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Systematic Review

Intrapartum Amnioinfusion for Recurrent Variable Decelerations and Neonatal Morbidity: A Systematic Review and Meta-Analysis

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Abstract

Background: The objective was to estimate the effect of intrapartum amnioinfusion (AI) for recurrent variable decelerations on neonatal morbidity. The primary outcome was composite neonatal neurologic morbidity assembled from individual neonatal outcomes used clinically with suspected hypoxic-ischemic encephalopathy (HIE). Secondary outcomes were composite neonatal morbidity not associated with HIE. **Methods**: Data Sources: A predefined, systematic search was conducted through Ovid Medline, Embase, CINAHL PLUS, Cochrane library (including CENTRAL), Scopus, and Clinicaltrials.gov and was used to identify studies assessing the relationship between intrapartum AI and neonatal morbidity yielding 345 unique citations from 1982 to 2018. Study Eligibility Criteria: Randomized control trials that compared intrapartum AI to no AI for recurrent variable decelerations and included neonatal outcomes were included. Randomized trials comparing AI for other indications (e.g., meconium aspiration syndrome) were excluded, as were studies on intrapartum AI that lacked a control group (i.e., no amnioinfusion). **Results**: A total of 3 randomized control trials met the selection criteria. Outcomes from 282 neonates exposed to intrapartum AI for recurrent variable decelerations were compared to those from 286 who had fetal monitoring with recurrent variable decelerations but did not receive AI. There were no data on neonatal neurologic morbidity outcomes related to HIE. Among the data available, composite neonatal morbidity was not significantly different with AI (28.7% *vs*. 59.1%, pooled risk ratio, –0.30; 95% CI (95% confidence interval) –0.99–0.40; I^2 = 94.51%; p = 0.40). Separated by individual outcomes contributing to the composite, intensive care unit admissions (ICU) (1 study; 6.8% *vs*. 16.5%; risk ratio 0.45; 95% CI 0.25–0.83) were less likely in those receiving an intrapartum AI, compared to no intrapartum AI while there was no difference in umbilical cord pH $<$7.20 (1 study; 19% *vs*. 8%; p = 0.62). There was no difference in Apgar scores $<$7 at 1 and 5 minutes on pooled analysis. **Conclusions**: Few studies have been published on the effect of intrapartum AI for recurrent variable decelerations on neonatal morbidity. Nevertheless, this meta-analysis suggests that intrapartum AI for recurrent variable decelerations may improve surrogate markers of neonatal morbidity, but further research is warranted.

Keywords: amnioinfusion; labor; intrapartum; recurrent variable decelerations; neonatal morbidity; neurologic morbidity

1. Introduction

Hypoxic ischemic encephalopathy (HIE) occurs in 2–9 per 1000 neonates after delivery and has high rates of long-term neurologic morbidity and mortality [1–5]. Risk factors for HIE include abnormal fetal heart tracings [1,6], maternal fever, and maternal infection [6–9]. Therapeutic cooling of neonates with HIE after delivery reduces the risk of neurologic motor and cognitive deficits and earlier cooling is associated with improved outcomes [3–5,10–12]. Though animal studies show that brain cooling may be more beneficial when given in utero during insult from cellular hypoxia [13], therapeutic cooling in utero has yet to be explored.

Intrapartum amnioinfusion (AI)—the administration of fluid via an intrauterine catheter inserted through the cervix—has been a common intervention during labor for the last 40 years in the United States [6,14,15] and provides a unique opportunity for in utero intervention for neonates at risk of HIE. First introduced in 1983, AI was initially utilized for a broad array of indications: Non-reassuring fetal status, meconium aspiration syndrome [16], oligohydramnios [17,18], previable and premature prelabor rupture of membranes [18,19], and intraamniotic infection [16–20]. Currently, however, the American College of Obstetrics and Gynecology only recommends intrapartum AI as a method of in utero resuscitation for recurrent variable decelerations observed on fetal heart rate monitoring [15]. These decelerations are important as the total deceleration area in the two hours before delivery has been found to be the most predictive features of neonatal acidosis, which may contribute to HIE [21].

