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Predictive factors for obstetric anal sphincter injury (OASI) in nulliparous women: systematic review and meta-analysis

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CONTRIBUTION

What are the novel findings of this work?

Increasing gestational age, shorter antepartum perineal body length, labor augmentation, forceps extraction, shoulder dystocia, episiotomy use and shorter episiotomy length are associated with structural anal sphincter damage following a first vaginal delivery.

What are the clinical implications of this work?

Given there is ultrasound evidence of structural damage to the anal sphincter in 26% of women who first delivered vaginally, clinicians should have a low threshold of suspicion. Our systematic review identified several predictive factors for this.

ABSTRACT

Objectives: The primary objective was to perform a systematic review on predictive factors for Obstetric Anal Sphincter Injury (OASI) occurrence at a first vaginal delivery, where the diagnosis was made by ultrasound (US-OASI). The secondary objective was to report on incidence rates of sonographic AS trauma, including trauma that was not clinically reported on at childbirth, among the studies providing data for our primary endpoint.

Methods: We conducted a systematic search of MEDLINE, Embase, Web of Science, Cinahl, Cochrane library and Clinicaltrials.gov databases. Both observational cohort studies and interventional trials were eligible for inclusion. Study eligibility was assessed independently by two authors. Random-effect meta-analyses were performed to pool effect estimates from studies reporting on similar predictive factors. Summary Odds Ratios (ORs) or Mean Differences (MDs) were reported with 95% CI. Heterogeneity was assessed using the I^2 statistic. Methodological quality was assessed using the Quality in Prognosis Studies tool.

Results: 2805 records were screened and 21 met the inclusion criteria (16 prospective cohort, three retrospective cohort and two interventional non-randomized trials). Increasing gestational age at delivery (MD 0.34w [0.04, 0.64]), shorter antepartum perineal body length (MD -0.60cm [-1.09, -0.11]), labor augmentation (OR 1.81 [1.21-2.71]), instrumental delivery (OR 2.13 [1.13-4.01]), in particular forceps extraction (OR 3.56 [1.31-9.67]), shoulder dystocia (OR 12.07 [1.06-137.6]), episiotomy use (OR 1.85 [1.11-3.06]) and shorter episiotomy length (MD -0.40cm [-0.75, -0.05]) were associated with US-OASI. When pooling incidence rates, 26% of women who first delivered vaginally, had sonographic evidence of AS trauma (95%CI 20-32%, 20 studies, I^2=88%). In studies reporting on both clinical and ultrasound OASI rates, 20% of women had AS trauma on ultrasound, that was not reported on at childbirth (95%CI 14-28%, 16 studies, I^2=90%). No differences were found in maternal age, BMI, weight, subpubic arch angle, induction of labor, epidural analgesia, duration of first/second/active second stage, vacuum extraction, neonatal birthweight or head circumference. Also, antenatal perineal

massage and use of an intrapartum pelvic floor muscle dilator did not affect the odds of US-OASI. Most studies (81%) were judged at high risk of bias on at least one domain, and only four studies (19%) had an overall low risk of bias.

Conclusion: Given there was ultrasound evidence of structural damage to the AS in 26% of women who first delivered vaginally, clinicians should have a low threshold of suspicion. Our systematic review identified several predictive factors for this.

