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REVIEW ARTICLE

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Risk factors for failure of conversion from epidural labor analgesia to cesarean section anesthesia and general anesthesia incidence: an updated meta-analysis

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ABSTRACT

Objectives: Ongoing controversies persist regarding risk factors associated with the failure of transition from epidural labor analgesia to cesarean section anesthesia, including the duration of labor analgesia, gestational age, and body mass index (BMI). This study aims to provide an updated analysis of the incidence of conversion from epidural analgesia to general anesthesia, while evaluating and analyzing potential risk factors contributing to the failure of this transition to cesarean section anesthesia.

Methods: We conducted an extensive literature search utilizing databases such as PubMed, Embase, Cochrane Library, Web of Science, China National Knowledge Infrastructure (CNKI), WANGFANG, and the Chinese Biomedical Literature Database (CBM) up to September 30, 2022. The meta-analysis was performed using STATA 15.1 software. The quality of the included studies was assessed using the 11-item quality assessment scale recommended by the Agency for Healthcare Research and Quality (AHRQ).

Results: A total of 9,926 studies were initially retrieved, and after rigorous selection, 19 studies were included in the meta-analysis. The overall incidence of conversion from epidural analgesia to general anesthesia was found to be 6% (95% confidence interval [CI]: 5–8%). Our findings indicate that, when compared to patients in the successful conversion group, those in the failure group tended to be younger (weighted mean difference [WMD] = −1.571, 95% CI: −1.116 to −0.975) and taller (WMD = 0.893, 95% CI: 0.018–1.767). Additionally, the failure group exhibited a higher incidence of incomplete block in epidural anesthesia, received a higher dosage of additional epidural administration, experienced a greater rate of emergency cesarean sections, and received anesthesia more frequently from non-obstetric anesthesiologists. However, no statistically significant differences were observed in gestational age, depth of the catheter insertion into the skin, epidural catheter specifics, duration of epidural analgesia, infusion rate of epidural analgesia, primiparity status, cervical dilatation during epidural placement, BMI, or weight.

Conclusion: Our study found that the incidence of conversion from epidural analgesia to cesarean section under general anesthesia was 6%. Notably, the failure group exhibited a higher rate of incomplete block in epidural anesthesia, a greater incidence of emergency cesarean sections, a more frequent provision of anesthesia by non-obstetric anesthesiologists, a higher dosage of epidural administration, and greater height when compared to the success group. Conversely, women in the failure group were younger in age compared to their counterparts in the success group.

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General anesthesia; epidural analgesia; risk factors; cesarean section; pregnant patient

Introduction

With the advancement in medical technology and the growing demand for comfortable medical care during pregnancy, labor analgesia has been increasingly utilized. Among the various methods of labor analgesia, epidural analgesia stands out as the most effective technique for alleviating labor pain [1,2]. However, it's worth noting that a portion of pregnant women (4–14%) who receive

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epidural analgesia during labor ultimately require a cesarean section [3]. In cases where a parturient woman who is already receiving epidural labor analgesia requires an emergency cesarean section, it is possible to convert the epidural labor anesthesia into epidural surgical anesthesia by utilizing the existing epidural catheter to administer local anesthetics. This process is commonly referred to as epidural conversion [3,4]. It's essential to acknowledge that the failure of epidural conversion occurs when there is a need for the induction of general anesthesia due to suboptimal anesthetic effects during the epidural conversion. However, it is crucial to bear in mind that general anesthesia itself carries independent risks for both maternal and fetal complications, including potential challenges in airway management, the risk of aspiration, and the exposure of both mother and fetus to general anesthetics. Therefore, international guidelines strongly recommend the preferential use of spinal or epidural anesthesia over general anesthesia for cesarean sections, with the rate of general anesthesia ideally not exceeding 5% [5–7].

The conversion from epidural analgesia to cesarean anesthesia is generally considered dependable; however, the failure rate is reported to be as high as 38% [8]. Unplanned and emergent transitions in anesthesia strategies are linked to increased risks in both parturient women, their fetuses, and the anesthesiologists involved [9]. The success of converting to epidural analgesia not only signifies the efficacy of labor pain management but also diminishes the need for general anesthesia and related complications [10]. It results in shorter preparation times and ensures the safety of both mothers and infants. Consequently, the successful conversion from epidural analgesia to anesthesia holds significant importance in the overall delivery process [11].

A meta-analysis published in 2012 [8] examined factors related to the failure of epidural analgesia conversion and the incidence of cesarean sections under general anesthesia. However, this analysis was limited by a small number of included studies, a restricted sample size, and a limited set of research factors, such as the exclusion of variables like gestational age and height. Given the increasing societal interest in labor analgesia for pregnant patients, several relevant articles have emerged in recent years. Nonetheless, the latest studies have reported conflicting findings. For instance, Dunn et al. suggested that BMI was a risk factor, whereas a prior meta-analysis presented opposing results [8,12]. Height was another variable that different studies yielded varying outcomes [13,14]. To validate and confirm previously identified risk factors for epidural analgesia conversion failure, this study incorporates more contemporary literature and conducts a comprehensive meta-analysis. By doing so, it aims to provide a valuable reference for understanding epidural analgesia conversion failure in the future.

Materials and methods

The current study adhered to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. The study protocol was also registered on PROSPERO with the registration number CRD42022377242.

Retrieval strategy

Two independent researchers conducted a thorough search and screening of relevant observational studies from various databases, including PubMed, Embase, Cochrane Library, Web of Science, CNKI, WANGFANG, and CMB. The search encompassed studies published up to September 30, 2022. In instances where disagreements arose, a third researcher was consulted to facilitate the final decision. The search strategy employed a combination of subject headings and free-text terms, which included the following keywords: (Cesarean Section OR C Sections OR Abdominal Deliveries OR Abdominal Delivery Cesarean OR C Section Cesarean OR Postcesarean Section) AND (Epidural Analgesia OR epidural anesthesia OR epidural anesthesia OR Peridural Anesthesia OR Peridural Anesthesia OR Extradural Anesthesia OR Extradural Anesthesia OR Epidural Anesthesia OR Epidural Anesthesia OR labor epidural OR labor epidural OR anesthesia, spinal OR spinal anesthesia OR spinal anesthesia OR combined spinal epidural) AND (General Anesthesia OR General Anesthesia).

Inclusion and exclusion criteria

To provide a summary of the evidence regarding the failure of epidural conversion, specifically, the incidence of conversion from epidural analgesia to general anesthesia, and to conduct an analysis and evaluation of potential risk factors for epidural conversion failure, we established the following inclusion and exclusion criteria.

Inclusion criteria: (1) Study Type: Cross-sectional studies; (2) Participants: Pregnant patients who underwent epidural analgesia; (3) Data Availability: Studies that provided both the total number of women receiving epidural analgesia and the number of cases experiencing analgesic failure; (4) Risk Factor Reporting: Studies that presented one or more risk factors, such as conversion to cesarean section, conversion to epidural anesthesia, and cesarean section under general anesthesia, along with the corresponding number, percentage, or odds ratio with a 95% confidence interval for these risk factors in both the failure group and the successful group.

Exclusion criteria: (1) Study Type: Case reports, correspondence, web pages, reviews, systematic reviews, meta-analyses, or articles not relevant to epidural analgesia conversion; (2) Full Text: Studies lacking full-text availability.

Data extraction

In accordance with the specified inclusion and exclusion criteria, two independent researchers conducted literature screening, data extraction, and cross-verification of results. In instances where discrepancies arose, the two researchers engaged in discussions to resolve them and consulted with a third researcher when necessary to arrive at a final decision. The extracted data encompassed the following information: author, year of publication, country of origin, sample size, number of pregnant patients who underwent conversion to cesarean section under general anesthesia, study type, risk factors like age, complications, gestational age, BMI, weight, height, emergency cesarean section, incomplete block, and epidural analgesia-related factors.

Quality evaluation

The quality assessment of the included studies was conducted using the quality assessment scale recommended by the Agency for Healthcare Research and Quality (AHRQ) [15]. This scale comprises 11 items, which evaluate various aspects of study quality, including the definition of information source, inclusion and exclusion criteria, time period for identifying patients, continuity of patients, blinding of participants, quality assurance assessment, control of confounding variables, handling of missing data, patients' response, completeness of data collection. Each of these items can be assessed with one of three responses: Yes, No, or Unclear. Studies are awarded one point for each "Yes" response and zero points for "No" or "Unclear" responses. Studies scoring 0-3 points are classified as low quality, those scoring 4-6 points are considered moderate quality, and those scoring 7-11 points are rated as high quality [16].

Data analysis

The statistical analysis was conducted using STATA 15.1 software. The following methods were employed for data analysis: (1) Calculation of Total Incidence: The total incidence of cesarean sections under general anesthesia was calculated along with a 95% confidence interval (CI); (2) Presentation of Results: Binary variables were reported as the odds ratio (OR) with a 95% CI. Continuous variables were presented as the weighted mean difference (WMD) with a 95% CI; (3) Assessment of Heterogeneity: Heterogeneity among studies was assessed using the Q test and I2 test. If $I2 \geq 50\%$ and $p < 0.05$, significant heterogeneity was considered, and a random-effects model was applied. If heterogeneity was small ($I2 < 50\%$ and $p \geq 0.05$), a fixed-effects model was used for analysis; (4) Sensitivity Analysis: A sensitivity analysis of all risk factors was conducted to assess the robustness of the findings; (5) Publication Bias Assessment: Publication bias was assessed using Begg's test and Egger's test. A bilateral $p < 0.05$ was considered to indicate a statistically significant difference.

Results

A comprehensive search of the databases yielded a total of 9,926 articles. Following the initial screening process, 4,722 duplicate articles were removed. After reviewing the titles and abstracts of the remaining articles, 5,204 were excluded for various reasons, including their irrelevance ($n = 3{,}659$), animal experiments ($n = 48$), meta-analyses or reviews ($n = 351$), conference presentations or case reports ($n = 880$), popular science articles ($n = 41$), and web pages or registration documents ($n = 156$). Subsequently, a full-text review was conducted on the remaining 69 articles. Among these, 50 studies were further excluded, including 10 studies with unavailable data, 26 studies that focused solely on epidural analgesia or general anesthesia without relevant data, three studies that did not provide full-text access, and 11 studies that reported ineligible research results. Consequently, a total of 19 studies, encompassing 19,420 patients, met the inclusion criteria and were included in the analysis [12–14,17–32] (Figure 1).