An unintended consequence of intrapartum AI is a demonstrated reduction of in utero temperature by 1.0° Celsius (36.4° Celsius versus 37.4° Celsius, $p < 0.01$) with sub-

sequent differences in neonatal core temperature at delivery [6]. Given that a neonatal temperature reduction of one degree is neuroprotective [22,23], it is possible that intrapartum AI could be protective against neurologic injury for at risk neonates. Prior meta-analyses that attempted to examine the potential association between intrapartum AI and adverse neonatal outcomes were confounded by the inclusion of studies that utilized AI for historic, but not current, indications (i.e., meconium aspiration and oligohydramnios) [16–20]. Thus, to estimate the effect of intrapartum AI for recurrent variable decelerations on neonatal neurologic morbidity, we performed a systematic review and meta-analysis of prospective studies comparing the presence or absence of intrapartum AI for recurrent variable decelerations and neonatal neurologic morbidity outcomes. We hypothesized that neonates exposed to intrapartum AI for recurrent variable decelerations would have improved neurologic outcomes compared to those who were unexposed but had recurrent variable decelerations.

2. Objective

We performed a systematic review and meta-analysis to estimate the effect of intrapartum AI for recurrent variable decelerations on neonatal morbidity. The primary outcome was composite neurologic neonatal morbidity derived from common clinical indicators of suspected HIE (Box 1). The secondary aim was to examine the effect of intrapartum AI for recurrent variable decelerations on individual and composite neonatal morbidity outcomes, as HIE is mainly a clinical diagnosis with broad diagnostic criteria [12,24].

Box 1. Selected neonatal outcomes based on clinical criteria used for hypoxic-ischemic encephalopathy.

Diagnosing suspected HIE
- Death
- Seizures
- Therapeutic hypothermia
- Apgar score less than 7 at 1, 5 and 10 minutes of life
- Umbilical cord gases including umbilical artery lactate, pH, and/or base deficit
- Neonatal head imaging including brain magnetic resonance imaging, ultrasound, electroencephalogram
- Neonatal resuscitation at delivery defined by resuscitation greater than 10 minutes at delivery with assisted ventilation, chest compression, or cardiac medications
- Neonatal physical exam findings consistent with neurologic dysfunction such as hyperalert, irritable, lethargic, obtunded, diminished spontaneous movements, weak/absent cry, respiratory difficultly, feeding difficultly, posturing, abnormal reflexes
- Other outcomes related such as intensive care unit admission, specialty care nursing, hospital length of stay

HIE, hypoxic ischemic encephalopathy.

3. Methods

3.1 Eligibility, Information Sources and Search Strategy

The published literature was searched using strategies designed by a medical librarian (AH) for the concepts of AI and neonatal morbidity, with related synonyms. These strategies were created using a combination of controlled vocabulary terms and keywords, and were executed in Ovid MEDLINE (1946 to present), Embase.com (1946 to present), CINAHL Plus, Cochrane Library (including CENTRAL), Scopus (1823 to present), and Clinicaltrials.gov (1997 to present) from database inception. No limits or filters were applied to the search results. All database searches were completed on 24 November 2021. Details to reproduce the search are available in our **Supplementary Material**.

3.2 Eligibility Criteria and Study Selection

Studies were excluded if they received AI for any other indication (e.g., meconium aspiration syndrome, previable and prelabor premature rupture of membranes, intraamniotic infection, oligohydramnios), neonatal morbidity outcomes were not separated by indication for AI, there was no control group (i.e., no AI), contained duplicate data previously in another publication by the same or different author, or if the authors did not report raw data for included neonatal outcomes. In addition, all review/commentary articles identified by our literature search were reviewed to ensure no studies were missing in our literature review. Two studies had multiple indications for AI (including recurrent variable decelerations as the predominant group) [25,26]. These authors were contacted in attempt to obtain individual patient data; however, the author was deceased and the data no longer available and the other author reported the original data were unavailable as they were more than 40 years ago [25,26].

We used a predesigned methodology according to guidelines for Preferred Items for Systematic Reviews and Meta-analysis and Meta-analysis of Observational Studies in Epidemiology [27,28]. The study protocol was registered with the International Prospective Register of Systematic Reviews (#PROSPERO 2022 CRD42022327133 Available from: https://tinyurl.com/2p9238x7) prior to review of articles.