INTRODUCTION

Obstetric Anal Sphincter Injury (OASI) is defined as a perineal tear extending into the anal sphincter (AS) complex during vaginal childbirth[1,2]. It reportedly occurs in 5-7% of first vaginal deliveries[3]. Clinical examination of the perineum at delivery may have poor diagnostic accuracy, and incidence rates of sonographic AS trauma between 12 and 35% have been reported in primiparous women, depending on the nature of the cohort, ultrasound technique and interval after delivery[4]. Authors have stated that these lesions are not actually occult, but rather undetected at childbirth because of an incomplete or inadequate clinical assessment[5-7]. Identification is crucial, since primary repair results in better functional outcome[8]. Endoanal ultrasound (EAUS) is considered the reference standard for evaluating structural pathology in the AS[2,9,10]. EAUS findings of sphincter defects have been validated against histologically confirmed tears in the AS muscles[11,12]. Moreover, characterization of the structural defect by EAUS in women who sustained OASI, can predict functional outcome in a subsequent pregnancy[13,14]. EAUS requires insertion of an ultrasound probe within the anal canal, and this can distort normal anatomy[15]. Exoanal imaging techniques, such as trans-perineal or trans-introital ultrasound (TPUS/TIUS), have been proposed as alternatives[2,16]. They have some advantages, such as wider availability, non-invasive character and ability to visualise the AS in an undistorted state[10,15]. Different strategies have been developed to quantify the extent of AS trauma on TPUS, either focusing on “residual” or “significant” defects, or by also considering more minor forms of trauma to determine the likely grade of perineal trauma sustained at childbirth (i.e., the Gillor algorithm)[17-19].

Vaginal childbirth-related pelvic floor trauma has gained increasing attention in recent years, and this has prompted discussions on whether pregnant women are given correct and balanced information on birth options available to them[20-22]. To aid women with their decision making, clinicians require accurate information on predictive factors associated with a certain health condition[23]. Studies investigating these predictive factors, require reliable diagnostic tools to measure the outcome of interest[24,25]. As such, poor outcome assessment can impair identification and quantification of all

relevant factors. In conclusion, this systematic review aims to summarize predictive factors associated with structural AS trauma in vaginally primiparous women, as demonstrated by ultrasound after delivery.

METHODS

This systematic review and meta-analysis was conducted according to the 2020 Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guideline[26]. The 2018 guideline on systematic reviews and meta-analyses of prognostic factor studies was also followed[24]. The protocol was registered in PROSPERO (registration number CRD42022344228).

Research question – PICOTS format

Our primary research question was to identify predictive factors for OASI occurrence at a first vaginal delivery, where the diagnosis of structural AS trauma was made by ultrasound at any time point prior to a subsequent vaginal delivery. This research question was transferred into a "PICOTS" format to aid the identification of relevant studies[24]:

- *Population*: unselected population of pregnant women without a previous vaginal delivery beyond 20 weeks of gestation, without restrictions regarding age, ethnicity, or geographical location. Studies that *only* recruited "high-risk" women (e.g., clinical suspicion of severe perineal trauma at delivery, women delivered exclusively by forceps and/or vacuum, or suffering from postnatal anal incontinence), were not eligible for inclusion.
- *Influence:* all predictive factors potentially associated with sonographic AS trauma, including, but not limited to, demographical variables (e.g., age, ethnicity, BMI), pregnancy or labour related characteristics (anticipated fetal size, gestational age, labour onset, (epidural) analgesia, labour augmentation, duration of the first/second/active second stage, delivery mode, etc.) or neonatal characteristics (e.g., head circumference, birth weight).
- *Comparator group:* women with similar predictive factors, yet without sonographic evidence of structural AS trauma.
- *Outcome:* ultrasound detected OASI (US-OASI), defined as evidence of structural AS trauma on ultrasound after vaginal childbirth, performed at any interval prior to a subsequent vaginal

delivery. No restrictions were used regarding sonographic technique (EAUS, TPUS or TIUS), hardware used, or diagnostic criteria that were applied to diagnose US-OASI[16]. For clarity, studies only reporting on the clinical findings at delivery without a sonographic diagnosis, were not eligible for inclusion.

- *Timing:* predictive factors identifiable throughout pregnancy, during labour or at delivery. Factors identifiable after the causal event (vaginal delivery) were not eligible for inclusion (e.g., postpartum perineal body length).
- *Setting*: hospital setting.

Systematic search

A systematic search was conducted in the following biomedical databases: MEDLINE through PubMed, Embase, Web of science Core Collection, Central and Cinahl. Search strings were developed around the concepts "anal sphincter", "vaginal childbirth" and "ultrasound", and consisted of "MESH" terms (Medical Subject Headings) for Medline, "Emtree" terms for Embase, as well as free text words for all databases. Strings were developed by the first author (BP) and peer-reviewed by two other reviewer authors (ASP/LC) and a librarian of the biomedical library at KU Leuven (following guidance provided by the 2015 PRESS checklist, Peer Review of Electronic Search Strategies)[27]. The full search strings for every database are available in Appendix S1.