Basic characteristics and quality evaluation

The basic characteristics of the included studies are presented in Table 1; quality evaluation is presented

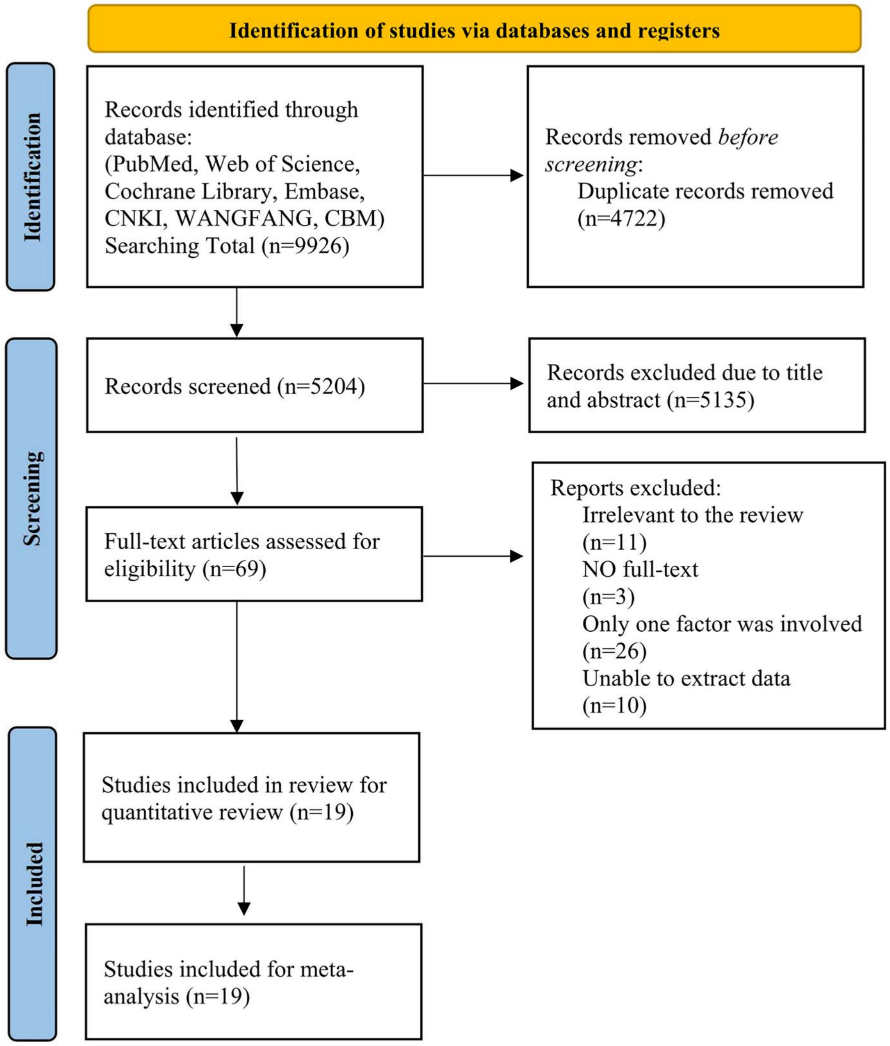

Figure 1. Flowchart of the depicted studies.

in Table 2; and risk factors are presented in Table 3. A total of 19 studies with 19,420 pregnant participants were included. The sample size ranged from 93 to 4,259 pregnant participants. Importantly, all 19 included studies scored greater than 8 on the AHRQ (Agency for Healthcare Research and Quality) scale, indicating that these articles were of high quality. This high-quality assessment lends reliability to the study's findings.

Incidence of general anesthesia

Among the 19 included studies, the incidence of general anesthesia was found to vary, ranging from 2% to 21%. The heterogeneity test indicated significant heterogeneity among these studies (I2 = 97.5, $p < 0.001$). Consequently, a random-effects model was employed to pool data, resulting in a pooled incidence of general anesthesia estimated at 6% (95% CI: 5–8%) (Figure 2).

Risk factors for failed epidural anesthesia

We have classified the 15 risk factors included in the analysis into three categories based on their characteristics: demographic-related risk factors (age, height, weight, BMI), clinical surgery-related risk factors (epidural indwelling catheter length, catheter depth into the skin, duration of epidural analgesia, infusion speed of epidural analgesia, epidural block effect, additional epidural administration dosage, emergency cesarean section, non-obstetric anesthesiologists), and childbirth-related factors (cervical dilatation size, gestational age, first delivery). The analysis results for all the identified risk factors are presented in Table 3.

Risk factors related to demographic characteristics

There are four demographic-related factors associated with failed epidural anesthesia: age, height, BMI, and weight. For age, height, and BMI, there is no statistically significant heterogeneity ($I^2 < 50\%$, $p > 0.05$), and the data were combined using a fixed-effects model.

Table 1. Characteristics of articles included for systematic review.

First author	Year	Country	Type of Research	Total	Age	Gestational age	BMI	General	Quality score
Shen et al.	2022	China	cross-sectional study	1,254	F: 25.4 (4.2) S: 25.7 (3.5)	F: 38 (2.5) S: 39 (3.5)	F: 27.3 (7.7) S: 27.6 (0.5)	98	9
Pham	2022	France	cross-sectional study	3,300	S: 33 [20 – 37] F: 31 [28 – 36]	S: 40 [39 to 41] F: 40.2 [39 to 41]	NS	113	8
Jian	2022	China	cross-sectional study	1,084	S(704): 29.2 (3.6) F [23]: 28.4 (4.0)	S(704): 29.2 (3.6) F [23]: 28.4(4.0)	S(704): 26.9 (2.8) F [23]: 26.4 (2.8)	23	8
Grap	2021	USA	cross-sectional study	673	S: 29.01 (5.73) F: 26.99 (5.13)	NS	S: 33.65 (6.37) F: 33.36 (7.06)	142	8
Pandya	2022	India	cross-sectional study	4,259	Not defined	Not defined	NS	19	8
Yoon	2017	Korea	cross-sectional study	163	ESA: 33.8 ± 3.5 SA: 34.3 ± 3.4	ESA: 68.7 ± 7.6 SA: 67.9 ± 8.7	NS	4	8
Dunn	2016	Singapore	cross-sectional study	93	T: 30 (6)	T: 37 (6)	T: 28.2 (4.9)	12	9
Ismail	2015	Pakistan	cross-sectional study	629	SVD: 27.94 ± 4.07 AVD: 26.15 ± 4.06 CS: 27.37 ± 4.05	NS	NS	83	9
Lee	2009	Singapore	cross-sectional study	1,033	Not defined	NS	NS	23	8
Halpernl	2009	Israel	cross-sectional study	501	S(471): 33.5 (4.4) F(30): 33.1 (5.7)	S(471):29.01 (5.73) F(30): 26.99 (5.13)	S(471): 29 (6.4) F(30): 29 (5.7)	21	9
Campbell	2009	Canada	cross-sectional study	895	S(775): 28.1 (6.8) F(120): 26.7 (6.2)	S(775): 39.8 (1.6) F(120): 39.6 (1.9)	NS	39	8
Bamgbade	2009	UK	cross-sectional study	94	Not defined	NS	NS	2	8
Kinsella	2008	UK	cross-sectional study	1,392	NS	NS	NS	94	9
ORBACH-ZINGER	2006	Israel	cross-sectional study	103	S(81): 29.7 (4.1) F(20): 27.2 (4.0)	S(81): 39.4 (1.4) F(20): 40.4 (1.0)	S(81): 27.7 (3.7) F(20): 31.5 (3.8)	22	8
Pan	2004	USA	cross-sectional study	1,830	NS	NS	NS	74	8
Kan	2004	Singapore	cross-sectional study	850	NS	NS	NS	59	8
Tortosa	2003	France	cross-sectional study	194	S: 31 [18–43] F: 30 [17–44]	S:40 F:38	NS	3	8
Riley	2002	USA	cross-sectional study	246	NS	NS	NS	13	8
Garry	2002	UK	cross-sectional study	827	NS	NS	NS	87	8

Values are presented as mean ± SD, median (interquartile range), or number (%); ESA, epidural surgical anesthesia for cesarean section after epidural labor analgesia; SA, spinal anesthesia for cesarean section after epidural labor analgesia; F, failed conversion; S, successful conversion; T, totality; BMI, body mass index; SVD, spontaneous vaginal delivery; AVD, assisted vaginal delivery; CS, cesarean section.

However, for weight, there is significant heterogeneity (I^2>50%, $p < 0.05$), and the data were combined using a random-effects model.

Six studies [13,14,18,20,25,28] were included in the analysis of the maternal age. The results showed that patients in the failure group were younger than those in the success group (WMD = −1.571, 95% CI: −2.166, −0.975; $p < 0.05$), indicating that younger age is a risk factor for epidural anesthesia failure (Figure 3).

Six studies [13,14,22,25,26,28] reported maternal height. The analysis results showed that patients in the failure group were taller than those in the success group (WMD =0.893, 95% CI: 0.018, 1.767; $p = 0.045$), indicating that a higher height is associated with a higher risk of failure of the block (Figure 4).

Body weight was reported in seven studies [13,14,20,22,25,26,28]. The combined results showed no difference in body weight between the failure and success groups (WMD =1.330, 95% CI: −1.1624, 4.284, $p > 0.05$), indicating that weight may not be a risk factor for epidural conversion failure (Figure 5).

BMI was discussed in three studies [13,20,25]. The results showed no difference in BMI between the failure and success groups (WMD = −0.150, 95% CI: −1.116, 0.816; $p > 0.05$), indicating that BMI may not be a risk factor for epidural conversion failure (Figure 6).

Risk factors related to clinical surgery

A total of eight clinical surgery-related factors were associated with epidural failure. No significant heterogeneity was observed for epidural indwelling catheter length, catheter depth into the skin, infusion speed of epidural analgesia. A fixed-effects model was used to combine the data ($I^2 < 50\%$, $p > 0.05$). In contrast, a random-effects model was used for the mate-analysis of duration of epidural analgesia, epidural block effect, additional epidural administration dosage, in emergency cesarean, section, non-obstetric anesthesiologists ($I^2 > 50\%$, $p < 0.05$).

Epidural indwelling catheter length was reported in three studies [13,20,25]. The results showed that there was no difference in the length of indwelling epidural catheter between the failure group and the success group (WMD =0.035, 95% CI: −0.070, −0.140; $p > 0.05$), indicating that the length of the indwelling epidural catheter may not be a risk factor for epidural anesthesia failure (Figure 7).

Catheter depth into the skin was reported in three studies [20,25,26]. The results revealed no difference in

Table 2. Agency for healthcare research and quality (AHRQ) checklist (cross-sectional) for studies included in this meta-analysis.

	Define the source of information (survey, record review)	List inclusion and exclusion criteria for exposed and unexposed subjects (cases and controls) or refer to previous publications.	Indicate time period used for identifying patients	Indicate whether or not subjects were consecutive if not population-based.	Indicate if evaluators of subjective components of study were masked to other aspects of the status of the participants.	Describe any assessments undertaken for quality assurance purposes (e.g. test/retest of primary outcome measurements).	Explain any patient exclusions from analysis	Describe how confounding was assessed and/or controlled.	If applicable, explain how missing data were handled in the analysis.	Summarize patient response rates and completeness of data collection.	Clarify what follow-up, if any, was expected and the percentage of patients for which incomplete data or follow-up was obtained.	Total score
Shen et al.	1	1	1	1	1	1	1	1	0	0	1	9
Dunn	1	1	1	1	1	1	1	1	0	1	1	9
Halpernl	1	1	1	0	1	1	1	1	1	1	0	9
Bamgbade	1	1	1	1	0	1	1	1	0	0	1	8
Pham	1	1	1	1	1	1	1	1	0	0	0	8
Jian	1	1	1	1	1	1	1	1	0	0	0	8
Grap	1	1	1	1	1	1	1	0	0	1	0	8
Pandya	1	1	1	1	1	1	1	0	1	0	0	8
Yoon	1	1	1	1	1	1	1	1	0	0	0	8
Ismail	1	1	1	1	1	1	1	1	0	1	0	9
Lee	1	1	1	1	1	1	1	1	0	0	0	8
Campbell	1	1	1	1	1	1	1	1	0	0	0	8
Kinsella	1	1	1	1	1	1	1	1	1	0	0	9
ORBACH-ZINGER	1	1	1	1	1	1	1	0	0	1	0	8
Pan	1	1	1	1	1	1	1	0	0	1	0	8
Kan	1	1	1	1	1	1	1	0	0	1	0	8
Tortosa	1	1	1	1	1	1	1	0	0	1	0	8
Riley	1	1	1	1	1	1	1	0	0	1	0	8
Garry	1	1	1	1	1	1	1	0	0	1	0	8

Table 3. Risk factors for failed epidural anesthesia.