3.3 Data Extraction

Titles and abstracts were screened by 2 independent reviewers (BEP, KHB) for inclusion and full manuscripts were reviewed by (BEP, JR). Data pertaining to all primary and secondary outcomes were abstracted from the primary literature. Included studies reported on any of the following outcomes: Composite neonatal neurologic morbidity as defined by the primary source authors; composite neonatal morbidity defined by the primary source authors; neonatal death, seizures, HIE, and therapeutic hypothermia; apgar score less than 7 at 1, 5 and 10 minutes of life; um-

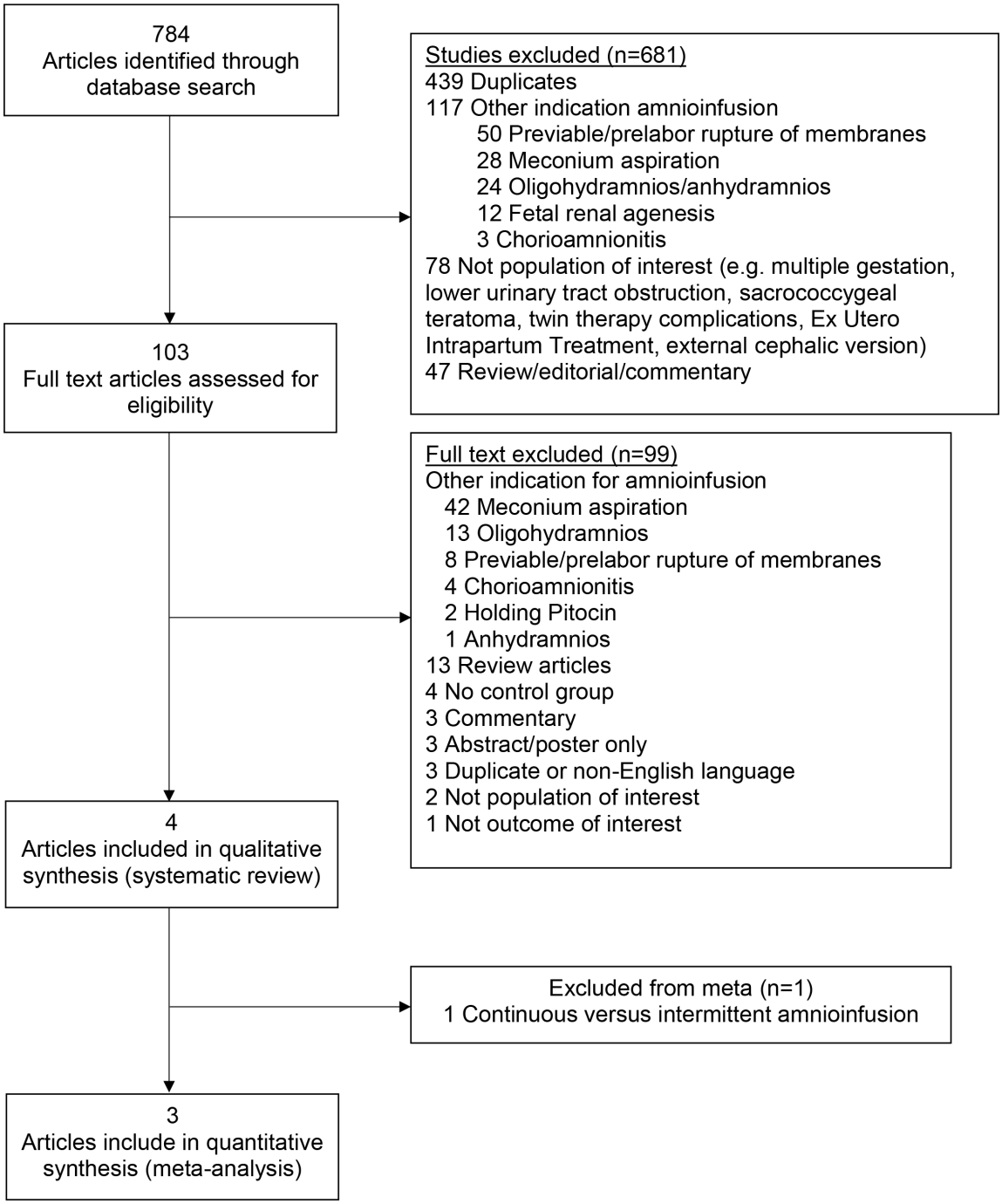

Fig. 1. Flow chart of literature review.

bilical cord gases including umbilical artery lactate, pH, and/or base deficit; neonatal head imaging including brain magnetic resonance imaging, ultrasound, electroencephalogram; neonatal resuscitation at delivery defined by resuscitation greater than 10 minutes at delivery with assisted ventilation, chest compression, or cardiac medications; neonatal physical exam findings consistent with neurologic dysfunction such as hyperalert, irritable, lethargic, obtunded, diminished spontaneous movements, weak/absent cry, respiratory difficultly, feeding difficultly, posturing, abnormal reflexes; and other outcomes related to morbidity such as intensive care unit admission, specialty care nursing, hospital length of stay. In addition, outcomes for this systematic review and meta-analysis included clinical criteria for hypoxic-ischemic encephalopathy utilized when making management decisions surrounding treatment for therapeutic hypothermia: Gestational age $\geq$36 weeks and $<$6 hours from birth, metabolic acidosis with pH $<$7.0 or base deficit $\geq$16, 10-minute Apgar score $<$5, and moderate to severe encephalopathy on clinical examination (Box 1) [12,24].