Prior to running the final searches, the PubMed search string was validated by combining the three concepts of interest with 5 key references (concepts and PubMed IDs combined with "AND"), which resulted in the successful retrieval of the study reports from the MEDLINE database[28-32].

Reports published from inception to the date the searches were run were eligible for inclusion. The use of predefined search filters was avoided in every database. Other resources were consulted to limit the risk of publication bias, including a search of trial registry Clinicaltrials.gov, and backwards

and forwards snowballing. Only records in English were eligible for inclusion, since there were no funds available for translation of full-text articles in other languages.

Study selection process

Results from the electronic searches were exported to Endnote reference manager for deduplication. Two reviewers (BP/ASP) independently screened titles and abstracts for eligibility using Rayyan software (Qatar Computing Research Institute, Doha, Qatar). Conflicts were resolved through discussion or by consulting a third review author (JDP/JRI) when consensus could not be reached. A similar strategy was followed during the full-text review phase. The PICOTS format was used to guide the study selection process. Both interventional trials (randomized or non-randomized), and observational (retro- or prospective) cohort studies were eligible for inclusion. Book chapters, letters to the editor, commentaries, case reports, case-series, case-control studies and narrative or scoping reviews were excluded. Conference abstracts were eligible for inclusion providing sufficient data could be derived from their content.

Data extraction process

A data extraction sheet was designed in Microsoft Excel based on the CHARMS-PF checklist (Checklist for data extraction and critical appraisal of prognostic factor studies)[24,33]. Relevant data were extracted from every record by the first author (BP), and checked for accurateness and completeness by the second author (ASP). Conflicts were resolved through discussion. When more than one article reported on the same cohort, we used the most complete report for data extraction. In cases of missing or incomplete data, we contacted corresponding authors for additional information by email. After an unsuccessful attempt and a one-month period had elapsed, we only included published data in this review. The data extraction sheets are available in Appendix S2.

Risk of bias

Two reviewers (BP/ASP) independently appraised the included studies for risk of bias using the QUIPS tool (Quality In Prognosis Studies tool)[25]. This tool allows for bias assessment in six different domains: study participation (selection bias), study attrition, prognostic factor measurement, outcome measurement, adjustments for confounding variables, and clarity of the statistical analysis and reporting. Each domain is judged to be at high, moderate or low risk of bias. Methodological comments were made, including quotes from the study publications, to support our judgments (Appendix S3).

For study attrition, we considered a rate of max. 25% as acceptable. For outcome assessment (presence/absence of US-OASI), studies were judged to be at low risk of bias when the following conditions were met: (1) clear documentation of the ultrasound features of what was considered an AS defect/tear, or reference made to another study with clear definition, and (2) documentation of the ultrasound device/technique and protocol used for scanning women (i.e., ensuring the same method and setting was used for all study participants). Discrepancies in judgement were resolved through discussion. Studies were given an overall score of "low risk of bias" if every domain was rated as low to moderate risk of bias, and no domains were rated at high risk of bias[24].

Data analysis

Our primary endpoint was to identify predictive factors for US-OASI after a first vaginal delivery, and estimate their effect size. We assumed a priori statistical heterogeneity due to methodological diversity among the included studies (i.e., different geographical locations, sonographic techniques, diagnostic criteria, timing of outcome assessment), and therefore performed random-effect meta-analyses of all studies reporting on similar predictive factors. For studies providing count data or mean+/-SD for both groups and each factor, the inverse variance (IV) method was used. When only Odds Ratios (ORs) or Mean Differences (MDs) with corresponding 95% confidence intervals (95% CIs)

were available, the generic inverse variance (GIV) method was used to pool data. Only unadjusted ORs were incorporated. Summary effect estimates are reported as ORs or MDs together with 95% CIs. Only data from studies that were sufficiently comparable in terms of design, population studied, predictive factor definition/assessment method, and reported effects measures were pooled.