Risk Factors	Study Number	Pregnant patients(N)	Heterogeneity I^2	Heterogeneity P	ES (95% CI)	P
Demographic characteristics						
Age[a#]	6(11, 12, 16, 18, 23, 27)	2,703	0%	>0.05	−1.571 (−2.166, −0.975)	<0.05
Height[a#]	6(11, 12, 20, 23, 25, 27)	2,596	31.7%	0.198	0.893 (0.018, 1.767)	0.045
Weight[b#]	7(11, 12, 18, 20, 23, 24, 27)	3,621	55.5%	<0.05	1.330 (−1.1624, 4.284)	>0.05
BMI[a#]	3 (12, 18, 23)	1,230	0.0%	>0.05	−0.150(−1.116, 0.816)	>0.05
Risk factors related to clinical surgery						
Epidural indwelling catheter length[a#]	3 (18, 24, 47)	983	18.5%	0.293	0.035 (−0.070, −0.140)	>0.05
Catheter depth into the skin[a#]	3 (11, 18, 47)	1,246	3.5%	0.355	0.067 (−0.151, 0.286)	>0.05
Duration of epidural analgesia[b#]	7(11, 12, 16, 22, 24, 25, 47)	3,286	78.9%	0.00	−0.582 (−1.761, 0.597)	>0.05
Infusion speed of epidural analgesia[a#]	3(22,29,32)	941	0.0%	0.409	0.314 (−0.080, 0.7070)	>0.05
Epidural Block Effect[b$]	3 (20,26,31)	1,678	89.9%	0.000	8.364 (1.897, 36.875)	0.005
Additional epidural administration dosage [b$]	4(15,16,20,24)	2,751	19.9%	0.290	2.672 (2.025, 3.527)	0.000
Emergency cesarean Section [b$]	4(12, 16, 22, 24)	2,125	78.1%	0.0003	2.444 (1.104, 5.410)	0.028
Non-obstetric Anesthesiologists [b#]	3(11, 24, 28)	1,240	0.0%	0.638	0.264 (0.124, 0.563)	0.001
Parturition related factors						
Cervical Dilatation Size[b#]	3 (12, 20, 23)	2,947	75.6%	0.017	−0.470 (−0.440, 1.379)	>0.05
Gestational Age [b#]	3 (12, 20, 23)	2,947	85.3%	0.001	0.253 (−0.351, 0.858)	>0.05
First Delivery [a$]	4(15,16,20,24)	2,751	0.0%	0.290	1.011 (0.728, 1.406)	0.946

Note: ES, effect size.
[a]Fixed effects model.
[b]Random effects model.
[#]WMD.
[$]OR.

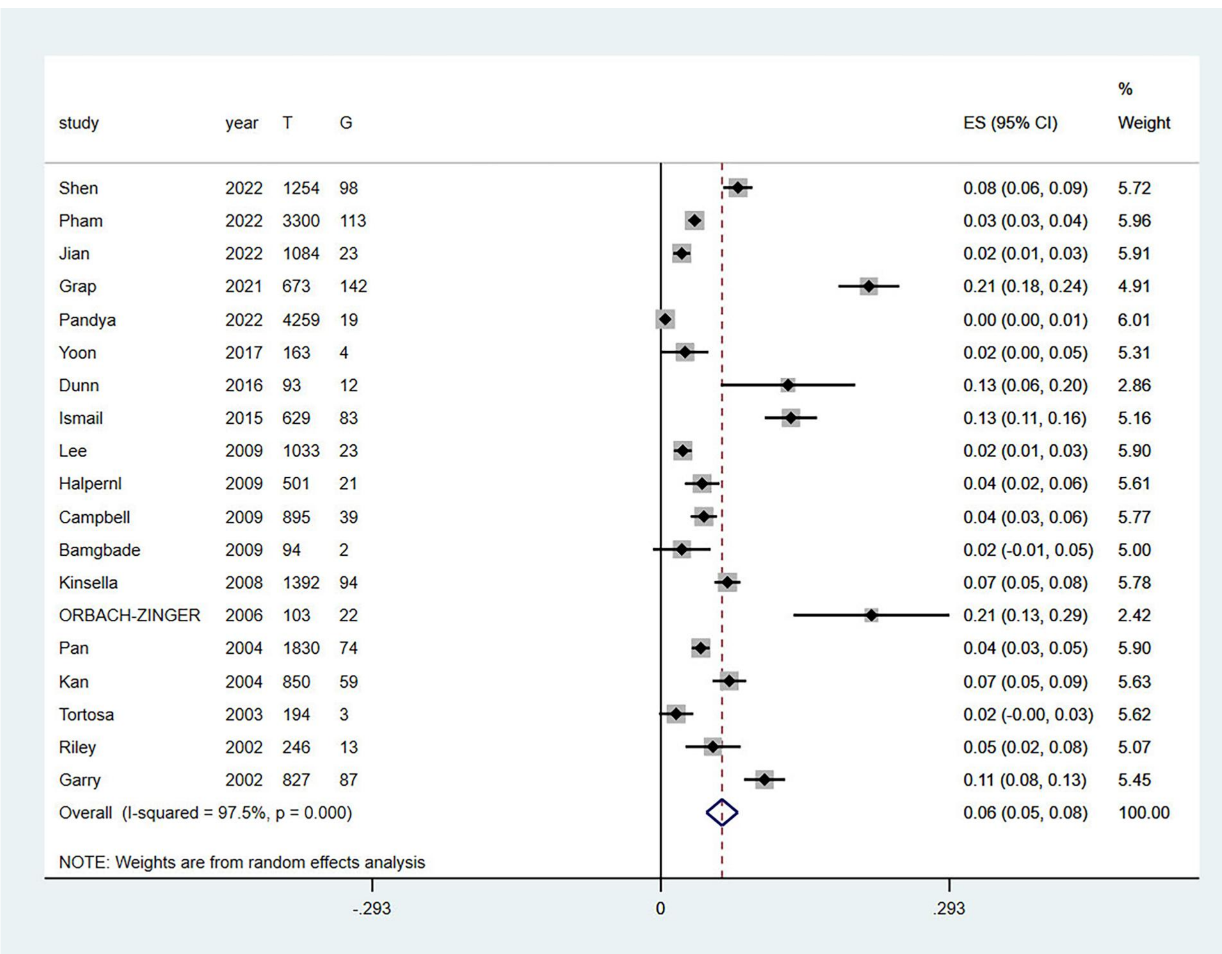

Figure 2. Summarized the number of patients converted to general anesthesia. CI, confidence interval.

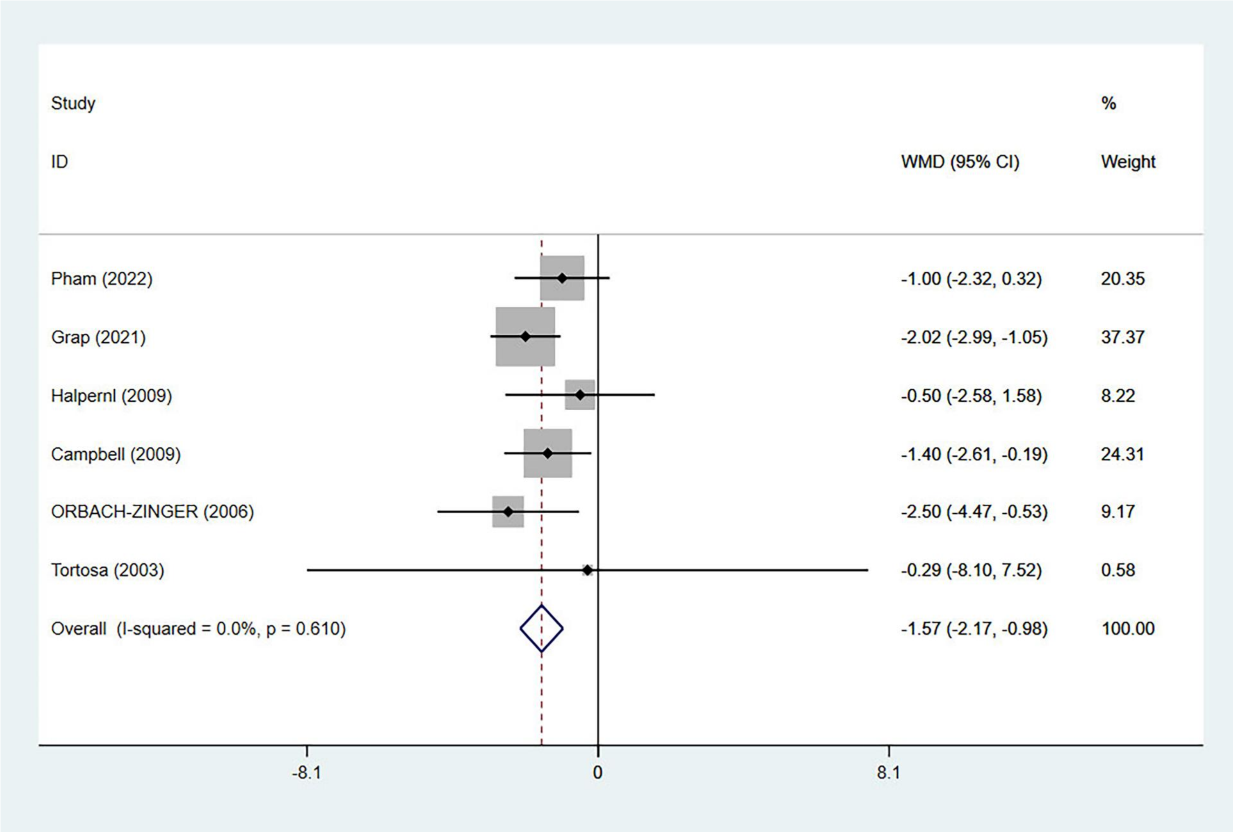

Figure 3. Summarized the effect of the age on failed epidural anesthesia conversion. WMD, weighted mean difference; CI, confidence interval.

catheter depth into the skin between the failure group and the success group (WMD =0.067, 95% CI: −0.151, 0.286; $p > 0.05$), indicating that catheter depth into the skin may not be a risk factor for epidural anesthesia failure (Figure 8).

Duration of epidural analgesia was discussed in seven studies [13,14,18,22,25,26,28]. No difference was found in epidural analgesia duration (WMD= −0.582, 95% CI: −1.761, 0.597; $p > 0.05$), indicating that duration of epidural analgesia may not be a risk factor for epidural anesthesia failure (Figure 9).

Three studies [20,25,28] were included in the analysis of infusion speed of epidural analgesia. The results suggested no difference in infusion speed of epidural analgesia between the two groups (WMD =0.314, 95% CI: −0.080, 0.7070; $p > 0.05$), indicating that infusion speed of epidural analgesia may not be a risk factor for epidural anesthesia failure (Figure 10).

For epidural block effect, three studies [18,24,28] were meta-analyzed. The results showed that the failure group had more incomplete epidural blocks than the success group (OR =8.364, 95% CI: 1.897, 36.875; $p = 0.005$), indicating that the epidural block effect may be a risk factor for epidural anesthesia failure (Figure 11).

For emergency cesarean section, there were 9 articles [14,17–20,24,26–28] on emergency cesarean section and general anesthesia, especially category 1 (threatening maternal and fetal life safety). Four studies [13,18,24,26] were included in the analysis of emergency cesarean section (Figure 12). The results showed that the emergency degree of cesarean section in the failure group was higher than that in the success group (OR =2.444, 95% CI: 1.104, 5.410; $p = 0.028$). This indicates that emergency cesarean section may be a risk factor for epidural anesthesia failure.

Three studies [14,26,31] were included in the analysis of anesthesiologists (Figure 13), although Ismail [31] reported no correlation between epidural anesthesia failure and type of anesthesiologists (obstetric vs. non-obstetric anesthesiologists). Three studies [14,26,31] showed that the failure group had a higher t proportion of patients anesthetized by a non-obstetric anesthesiologist than the success group (OR =0.264, 95% CI: 0.124, 0.563; $p = 0.001$), indicating that non-obstetric anesthesiologists may be a risk factor for epidural anesthesia failure.