Table 1. Systematic review study characteristics for intrapartum amnioinfusion for recurrent variable decelerations.

Author	Publication Year	Country	Inclusion criteria	Exclusion criteria	Amnioinfusion technique	Primary outcome	Secondary outcome
Abdel-Aleem [31]	2005	USA	438 women admitted in labor at Assiut University Hospital Singleton, vertex, term >37 weeks, cervical dilation <5 cm, and non-reassuring fetal tracing.	Vaginal bleeding, fetal anomalies, uterine scars, uterine anomalies, malpresentation, intrauterine growth restriction, maternal temperature greater than 38° Celsius, grand-multiparity defined as greater than 5, pre-eclampsia with severe features.	A pediatric nasogastric tube, 1 gram of amoxicillin intravenously as prophylactic antibiotics and antiseptic solution during cervical exam, clear guidelines of location during placement of the tube, the use of 500 millimeter sterile saline solution that was maintained at 37.8° Celsius in water bath, and lastly that fluid was infused over 30 minutes and followed by repeated slow infusions as needed. They further specified criteria for proceeding with operative delivery or AI failure. Of note, in 5 patients eligible for AI, the authors were unable to pass the nasogastric tube to administer the AI.	Cesarean section for fetal distress; Relative risk (RR) 0.7; 95% confidence interval (CI) 0.60–0.83) and a 30% reduction in abnormal fetal heart rate patterns (RR 0.7; 95% CI 0.60–0.83). Prespecified power calculation.	Neonatal and maternal complications; Significantly fewer newborns had an Apgar score less than 7 at 1 and 5 minutes in the intrapartum AI for variable decelerations group than the no AI groups (RR 0.38; 95% CI 0.26–0.55 & RR 0.31; 95% CI 0.13–0.97) respectively. 14 newborns in the AI group required intensive care unit admission compared to 31 newborns in the no AI group (RR 0.45; 95% CI) 0.25–0.83).

Table 1. Continued.

Author	Publication Year	Country	Inclusion criteria	Exclusion criteria	Amnioinfusion technique	Primary outcome	Secondary outcome
Miyazaki [32]	July 1982 to March 1984	USA	96 patients; First stage of labor with at least 5 consecutive variable decelerations that did not respond to change in position and oxygen.	Some patients were excluded from the study for the following reasons. (1) There were differences of opinion among the attending staff members as to severity of the variable decelerations requiring infusions, i.e., mild, moderate, or severe repetitive variable decelerations. (2) Three of 30 (10%) of the attending staff members refused to participate in the study. (3) Some multiparous patients seemed to be at the point of imminent delivery, i.e., multiparous patients with cervix at 8 to 9 cm , with vertex at 1+ station. (4) If the labor and delivery suite was unusually busy, patients with mild or moderate repetitive variable decelerations were more likely not to be included in the study. Also excluded were those patients with ominous signs, such as flat baseline, late decelerations, tachycardia to 180 bpm or more, and thick meconium.	1000 milliliters solution of normal saline, intravenous tubing, an 18" gauge needle, and short extension tubing. The 18" gauge needle was plugged into the side port of the extension tubing and the normal saline, at room temperature, was dripped in at 15 to 20 milliliters per minute until variable decelerations resolved and an additional 250 milliliters in excess was recommended. If variable decelerations were not relieved with an additional infusion of 800 milliliters, the infusion was deemed a failure. If gross leakage of fluid occurred after AI, then repeat infusion were performed. The amount of leakage of intrapartum AI for variable deceleration fluid was calculated using weighted Chux pads. During the AI, patients were also kept in one position while the no AI group was able to have their positions manipulated.	Complete relief of variable decelerations; Relief of variable decelerations occurred in 51% of the intrapartum AI compared to 4.2% with no intrapartum AI, p-value < 0.001.	Cesarean section for fetal distress, Apgar scores, incidence of cord complications, cord complications and relief by amnioinfusion; Cesarean section was also lower with intrapartum AI 18.4% compared to 25.5% with no intrapartum AI, p-value 0.547. No significant differences for Apgar score less than 7 at 1 and 5 minutes or incidence of cord complications.
Tomlinson [6]	December 2007 to June of 2008	USA	Prospective, Women with singleton gestations $\geq$34 weeks of gestation who had an indication for intrapartum intrauterine pressure catheter placement were approached for participation in the study at Barnes Jewish Hospital, St Louis, MO, USA from December 2007 to June 2008.	Because it has been shown that 85% of the heat transfer from the fetus occurs across the placenta, women were excluded if there was concern for placental insufficiency.	The AI utilized normal saline at room temperature and was administered at 600 milliliters/hours for the first hour followed by 180 milliliters/hour. 40 women agreed to participate, but data for 6 women were not included as the intrauterine temperature readings were erased resulting in 34 participants resulting in final cohort of 20 no AI and 14 AI group for variable decelerations.	Mean uterine temperature; When compared to controls, intrapartum AI for variable decelerations had a lower intrauterine temperature (36.4 versus 37.4° Celsius, p-value < 0.01). Upon subgroup analysis of afebrile patients revealed an even greater effect (37.3 versus 35.8° Celsius, p-value < 0.01).	Neonatal rectal temperature; Approximately 15% of neonates had umbilical artery pH less than 7.20, but none were less than 7.10. Importantly, umbilical cord gases were missing in 5 neonates. The remaining neonatal outcomes were not different.