The secondary endpoint was to pool incidence rates of ultrasound detected AS trauma after a first vaginal delivery, amongst the studies providing data for our primary endpoint, including trauma that was only detected by ultrasound and not clinically reported on at childbirth. We defined the following terms for the sake of our study: "ultrasound detected OASI" (US-OASI), referring to all cases with sonographic evidence of structural AS trauma after vaginal childbirth, involving the external and/or internal AS, irrespective of the magnitude or extent, and regardless of the clinical diagnosis at delivery. The term "occult-OASI" refers to cases with sonographic evidence of AS trauma that was not reported on at childbirth. Only data from cohort studies was used to pool incidence rates. Again, a random effect meta-analysis was applied, with further subgroup analyses according to sonographic technique (EAUS/TPUS/TIUS), timing of diagnosis (<7 days, <12 weeks or ≥ 12 weeks after delivery), study design (retro- or prospective) and year of publication (</>2010).

Heterogeneity was assessed using the I^2 statistic. Publication bias was assessed through visual inspection of funnel plots if at least ten studies were retrieved reporting on a similar predictive factor[24]. The meta-analyses were performed using RevMan software (Cochrane Collaboration, version 5.4.1) and MetaXL software (Epigear, version 5.3).

RESULTS

Literature searches

The electronic searches were run on 21/09/2022 and generated 4821 records. The study selection process is further described in Figure 1. No additional relevant records were identified by backward or forward citation searching, nor by searching the grey literature. Reasons for exclusion of articles in the full-text review phase are provided in Appendix S4.

Study characteristics

We retrieved full-text manuscripts of 21 studies eligible for inclusion in the qualitative and quantitative synthesis: 16 prospective and three retrospective cohort studies, and two interventional non-randomized trials. These studies provided outcome data on 3066 women, of whom 2582 delivered vaginally. The characteristics of these studies are displayed in Table 1. Two reports covered the same study population[28,30]: Caudwell-Hall et al.[28] reported on a large cohort regarding the effect of delivery mode, whereas Guzman Rojas et al. provided data on the effect of other factors[30]. Therefore, both studies were included, under the condition that their data could not be pooled.

Pooled US-OASI rate

The pooled US-OASI incidence rate was 26% (95% CI 20-32%, 20 studies, forest plot displayed in Figure 2). Heterogeneity was high (I^2=88%). Visual inspection of the funnel plot in Figure 3 demonstrates no asymmetry (i.e., no evidence of publication bias or small study effect). A subgroup analysis of studies using 4D-TPUS resulted in an incidence rate of 30% (95% CI 26-35%, 3 studies, I^2=0%)[28,30,34]. Similarly, when only results from studies at low risk of bias and using EAUS were pooled, heterogeneity was low (I^2=0%), and the incidence rate was higher (37%, 95%CI 28-50%, 2 studies)[29,35].

Further subgroup analysis according to publication before or after 2010, timing of outcome assessment and study design, did not reduce heterogeneity in results <70%. Forest plots for these analyses are available in Appendix S5.

Pooled occult-OASI rate

The pooled occult-OASI rate was 20% (95% CI 14-28%, 16 studies, I^2=90%, Figure 4). When only studies using 4D-TPUS were considered, the pooled rate was 23% (95% CI 19-29%, 2 studies), and heterogeneity was low (I^2=0%)[28,34]. Again, when only results from studies at low risk of bias and using EAUS were considered, heterogeneity was low (I^2=0%), and the incidence rate was higher (36%, 95%CI 26-48%, 2 studies)[29,35]. The funnel plot is shown in Figure 5**,** demonstrating higher incidence rates in the larger studies. Subgroup analysis according to publication before or after 2010, timing of outcome assessment and study design, did not reduce heterogeneity in results <70%. Forest plots for these analyses are available in Appendix S5.