Eight studies [13,14,18,22,25,26,28,31] focused on additional epidural administration dosage. Most

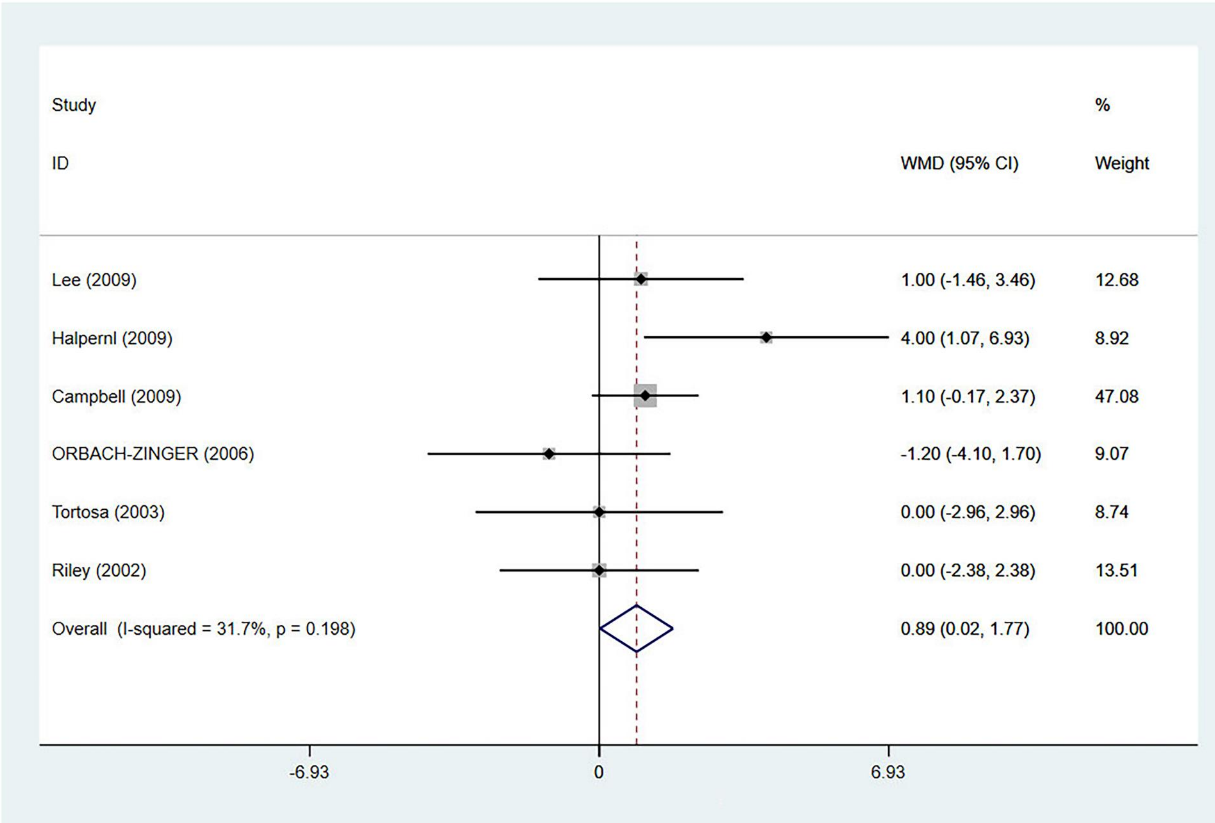

Figure 4. Summarized the effect of the height on failed epidural anesthesia conversion. WMD, weighted mean difference; CI, confidence interval.

studies showed that additional epidural administration dosage was related to conversion failure, but Ismail et al. and Tortosa et al. did not explicitly describe their correlation [28,31]. Four studies [13,14,18,22] were included in the analysis of additional epidural administration dosage (Figure 14). The results showed that additional epidural administration dosage in the failure group was higher than that in the success group (OR =2.672, 95% CI: 2.025, 3.527; $p < 0.001$), indicating that additional epidural administration dosage may be a risk factor for epidural anesthesia failure.

Parturition-related factors

A total of three birthing-related factors were associated with epidural conversion failure. There was significant heterogeneity in cervical dilatation size and gestational age, and thus data were combined using a random effects model ($I^2 < 50\%$, $p > 0.05$). The fixed-effect model was used for the meta-analysis of the first delivery ($I^2 > 50\%$, $p < 0.05$).

Cervical dilatation size was reported in three studies [13,22,25]. The results showed no difference in the size of cervical dilatation between the failure and success groups (WMD =−0.470, 95% CI: −0.440, 1.379; $p > 0.05$), indicating that the size of cervical dilatation may not be a risk factor for epidural anesthesia failure (Figure 15).

Gestational age was discussed in three studies [14,18,25]. The results showed no difference in gestational age between the failure and success groups (WMD =0.253, 95% CI: −0.351, 0.858; $p > 0.05$), indicating that gestational age may not be a risk factor for epidural anesthesia failure (Figure 16).

For first delivery, four studies [13,14,18,22] were meta-analyzed (Figure 17). The results showed that there was no difference in first delivery between the two groups (OR =1.011, 95% CI: 0.728, 1.406; $p = 0.946$), indicating that first delivery may not be a risk factor for epidural anesthesia failure.

Sensitivity analysis and publication bias

Sensitivity analysis was conducted by excluding the studies one by one. The results did not vary significantly, indicating that the meta-analysis's results were reliable (Figures 18–21). Publication bias in the incidence was analyzed using Begg's test ($p = 0.327$) and Egger's test ($p = 0.000$), and publication bias was found. The trim and fill method was used to adjust the studies, and the results did not change.

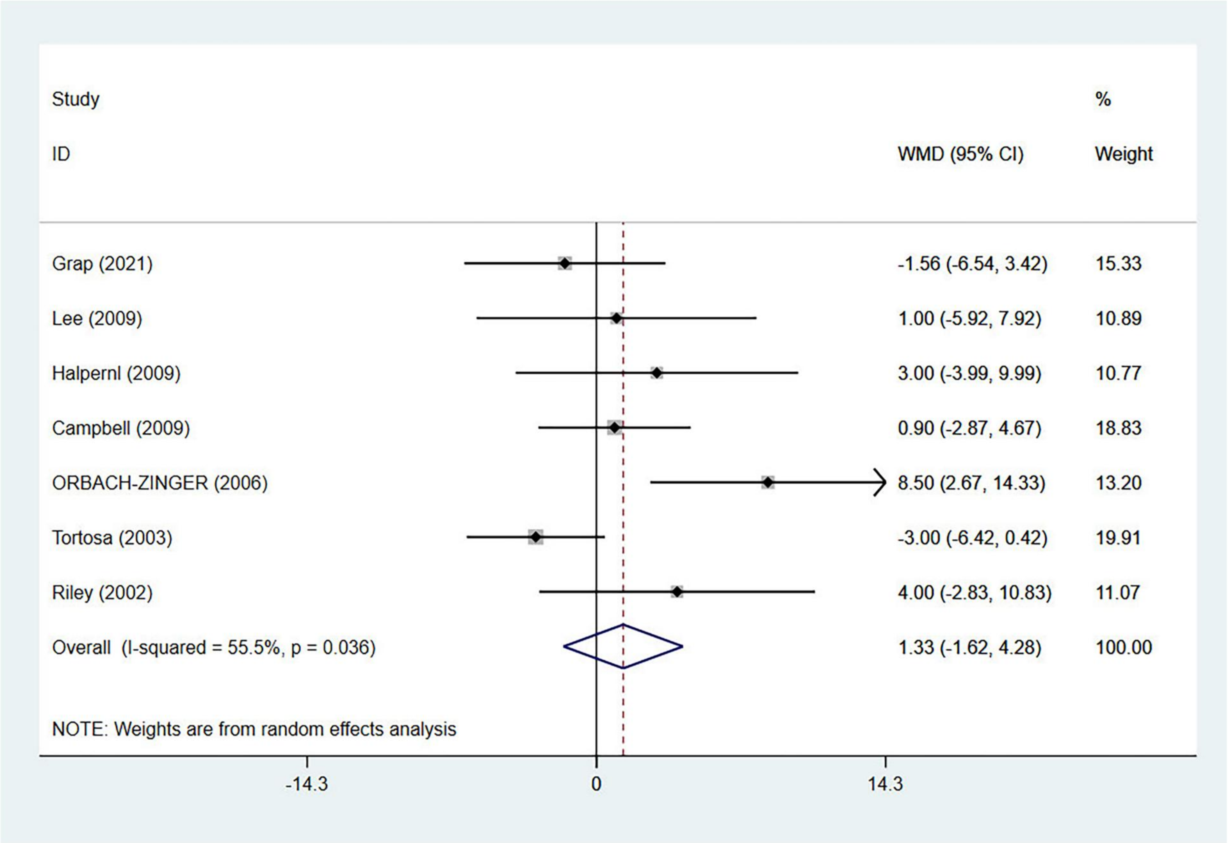

Figure 5. Summarized the effect of the weight on failed epidural anesthesia conversion. WMD, weighted mean difference; CI, confidence interval.

indicating that publication bias did not affect our results (Figures 22 and 23).

Discussion

The incidence of conversion from epidural analgesia to cesarean section under general anesthesia was determined to be 6% (95% CI: 5–8%). The present study identified six factors that increased the risk of conversion failure: age, height, incomplete block of epidural anesthesia, increased epidural administration dosage during delivery, emergency cesarean section, and anesthesia provided by non-obstetric anesthesiologists. Conversely, there were no statistically significant differences observed in gestational age, catheter depth into the skin, specific characteristics of the epidural catheter, duration of epidural analgesia, infusion rate of epidural analgesia, primiparity status, cervical dilatation during epidural placement, BMI or weight.

Despite previous studies yielding inconsistent findings, a majority of the recent studies have reported an increased frequency of remedial analgesia during labor analgesia, which may suggest suboptimal effectiveness of epidural analgesia and potentially indicate the risk of epidural analgesia conversion failure. Remedial analgesia encompasses various pain management interventions, such as the use of opioids [33]. The results of our analysis align with the findings of two earlier studies [2,8]. In recent reports, it has been noted that general anesthesia is administered in approximately one-fifth of cesarean sections due to the failure of epidural analgesia [11]. Pham's study [18] highlighted a significant increase in the proportion of patients requesting additional epidural administration in the conversion failure group. This sudden surge in pain experienced by pregnant patients could potentially be attributed to catheter displacement or the increased dosage of anesthesia required due to uterine dilation [13,22]. The abrupt pain experienced by pregnant patients often leads to multiple epidural injections. The additional injections, typically with lower-concentration analgesics, may dilute the high-concentration local anesthetics used during epidural anesthesia conversion, thereby reducing the potency of the anesthetic. Intriguingly, Pham et al. found that only 11% of women opted to change their epidural catheters when faced with excruciating pain [18]. This underscores the importance of considering catheter placement when patients experience severe pain. Studies have consistently demonstrated that the

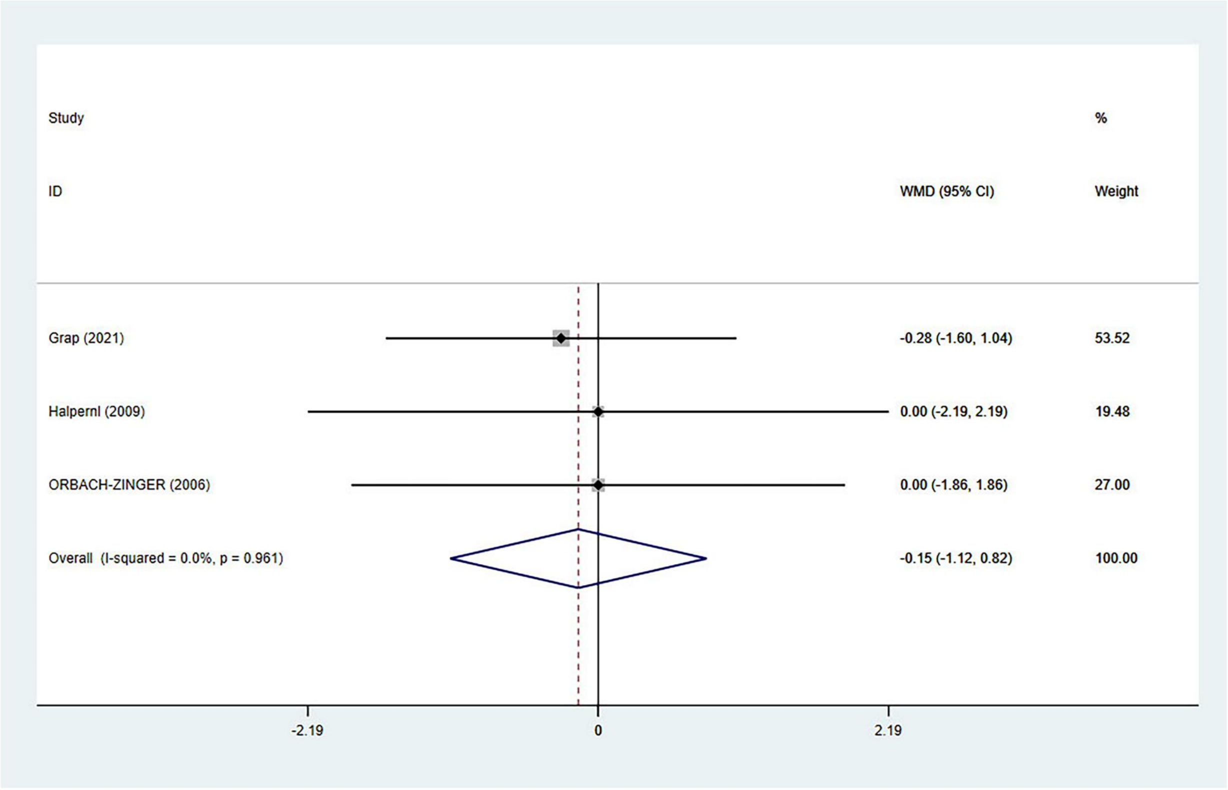

Figure 6. Summarized the effect of the BMI on failed epidural anesthesia conversion. WMD, weighted mean difference; CI, confidence interval.