AI, intrapartum amnioinfusion.

3.4 Data Synthesis

Meta-analysis was performed using the meta-analysis statistics in Stata (Stata SE 18.0, StataCorp, College Station, TX, USA). Two-by-two contingency tables were created to compare the presence or absence of composite neonatal morbidity and individual outcomes, stratified by the presence or absence of intrapartum AI for recurrent variable decelerations. As individual patient-level data were not available, each individual neonatal outcomes were summed in the composite neonatal morbidity until the overall cohort was reached for that specific randomized trial. Therefore, neonates may be counted more than once within the composite neonatal morbidity outcome. We calculated pooled risk ratios (RRs) using random effects models to account for the clinical heterogeneity between studies. We estimated heterogeneity across studies and tested its significance using the Higgins I^2 statistics and Cochran's Q test. I^2 of 50% was considered evidence of significant heterogeneity. Forest plots were created to visually assess both effect size and identify outliers.

3.5 Assessment of Quality

We assessed study quality using three key factors considered most likely to threaten the validity of study results: Valid randomization method, completeness of follow-up (loss less than 10%), use of intention-to-treat analysis [29]. Valid randomization included use of random number tables, computer-generated random sequences, and other widely accepted random allocation. Studies complying with all these criteria were considered to be of high quality. Studies were scored 0 to 4 with higher scores suggestive of high quality. Each study received a single point if it was randomized, had completed follow-up, performed an intention-to-treat analysis, and specified the primary outcome as neonatal neurologic morbidity.

3.6 Assessment of Bias

The risk of bias in each included study was assessed using the criteria outlined in the Cochrane Handbook for Systematic Reviews of Interventions using the revised Cochrane risk-of-bias tool for randomized trials [30]. Five domains (selection, performance, attrition, reporting, and other) related to risk of bias were assessed in each included trial: Random sequence generation, allocation concealment, selective reporting, other sources of bias, blinding (participants and personnel), blinding (outcome assessment), and incomplete outcome data. These were categorized as high, low or unclear risk of bias.

4. Results

The search yielded 784 results from 1982 to 2018 with 345 publications screened after removing duplicates. Of those 345, the majority of these citations were excluded for either utilizing intrapartum AI for other indications (n = 117), not having a study population of interest (n = 78) or being reviews or editorials (n = 47). Among the 103 abstracts that merited full review of the manuscript, 3 manuscripts met inclusion criteria (Fig. 1). In aggregate, these three randomized trials compared 282 neonates exposed to intrapartum AI for recurrent variable decelerations to 286 neonates that had recurrent variable decelerations during labor but did not receive intrapartum AI (Table 1, Ref. [6,31,32]). These three studies were also high quality with low-to-medium bias. The highest quality score was a 3 as no trial had neurologic outcomes as their primary outcome (Table 2, Ref. [6,31,32]).

4.1 Study Characteristics

Meta-analysis Description

A description of the meta-analysis studies is summarized in Table 1. All three studies included in the meta-analysis were randomized control trials (Abdel-Aleem 2005, Miyazaki 1985, Tomlinson 2000) [6,31,32]. The three studies used intermittent bolus infusions for intrapartum AI with only one describing a continuous infusion following this bolus.