Risk of bias

Figure 6 provides results of the risk of bias assessment of the studies included in this review. Overall, four studies (19%) were judged to have an overall low risk of bias. Therefore, most studies (81%) were judged to be at high risk of bias on at least one domain. All studies were judged to be at moderate or high risk of selection bias. Study attrition bias was low (<25%) in 33% of studies[28,35-40]. Most studies (67%) were judged at low risk of bias in the outcome assessment domain[28-31,34,37-45]. Lack of correction for confounding variables was a problem in most studies, and only 3 studies (14%) were judged to be at low risk in this domain[29,30,46]. Details on the quality assessment for individual studies are provided in Appendix S6.

Predict factors

Delivery mode

Figure 7 shows the effect of instrumental vaginal delivery (IVD, forceps or vacuum extraction) on the odds of US-OASI (pooled OR 2.13, 95%CI [1.13, 4.01], p=0.02, 11 studies reporting on 1778 women). There was substantial heterogeneity between studies (I^2=74%). The funnel plot showed no asymmetry (figure 8). In subgroup analysis, forceps delivery was associated with an OR for US-OASI of 3.56 (95%CI [1.31, 9.67], p=0.01, 8 studies reporting on 1086 women, Figure 9). Again, there was considerable heterogeneity amongst studies (I^2=77%). Vacuum extraction did not increase the odds of US-OASI, as demonstrated in Figure 10 (OR 1.32, 95% CI [0.66, 2.63], p=0.43, 8 studies reporting on 1345 women). Heterogeneity between these studies was lower (I^2=52%). Publication bias was not assessed because of the low number of studies in both meta-analyses.

Episiotomy

Episiotomy was associated with an OR of US-OASI of 1.85 (95% CI [1.11, 3.06], p=0.02, 9 studies, Figure 11). Heterogeneity between studies was rather moderate (I^2=42%). Not all studies reported on the type of episiotomy used (median, mediolateral or lateral), so we were not able to explore this in subgroup analyses. Publication bias was not assessed, since only nine studies were included in the meta-analysis.

Other associated factors

Increasing gestational age at delivery (MD 0.34w, 95%CI [0.04-0.64]), shorter antepartum perineal body length (MD -0.60cm, 95% CI [-1.09, -0.11]), labor augmentation (OR 1.81, 95% CI [1.21-2.71]), shoulder dystocia (OR 12.07, 95% CI [1.06-137.6]) and shorter episiotomy length (MD -0.40cm, 95% CI [-0.75, -0.05]), were also associated with increased odds of US-OASI. No significant differences were found in maternal age, maternal BMI, maternal weight, narrow vs. broad subpubic arch angle (at a 90° cut off), labor induction, epidural analgesia, episiotomy angle, duration of first/second/active second stage and neonatal birthweight or head circumference between groups. Antenatal perineal massage

and use of an intrapartum pelvic floor muscle dilator also did not significantly influence the odds of US-OASI, although the effect of both interventions was assessed in one trial respectively.

A summary of all predictive factors, their effect size and the number of studies reporting on them, is displayed in Table 2. The forest plots are provided in Appendix S7. In view of the low number of studies in each meta-analysis, subgroup analysis was not performed, and publication bias not assessed.

DISCUSSION

This systematic review showed that in vaginally primiparous women, US-OASI was present in 26% of cases. In studies also reporting on postnatal clinical perineal assessment, the rate of occult-OASIS was 20%. Regarding the effect of delivery mode, instrumental vaginal delivery was associated with an odds of US-OASI of 2.13. In subgroup analyses, the association was stronger and significant for forceps but not vacuum delivery, albeit with overlapping confidence intervals. The clinical relevance of instrumental delivery is that the method chosen for extraction, could be a modifiable risk factor. In its recent consensus paper, the International Urogynecological Association (IUGA) and International Continence Society (ICS), recommend the avoidance of forceps extraction as a primary or secondary preventive measure for reducing the risk of OASI[2].