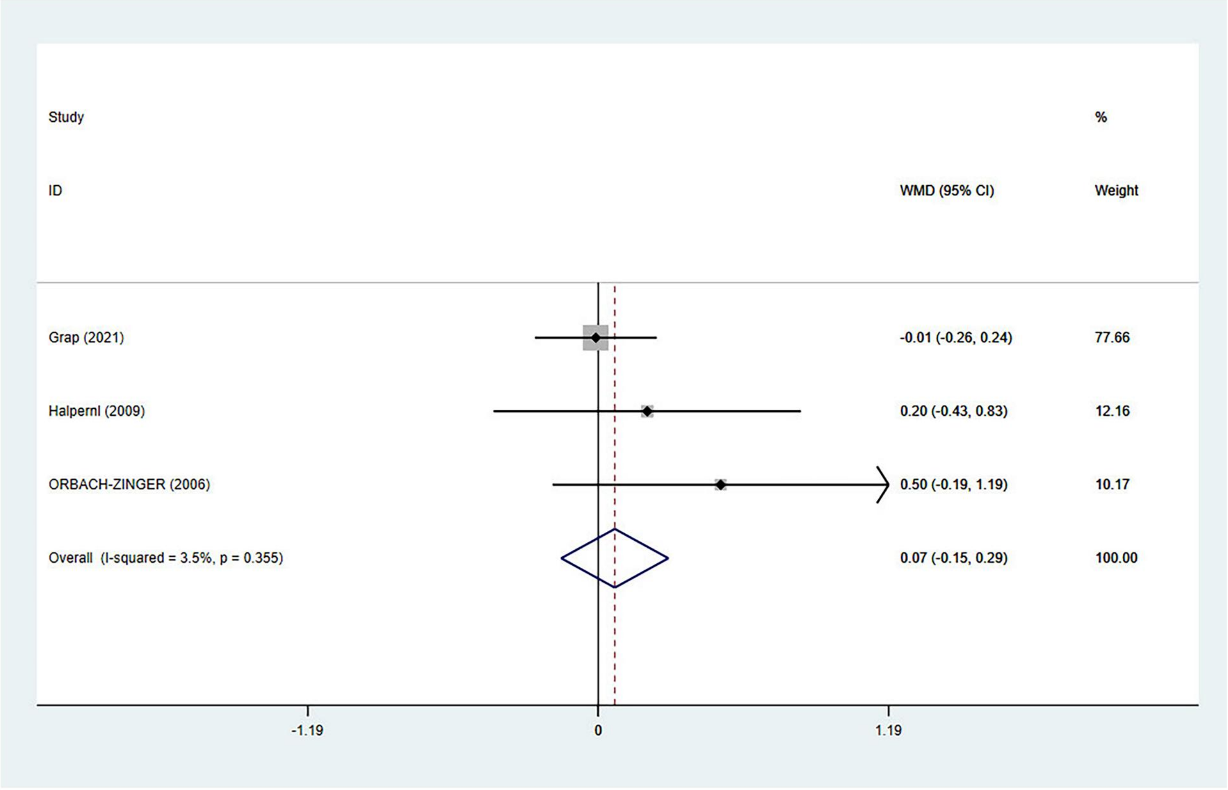

Figure 7. Summarized the effect of the catheter length in epidural space on failed epidural anesthesia conversion. WMD, weighted mean difference; CI, confidence interval.

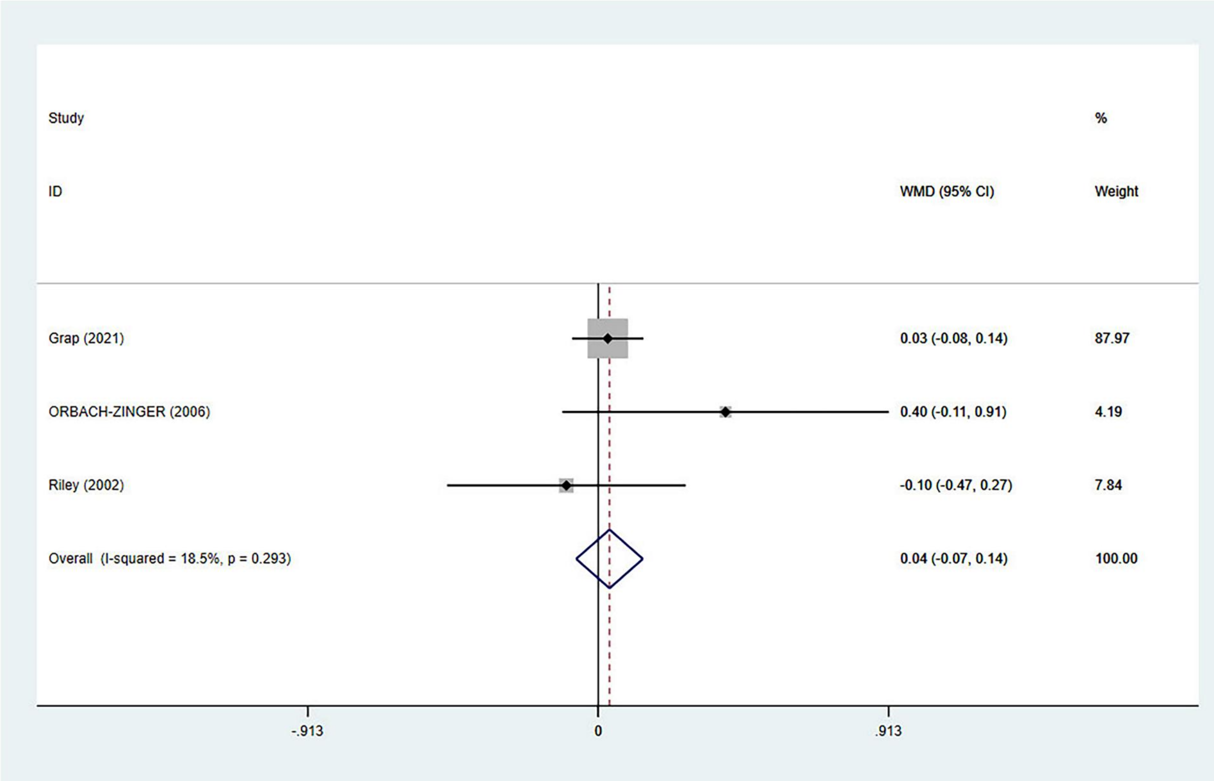

Figure 8. Summarized the effect of the catheter at skin on failed epidural anesthesia conversion. WMD, weighted mean difference; CI, confidence interval.

timely diagnosis and treatment of excruciating pain and incomplete block are crucial factors contributing to the success of epidural conversion [34].

In clinical practice, cesarean sections are categorized based on the urgency of the situation into primary, secondary, tertiary, and planned cesarean sections. Notably, the level of urgency is closely associated with the rate of epidural anesthesia conversion failure. In cases of high-emergency situations, such as placental abruption, uterine rupture, umbilical cord prolapse, prenatal hemorrhage, and fetal heart rate deceleration, the rate of general anesthesia utilization can be as high as 20% [35,36]. This study also observed that emergency cesarean sections were more likely to necessitate general anesthesia, which could be attributed to the need to expedite preoperative preparations, potentially due to insufficient time to transition from epidural analgesia to anesthesia in such critical emergencies [8,37]. However, it is worth noting that some studies have indicated that many emergency cesarean sections allow for adequate time for epidural analgesia conversion [38]. Given the risk of general anesthesia and its impact on newborns [39], it may not be reasonable to choose general anesthesia directly.

The incidence of general anesthesia also showed a correlation with the anesthesiologist's level of experience. According to Pham's report [18], the incidence of general anesthesia was less than 5%. This lower incidence was attributed to the extensive expertise of senior obstetrical anesthesiologists in the field of cesarean section. Another study conducted at a single center [40] found that when cesarean sections were managed by obstetrical anesthesiologists, there was a reduction in the utilization of general anesthesia. In comparison to non-obstetric anesthesiologists, those specializing in obstetrics may possess greater experience and proficiency in information assimilation, managing various emergencies, and optimizing the process of epidural analgesia. As a result, they are more likely to lower the rate of anesthesia failure [14,37,41].

We found that an incomplete epidural block may have been a factor of conversion failure [18,20], which has rarely been investigated in the past. Generally, an incomplete block is solved by additional local anesthetic through the epidural catheter, epidural catheter replacement, or conversion to subarachnoid anesthesia. However, the choice of strategy depends on the specific positioning of the catheter. Other strategies

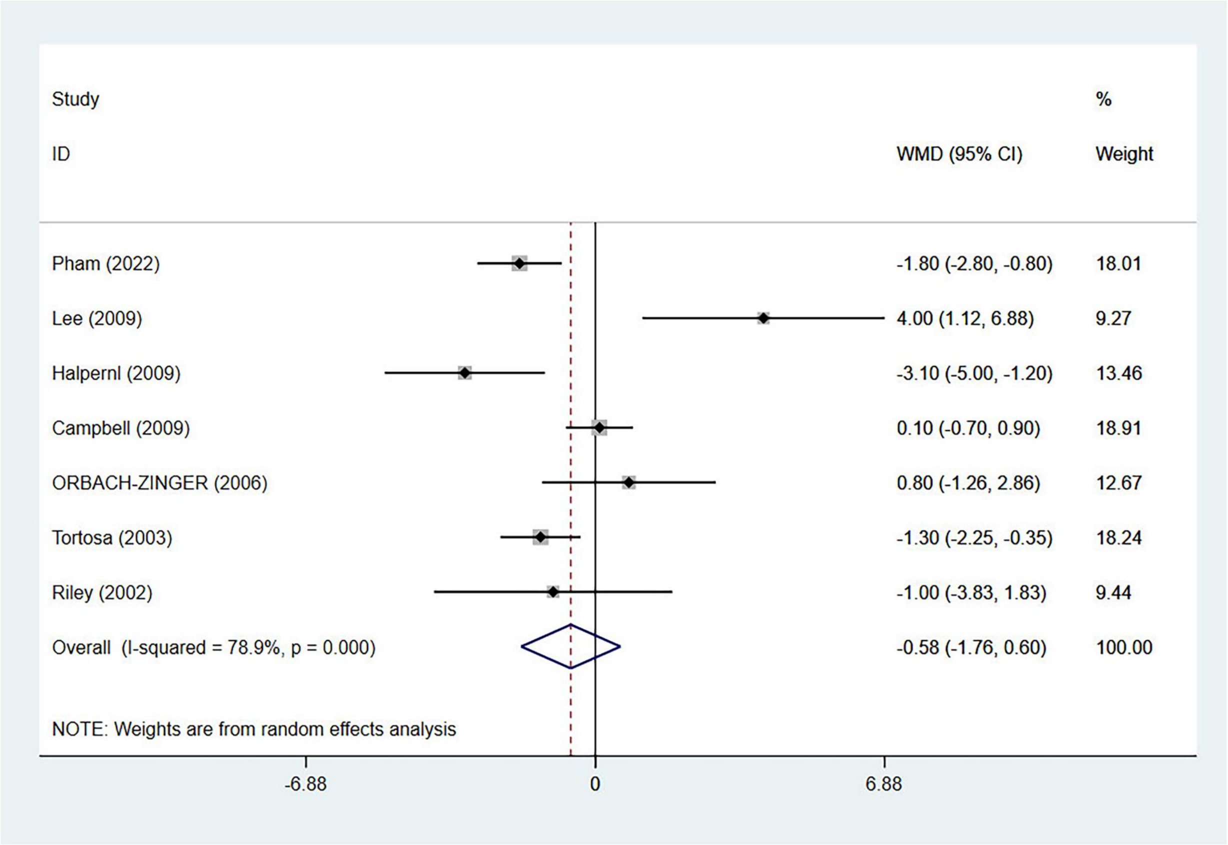

Figure 9. Summarized the effect of the duration of epidural analgesia on failed epidural anesthesia conversion. WMD, weighted mean difference; CI, confidence interval.

may involve adjusting the position of the catheter by either pulling it back or repositioning it. It's worth noting that some studies have indicated that multiple punctures might increase the risk of injury and make it challenging to control the dosage of local anesthetics in subarachnoid anesthesia. Given the potential risks associated with overdosing on local anesthetics, such as toxicity and high-level blocks, coupled with the urgency often involved in emergency operations, the selection of general anesthesia may be preferred [42,43].