4.2 Primary Outcome

We could not summarize data for our primary outcome—a composite of neonatal neurologic morbidity based on individual neonatal outcomes used clinically with suspected HIE and/or clinical criteria utilized when deciding to treat neonates with therapeutic hypothermia (Box 1)—as no included studies provided neurological outcome data [12,24].

4.3 Secondary Outcomes

Composite neonatal morbidity, defined as neonatal intensive care unit (ICU) admission, umbilical artery pH $<$7.20, and Apgar scores $<$7 at 1 and 5 minutes. This composite neonatal morbidity was not statistically different on pooled analysis (3 studies; 28.7% *vs.* 59.1%, pooled risk ratio, –0.30; 95% CI (95% confidence interval), –0.99–0.40; I^2 = 94.51%; p = 0.40; Fig. 2, Ref. [6,31,32]). When individual outcomes within the composite neonatal morbidity were examined independently, ICU admission occurred less frequently among those with recurrent variable decelerations randomized to intrapartum AI compared to no intrapartum AI (ICU: 1 study; 6.8% *vs.* 16.5%; risk ratio 0.45; 95% CI 0.25–0.83) while there were no differences in umbilical artery pH $<$7.20 (pH $<$7.20: 1 study; 19% *vs.* 8%; p = 0.62). There was no difference in Apgar score $<$7 at 1 minute (2 studies; pooled risk ratio –0.46; 95% CI –1.57–0.65; Fig. 3, Ref. [31,32]) or at 5 minutes (3 studies; pooled risk ratio –0.46, 95% CI –1.64–0.71; Fig. 4, Ref. [6,31,32]).

5. Discussion

5.1 Principal Findings

Intrapartum AI for recurrent variable decelerations is commonly utilized during labor, yet the impact of intra-

Table 2. Systematic review study characteristics for intrapartum amnioinfusion for recurrent variable decelerations, continued.

Author	Randomization	Intention to treat	Bias criteria	Quality
Abdel-Aleem [31]	Yes	Yes	Low risk	High quality
Miyazaki [32]	Yes, sealed envelope	Yes	Low risk	High quality
Tomlinson [6]	Yes	Yes Data for 6 women were not included as the intrauterine temperature readings were erased; umbilical cord gases not available for 5 neonates	High bias	High quality

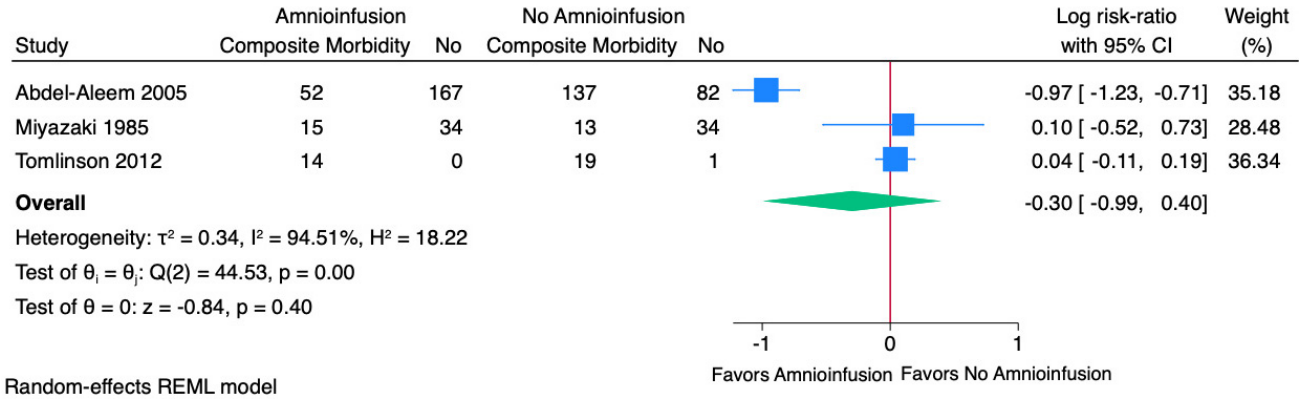

Fig. 2. Composite neonatal morbidity by amnioinfusion intrapartum for recurrent variable decelerations during electronic fetal monitoring. 95% CI, 95% confidence interval; REML, restricted maximum likelihood.