Episiotomy was another risk factor identified. We believe this association requires careful interpretation. First, most studies did not report on type of episiotomy, so we were not able to explore this in subgroup analyses. Median episiotomy is a well-established risk factor for OASI[47], whereas medio-lateral (MLE) or lateral episiotomy (LE) are considered more protective[48]. A recent observational study showed that in approximately one third of women who sustained OASI, episiotomies were cut in a way as to make OASI more instead of less likely[49]. In our systematic review, episiotomy angle did not significantly influence the odds of US-OASI, but the association was only assessed in one small (n=60) study[37]. Second, we could only pool count data and unadjusted ORs. Quite often an episiotomy is made during a more “difficult” delivery, i.e., when other risk factors are present. Therefore, our summary OR might be under the influence of confounding factors. Third, whilst episiotomy might be associated with increased odds of US-OASI in unselected “low-risk” parturient populations, a recent systematic review demonstrated its protective effect in nulliparous women requiring forceps delivery[50].

Also, increasing gestational age at delivery, labour augmentation and shoulder dystocia were associated with US-OASI. Two of these factors (shoulder dystocia, gestational age) have not been

identified in a previous systematic review[51]. The OR for shoulder dystocia was the highest compared to all other factors, albeit with low precision. The mean difference in gestational age at delivery between groups was 0.34 weeks. Although statistically significant, the clinical relevance of this finding is presumably limited. A similar reflection can be made regarding the effect of episiotomy length (MD 0.40 cm). However, this is in line with findings from a case-control study by Stedenfeldt et al., where increasing episiotomy length was associated with reduced odds of OASI[52]. Increasing duration of the second stage and higher neonatal birthweight have previously been shown to increase the risk of OASI[51]. These effects did not emerge in our systematic review. Again, the total number of studies reporting on these factors was low, and several were at high risk of bias, limiting the certainty of our findings. Regarding neonatal birthweight or head circumference, we believe antenatal estimates of fetal biometric properties (e.g., estimated fetal weight or head circumference by ultrasound) could be more informative for clinicians and women in their decision-making. However, it may be difficult to accurately predict these parameters in clinical practice[53].

To our knowledge, this is the largest systematic review to report on a wide range of predictive factors for sonographic AS trauma in vaginally primiparous women. It was conducted according to guidance provided by the Cochrane prognosis methods group, using specific tools and methods for qualitative and quantitative synthesis of prognostic factor studies[24]. We used a sensitive search strategy and consulted multiple databases, resulting in inclusion of a wide variety of studies, conducted in different countries, thus minimising the risk of publication and selection bias. We also acknowledge several limitations. First**,** when compared to systematic reviews of interventions, heterogeneity in systematic reviews of prognostic factor studies is usually high[24]. This was the case in several of our meta-analyses. Non-exhaustive reasons could be subtle differences in study designs or methods used to report on predictive factors or the outcome of interest. Moreover, subtle differences in obstetrical practices in different countries could also contribute to heterogeneity, and this is difficult to account for in subgroup analyses. Therefore, we used random-effect models to pool effect estimates, since this method takes into consideration in between study variability[54]. It has been stated that use of fixed-

effects models should be avoided in meta-analyses of prognostic factor studies[24]. Second, most studies in our quantitative synthesis only reported count data or unadjusted ORs. In studies where multivariable logistic regression was applied, variables were either not mentioned, or varied between studies, preventing us from pooling effect estimates similarly. Therefore, the possibility of confounding cannot be ruled out. Third**,** most studies were judged at high risk of bias, implying our results need careful interpretation. The outcome assessment domain was scored most favorable, although we acknowledge there was substantial variation in sonographic methods, timepoints and diagnostic criteria used to detect and define US-OASI. Some concerns could even be raised about overdiagnosis. Lack of comprehension of normal AS anatomy in women, with shorter anterior EAS length compared to posterior, could result in wrongly defining a "gap" in the hyperechogenic appearance of the EAS muscle at the level of the proximal anal canal, as an EAS defect[9,55]. Furthermore, some studies only reported on "defects", "scars" or "discontinuities" in the AS, without further annotations. Overdiagnosis and inclusion of minor forms of trauma in our meta-analyses, may have led to generous estimates of structural AS trauma following vaginal childbirth. Fourth, an OASI can be seen as a surrogate endpoint for what might be of true relevance to women, namely their risk of developing anal incontinence (AI) in later life[56,57]. However, in health conditions with possibly a long interval between the exposure and outcome of interest, surrogate endpoints are of value to inform the design of RCTs investigating primary or secondary preventive measures (i.e., allowing for shorter follow up)[58].