Age was linked to epidural anesthesia conversion failure. Studies by Grap and Orbach-Zinger [20,25] noted that younger pregnant patients were more susceptible to conversion failure, though the specific reasons were not explored. We speculate that younger patients, due to their limited childbirth knowledge, may experience heightened anxiety, panic, reduced confidence during delivery, and increased uncooperativeness, particularly in emergency cesarean sections [44–46]. Further research is required due to the relatively small observed differences in collected data.

Maternal height emerged as a risk factor for epidural anesthesia conversion failure. Halpern's study [13] indicated that taller pregnant patients faced a higher likelihood of experiencing conversion failure, potentially due to their longer spines. Previous research has demonstrated that in individuals with longer spines, a lower proportion of local anesthetics reaches the head, necessitating a greater amount of the substance to achieve an equivalent sensory block level [47–49]. Conversely, in shorter pregnant patients, local anesthetics take effect more rapidly, resulting in a higher block level and more effective labor analgesia.

In addition, we analyzed gestational age, catheter depth into the skin, length of epidural catheter, duration of epidural analgesia, infusion speed of epidural analgesia, cervical dilatation during epidural placement, first delivery, BMI, and weight. Although some studies [13,14,18,22,25–28] have shown that epidural analgesia conversion failure may be associated with these factors, we found no statistical significance in our meta-analysis, which was consistent with the results of previous meta-analyses. This result may have been obtained through early and close monitoring and processing of these factors by clinicians, who carefully conducted these operations to prevent complications.

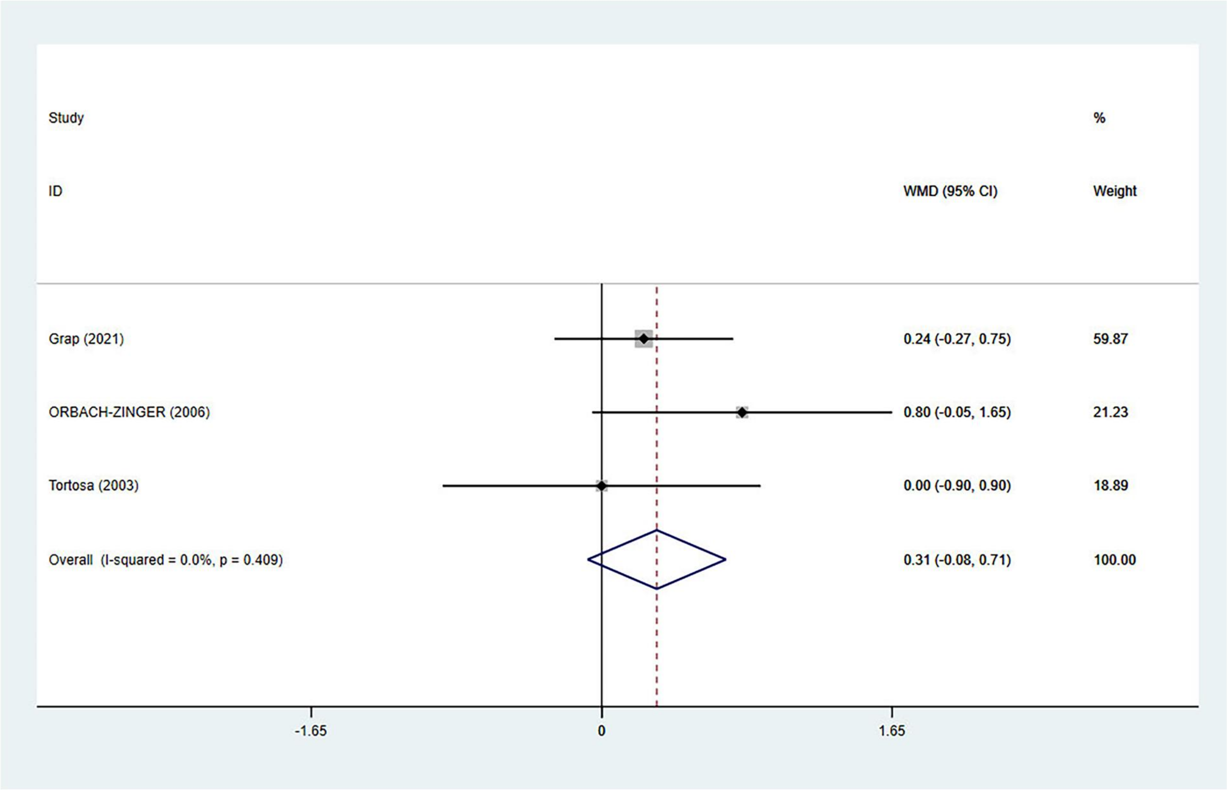

Figure 10. Summarized the effect of the infusion rate on failed epidural anesthesia conversion. WMD, weighted mean difference; CI, confidence interval.

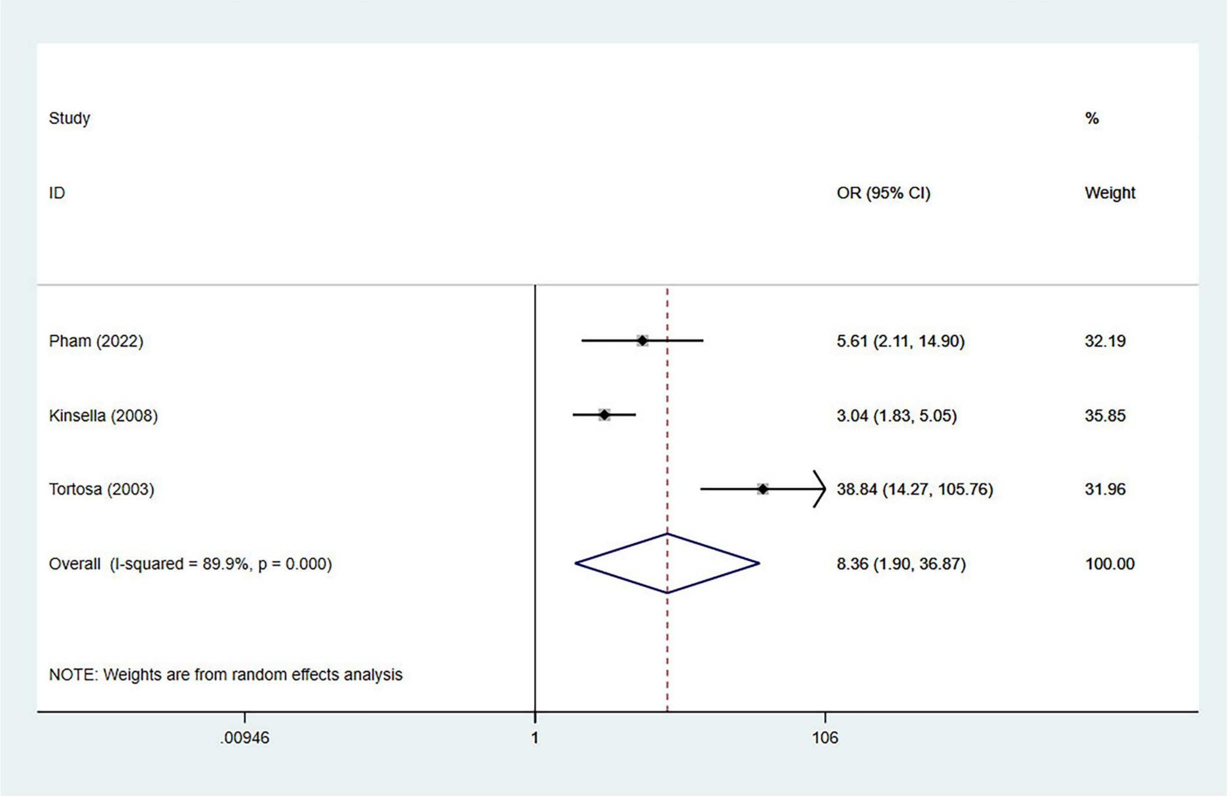

Figure 11. Summarized the effect of the poor blocking effect on failed epidural anesthesia conversion. CI, confidence interval; or, odds ratio.

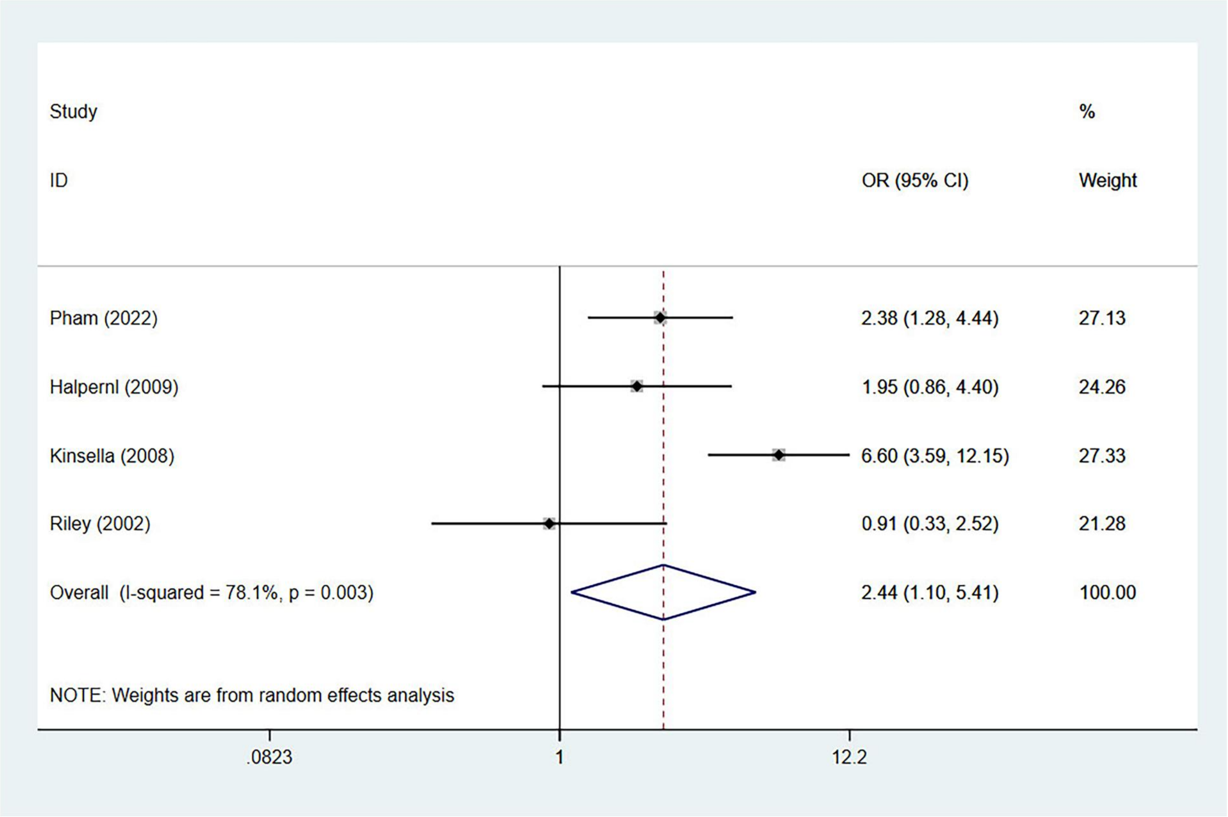

Figure 12. Summarized the effect of the urgent cesarean delivery on failed epidural anesthesia conversion. CI, confidence interval; or, odds ratio.