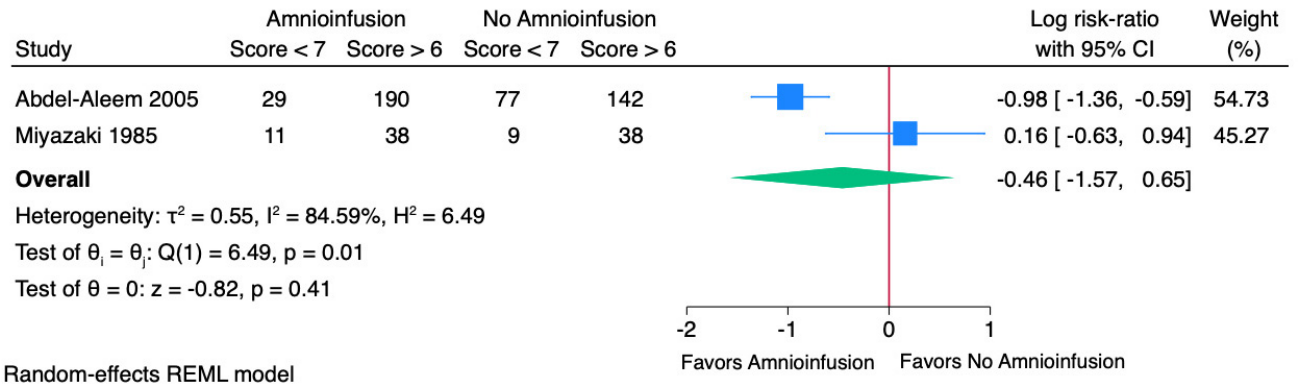

Fig. 3. Apgar score <7 at 1 minute by amnioinfusion intrapartum for recurrent variable decelerations during electronic fetal monitoring.

partum AI on neonatal morbidity, particularly neonatal neurologic morbidity, has not demonstrated conclusive evidence of benefit [16–20]. Results of this analysis suggest that there is insufficient high-quality evidence surrounding the effect of intrapartum AI for recurrent variable decelerations on neonatal morbidity, yet individual studies suggest a potential benefit in reducing short term surrogate markers of morbidity such as neonatal ICU admissions. We could not provide insight as to whether this intervention is associated with differences in neonatal neurologic morbidity due to a lack of primary data.

5.2 Strength and Limitations

We used strict inclusion criteria from the primary literature. Unlike prior meta-analysis analyzing neonatal outcomes after AI [33], our meta-analysis was limited to intrapartum AI utilized for in utero resuscitation of recurrent variable decelerations in labor and the results demonstrated that intrapartum AI may impact short-term neonatal morbidity such as intensive care unit admission but did not affect overall composite neonatal morbidity. More importantly, however, this review highlights the need for novel high-quality research aimed at examining whether intrapartum AI for recurrent variable decelerations affects

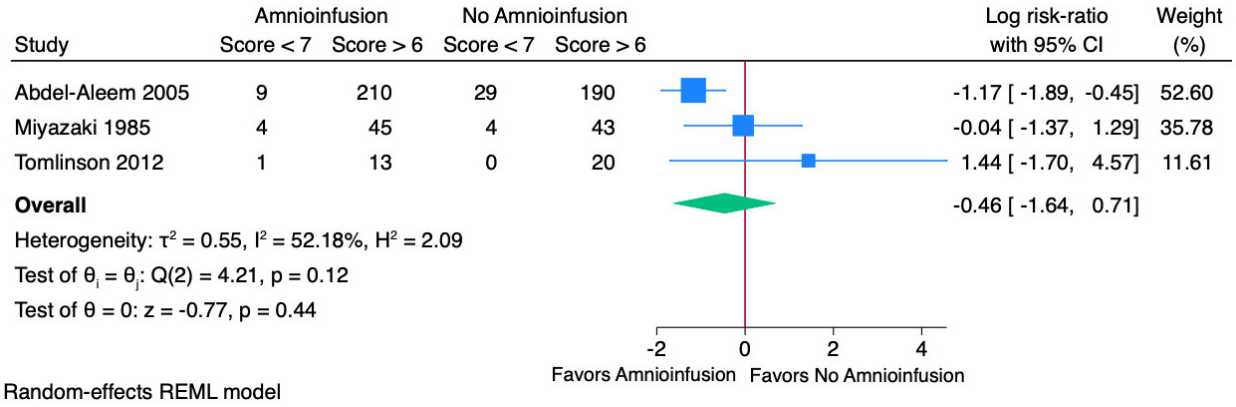

Fig. 4. Apgar score <7 at 5 minutes by amnioinfusion intrapartum for recurrent variable decelerations during electronic fetal monitoring.

neonatal outcomes, including neonatal neurologic morbidity. A main limitation of our systematic review and meta-analysis is the lack of patient-level data on neonatal morbidity outcomes. In particular, the generation of neonatal neurologic morbidity data after intrapartum AI should be a research priority given the absence of current data and the potential for intrapartum AI as a tool to begin therapeutic cooling in utero [12,24]. Lastly, our composite neonatal morbidity is largely built on surrogate markers and may overestimate the effect of intrapartum AI for recurrent variable decelerations as we were unable to rank which outcome occurred in an individual more than once and thus may over represent the morbidity.

