burst of labor induction observed in our study and highlight the need for careful patient selection and standardized intrapartum management.

Interestingly, recent burst keywords included diagnosis, placenta accreta spectrum, and postpartum hemorrhage, suggesting that research interest is extending from delivery mode alone toward complications related to previous uterine scars. Repeated cesarean delivery is associated with an increased risk of serious maternal complications, including placenta accreta and hysterectomy [15]. Placenta accreta spectrum is particularly associated with previous cesarean delivery and may result in severe obstetric hemorrhage, making prenatal diagnosis and multidisciplinary management important [16]. The emergence of these keywords may therefore reflect a broader research perspective that considers not only the success of VBAC but also the long-term reproductive consequences of cesarean scars.

This study has several limitations. First, only publications indexed in the Web of Science Core Collection were included, which may have resulted in the omission of relevant studies from other databases. Second, only English-language publications were analyzed. Third, bibliometric results may be influenced by database coverage, citation accumulation, and CiteSpace parameter settings. Despite these limitations, this study provides an overview of the development of post-cesarean delivery research. Current evidence indicates that risk assessment, uterine rupture, and labor induction remain central topics, while diagnosis, placenta accreta spectrum, and postpartum hemorrhage are emerging research hotspots. Future studies should focus on individualized risk prediction, standardized TOLAC management, and multicenter collaboration to improve maternal and neonatal outcomes.

Conflict of Interest Statement: The authors have no conflict of interest to declare.

Data Availability Statement: The data used in this study were retrieved from the Web of Science Core Collection. All bibliographic records included are publicly available and can be accessed using the described search strategy.

Institutional Review Board Statement: This study did not involve human participants, animals, or identifiable personal data. All data were obtained from publicly accessible bibliographic databases; therefore, ethical approval and informed consent were not required.

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