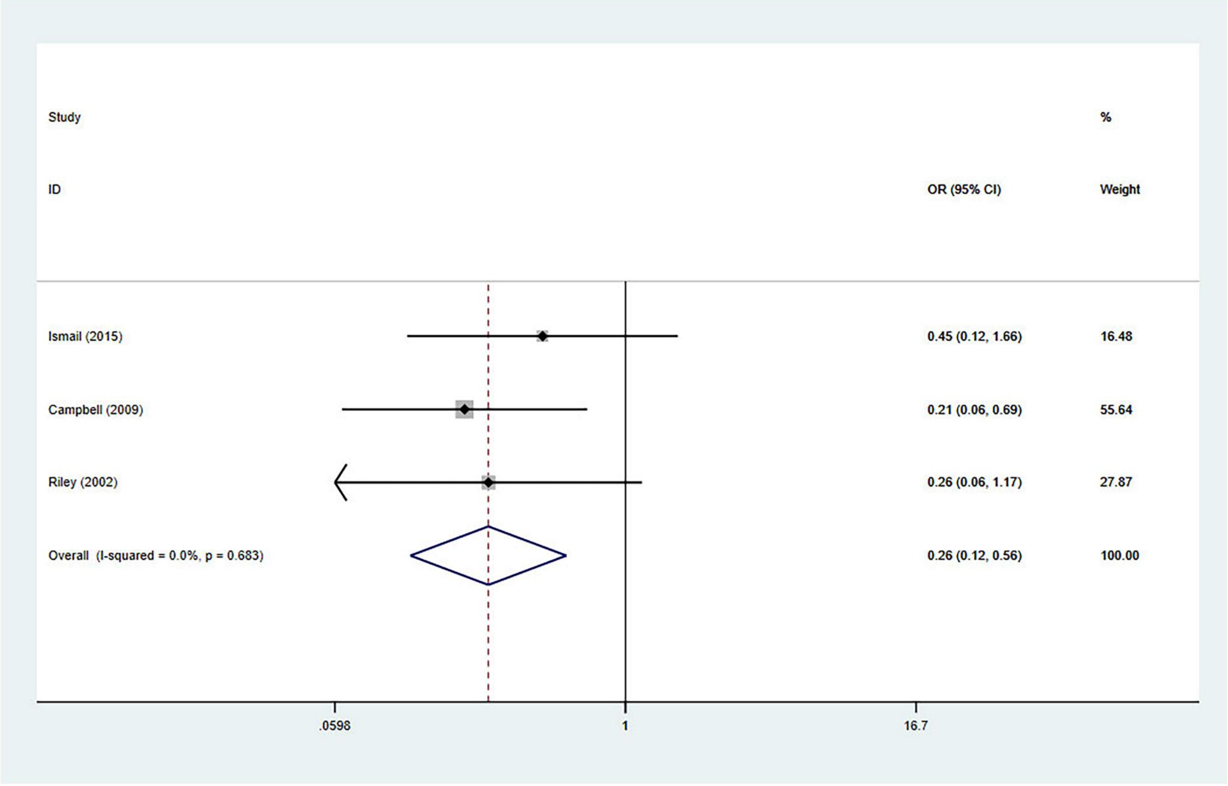

Figure 13. Summarized the effect of obstetric anesthesiologist effect on failed epidural anesthesia conversion. CI, confidence interval; or, odds ratio.

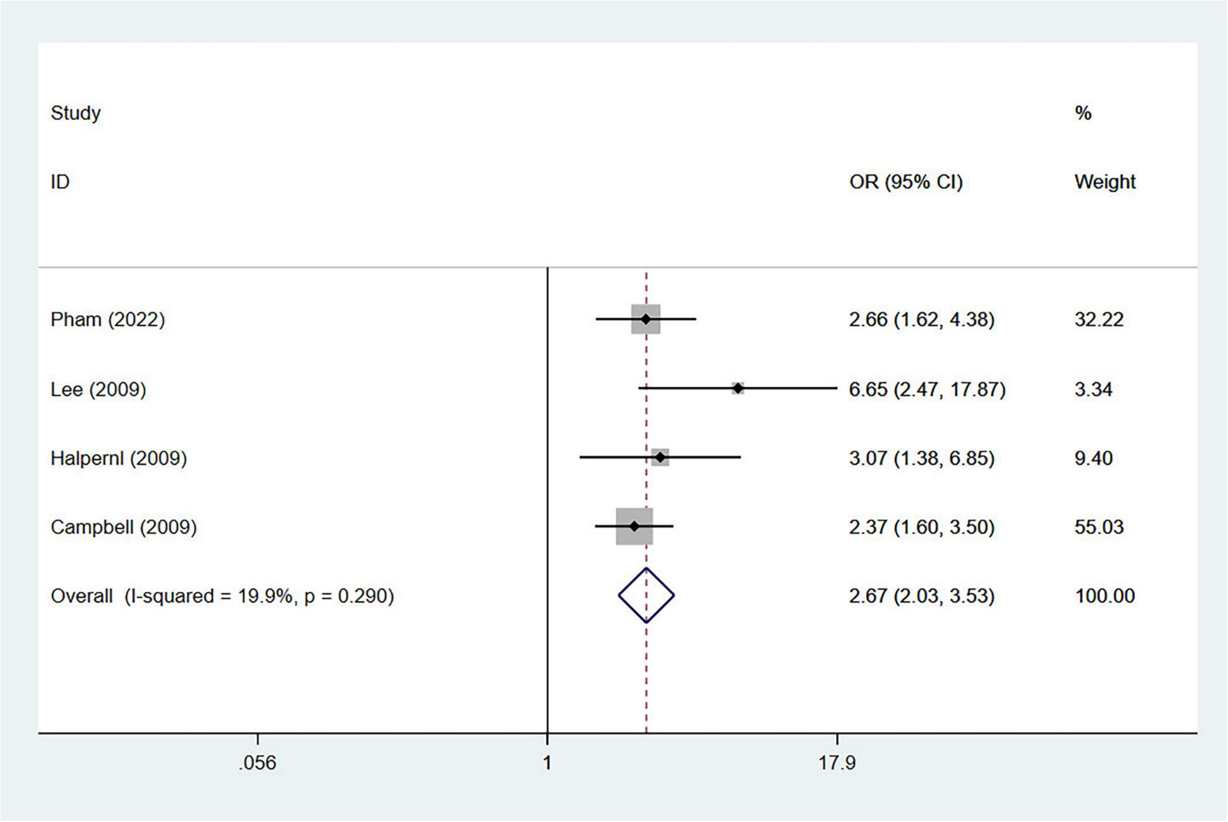

Figure 14. Summarized the effect of the number of top-ups during labor on failed epidural anesthesia conversion. CI, confidence interval; or, odds ratio.

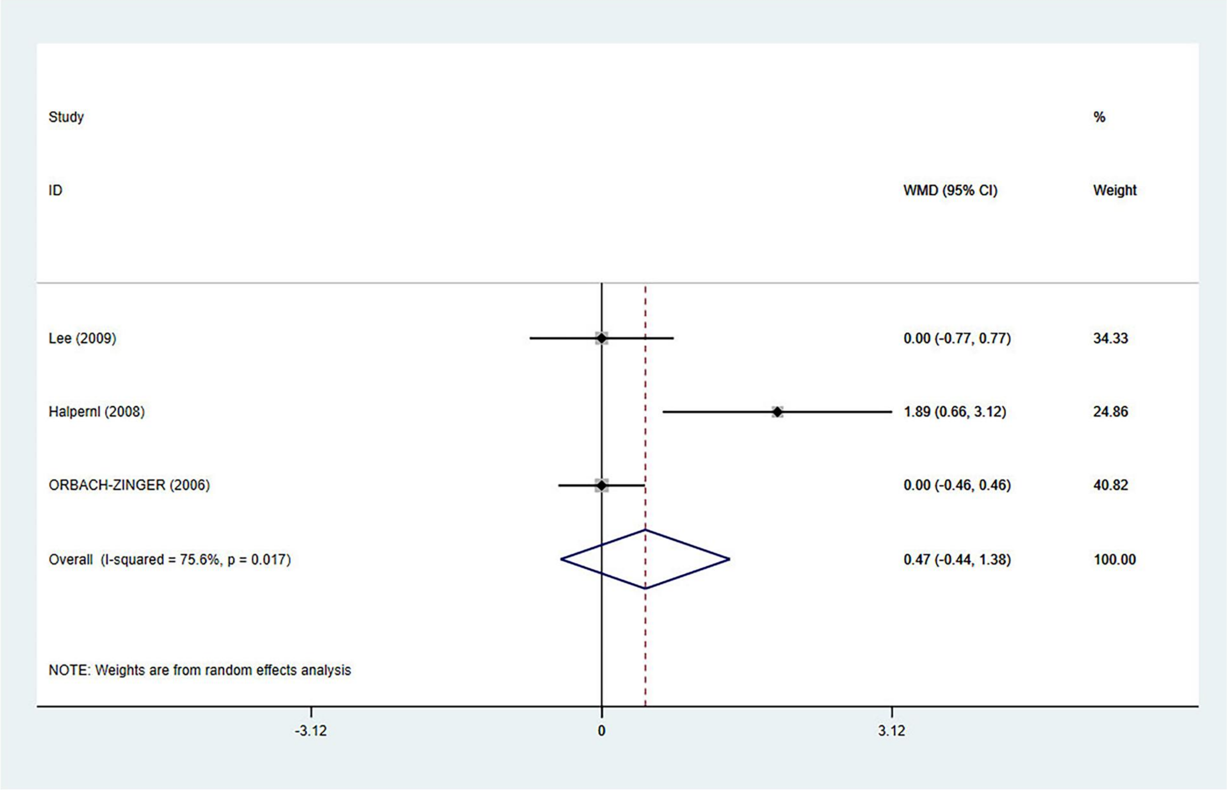

Figure 15. Summarized the effect of the cervical dilatation on failed epidural anesthesia conversion. WMD, weighted mean difference; CI, confidence interval.