5.3 Results

A similar systematic review was performed by Hofmeyr *et al*. [33] examining AI for potential or suspected umbilical cord compression. They concluded AI may be of considerable benefit resulting in a higher mean umbilical cord artery pH (mean difference 0.03, 95% CI 0.00–0.06) and fewer neonates with low cord arterial pH (average risk reduction 0.58, 95% CI 0.29 to 1.14) but these data are not statistically significant, demonstrate a small effect size, and are not clinically meaningful [33]. Our results demonstrate a similar trend in surrogate markers but represents a purely defined cohort of intrapartum AI for recurrent variable decelerations suggesting a role in reducing morbidity.

5.4 Clinical Implications

Data from this systematic review and meta-analysis suggests that intrapartum AI for the resuscitation of fetal tracings with recurrent variable decelerations is insufficiently studied, yet individual studies suggest intrapartum AI may plausibly reduce the risk of short-term neonatal morbidity such as ICU admission [34]. We speculate this reduction in neonatal morbidity occurs through a reduction in the total deceleration area—a feature of electronic fetal monitoring found to be the most predictive feature for umbilical artery acidemia in the two hours before delivery [21]. However, the clinical significance of intrapartum AI on neonatal morbidity remains insufficiently studied. Clinicians should consider these limited data when deciding to use an amnioinfusion during childbirth.

5.5 Research Implications

The results also demonstrate the need to critically assess in utero resuscitation techniques. For example, intermittent versus continuous AI techniques demonstrated no difference in outcomes except for lower amount of AI fluid and decreased costs [35]. However, the indication for intrapartum AI (e.g., recurrent variable deceleration versus reducing risk of neurologic injury) is important when considering administration techniques. For example, to decrease in utero and fetal temperatures, a continuous AI may counteract the blood flow from the gravid uterus and fetus which are being continuously warmed. The review also highlights varying descriptions for intrapartum AI techniques including the use of prophylactic antibiotics or antiseptics; type, temperature, amount, rate and specific fluid content of the AI; definitions of "recurrent" variable decelerations and when an intrapartum AI is classified as failed. While intrapartum AI for recurrent variable decelerations holds promise to reduce neonatal morbidity, we also highlight the rise and fall of intrapartum AI for meconium aspiration syndrome as a cautionary tale of changing clinical practice before intrapartum AI for reducing neonatal morbidity is rooted in evidence-based, high-quality data [16]. Overall, our systematic review and meta-analysis highlight there are insufficient high quality, randomized trials that examine the effect of amnioinfusion on neonatal morbidity outcomes, in particularly neonatal neurologic morbidity. Future research should identify the optimal amnioinfusion technique (e.g., type, temperature, amount, rate and specific fluid content), indication for amnioinfusion (e.g., reducing recurrent variables, intrauterine neuroprotection, thermoregulation), and examine clinically meaningful neonatal and maternal outcomes as they relate to the use of intrapartum AI.

6. Conclusions

No studies have been published on the effect of intrapartum AI for recurrent variable decelerations on neonatal neurologic morbidity. While there is insufficient high-quality evidence, individual studies in this meta-analysis suggest intrapartum AI for recurrent variable decelerations may reduce short-term neonatal morbidity such as neonatal ICU admissions. Further studies are needed to explore how and if intrapartum AI for recurrent variable decelerations may impact neonatal neurologic morbidity.

Author Contributions

BEP, JR, KHB, AH, MGT, AKL designed the research study. BEP, JR, KHB performed the data collection. BEP performed the data analysis. BEP, JR, KHB, AH, ESM, MGT, and AKL interpreted data analysis and results. All authors contributed to editorial changes and interpretation of results. All authors read and approved the final manuscript. All authors have participated sufficiently in the work and agree to be accountable for all aspects of the work.

Ethics Approval and Consent to Participate

Not applicable.

Acknowledgment

Not applicable.

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Conflict of Interest

The authors declare no conflict of interest.

Supplementary Material

Supplementary material associated with this article can be found, in the online version, at https://doi.org/10.31083/j.ceog5103075.

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