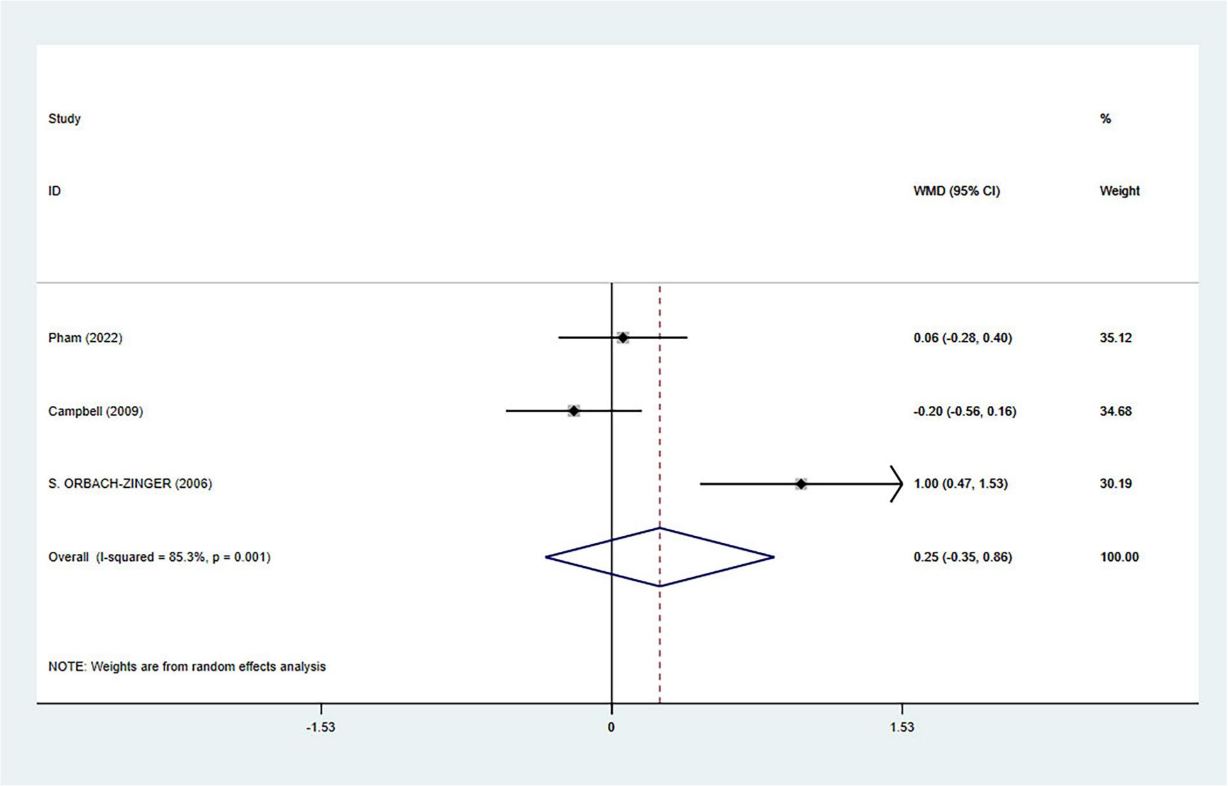

Figure 16. Summarized the effect of the gestational age on failed epidural anesthesia conversion. WMD, weighted mean difference; CI, confidence interval.

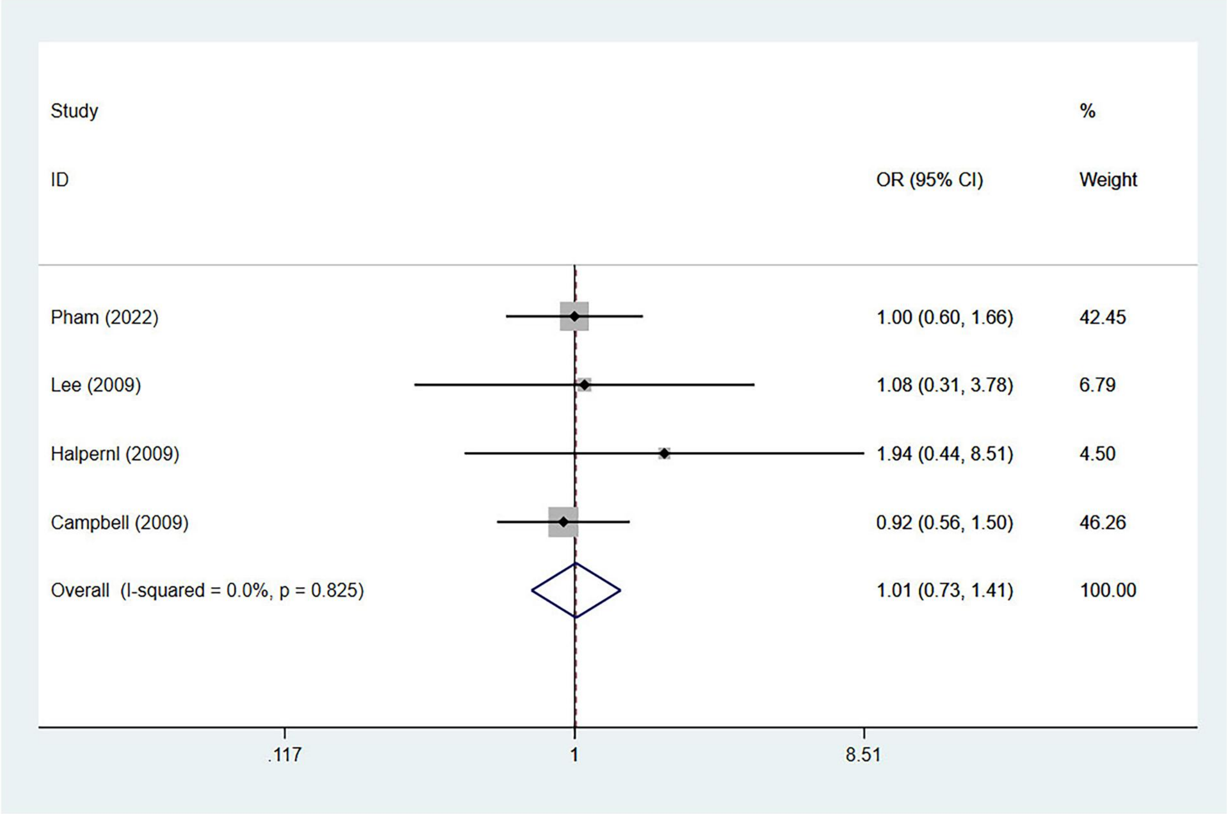

Figure 17. Summarized the effect of the nulliparous on failed epidural anesthesia conversion. CI, confidence interval; or, odds ratio.

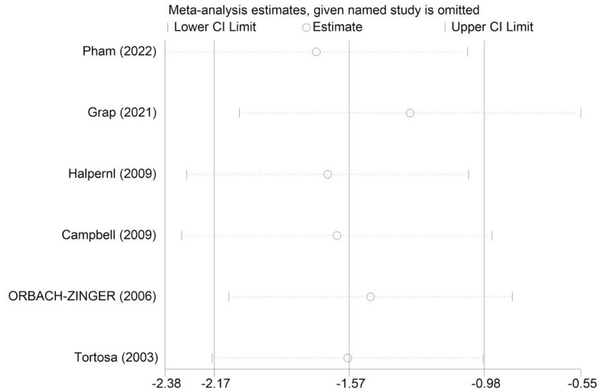

Figure 18. Sensitivity analysis of age.

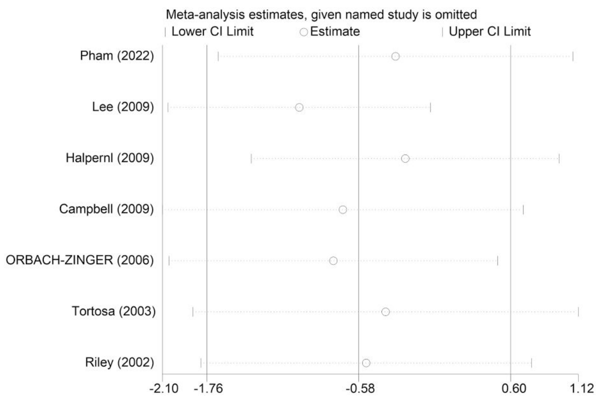

Figure 19. Sensitivity analysis of the duration of epidural analgesia.

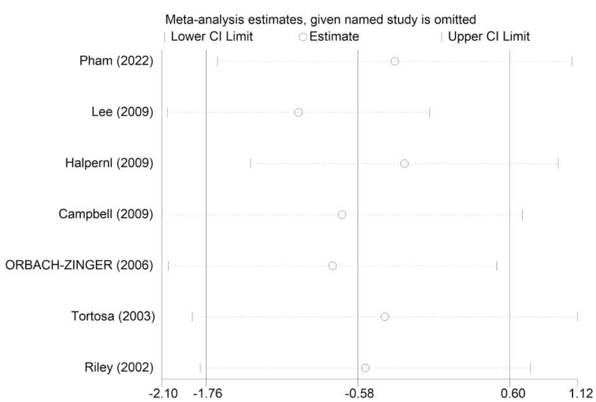

Figure 20. Sensitivity analysis of the weight.

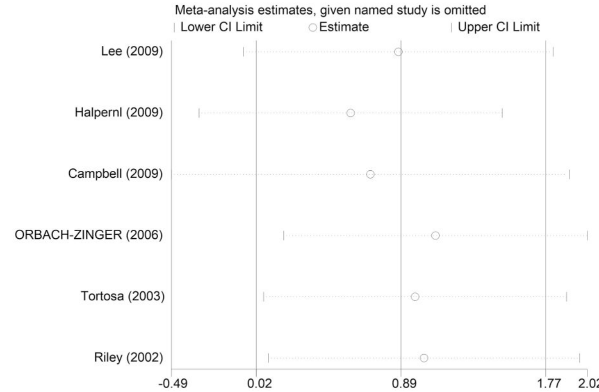

Figure 21. Sensitivity analysis of the height.

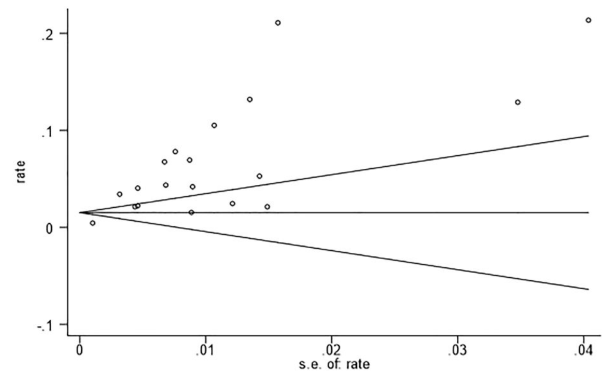

Figure 22. Begg's funnel plot with pseudo 95% confidence limits.

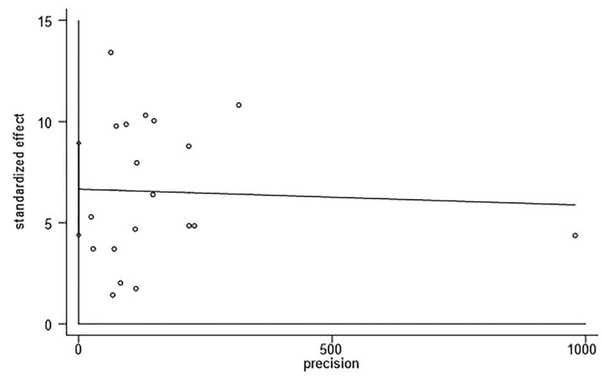

Figure 23. Egger's publication bias plot.

Limitations

Several limitations were observed in our study. Firstly, despite conducting a comprehensive and systematic search, the number of included studies remains limited. This limitation restricted the extent to which we could perform in-depth quantitative analyses for outcomes characterized by high heterogeneity. Secondly, while the overall heterogeneity in our research results was deemed acceptable, there were notable instances of heterogeneity in factors such as epidural block effectiveness, emergency cesarean section, cervical dilatation size, and gestational age. The high heterogeneity in studies analyzing epidural block effectiveness and emergency cesarean sections may be attributed to the wide timespan encompassed by the included studies, resulting in variations in epidural anesthesia methods, including different dosages and anesthetic drugs. Additionally, the high heterogeneity can also arise from the different proportions of nulliparas in the included population. In addition, the study by Kinsella et al. [24]. did not report age information, so the heterogeneity may also result from baseline information of participants. Similarly, among the three studies reporting cervical dilatation size, the baseline age of the population in Orbach Zinger et al. [25]. was 27.2-29.7; and the subjects included in Halpern were about 33 years old [13]; Lee et al. [22]. did not report age information. The difference in baseline age may cause certain heterogeneity in the pooled effect size of cervical dilatation size. In the three studies reporting gestational age, Campbell et al. and Pham et al. [14,18] reported similarities in baseline characteristics (age, weight, and BMI) between the success and failure groups, these important factors were not matched between groups in the study by Orbach Zinger et al. [25], potentially introducing confounding factors and contributing to high heterogeneity in the combined results. Thirdly, due to the limited number of included studies, an evaluation of publication bias·was not feasible. Lastly, our search·was limited to reports published in English, which may introduce potential publication bias.

Conclusions

The incidence of conversion from epidural analgesia to general anesthesia stands at 6%. Maternal age, height, emergency cesarean delivery, incomplete epidural block, epidural analgesia dose, and non-obstetric anesthesiologist care heighten the risk of epidural conversion failure. For patients with these risk factors, vigilant monitoring, early detection, and prompt intervention are imperative. Further research is warranted to delve deeper into potential risk factors.

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