Conclusion

This systematic review identified several predictive factors for ultrasound demonstrable AS trauma, which was present in 26% of vaginally primiparous women. The most prominent factors were shoulder dystocia and forceps delivery. Methodological diversity between studies indicates there is a need for standardization of ultrasound techniques and criteria to detect and define structural AS trauma, as this will improve the scientific merit of future studies on this topic.

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FIGURE LEGENDS

Figure 1: PRISMA flowchart illustrating the study identification and selection process.

Figure 2: Forest plot for the pooled US-OASI incidence rate.

Figure 3: Funnel plot of studies reporting on US-OASI incidence rates.

Figure 4: Forest plot for the pooled occult-OASI rate.

Figure 5: Funnel plot of studies reporting on occult-OASI rates.

Figure 6: Risk of bias according to the different domains of the QUIPS tool.

Figure 7: Forest plot for instrumental vaginal delivery (IVD) vs. spontaneous vaginal delivery (SVD).

Figure 8: Funnel plot of studies reporting on the effect of instrumental vaginal delivery (IVD).

Figure 9: Forest plot for forceps delivery vs. spontaneous vaginal delivery (SVD).

Figure 10: Forest plot for vacuum delivery vs. spontaneous vaginal delivery (SVD).

Figure 11: Forest plot for the effect of episiotomy.

Table 1: Characteristics of studies included in qualitative and quantitative synthesis.

First author Publication Year	Study type	Country	US	Interval from delivery	VD (n)	OASI rate(%)	IVD rate(%)	Predictive factors
Belmonte-Montes 2001(41)	Prospective cohort	Mexico	2D-EAUS	6w (protocol)	98	28.6	23.5	Forceps, vacuum, instrumental delivery.
Caudwell Hall 2020(28)	Retrospective cohort (secondary analysis from multicentric RCT)	Australia	4D-TPUS	Mean 4.5m (range 2.3-22.4m)	371	29.1	27.8	Forceps, vacuum, instrumental delivery.
Chaliha 2001(31)	Prospective cohort	UK	2D-EAUS	12w (protocol)	130	44.6	31.5	Epidural, augmentation, first/active second/passive second/total second stage length, neonatal weight, neonatal head circumference.
Damon 2005(36)	Prospective cohort	France	2D-EAUS	12w (protocol)	197	33.5	31.5	Forceps, instrumental delivery.
Drusany Staric 2017(37)	Prospective cohort	Slovenia	3D-EAUS	6-7w (protocol)	60	10.0	0.0	Episiotomy, episiotomy length/angle
Eogan 2009(59)	Interventional (non-randomized) trial	Ireland	EAUS (us)	3m (protocol)	114	37.7	/	Antenatal perineal massage
Frudinger 2002(42)	Prospective cohort	UK	2D-EAUS	3-8m (range)	119	17.6	16.8	Narrow vs. broad Subpubic Arch Angle (SAA </> 90° respectively)
Geller 2014(32)	Prospective cohort	USA	2D-EAUS	6w (protocol)	62	16.1	17.7	Forceps, vacuum, instrumental delivery, maternal age, BMI, ethnicity, gestational age, second stage length, neonatal birth weight & head circumference, antepartum perineal body length

Guzman Rojas 2013(30)	Retrospective cohort (secondary analysis from multicentric RCT)	Australia	4D-TPUS	5,2m (IQR 3,8-5,6)	/	/	/	Forceps, vacuum, instrumental delivery, maternal age, BMI, ethnicity, gestational age, augmentation, epidural, episiotomy, second stage length, neonatal birth weight.
Guzman Rojas 2020(60)*	Prospective cohort	Spain Chile	4D-TPUS	3-6m (protocol)	216	31.0	27.8	Episiotomy
Kwok 2019(43)	Retrospective cohort	Hong Kong	3D-EAUS	6-12m (protocol)	542	6.5	62.2	Forceps, vacuum, instrumental delivery, maternal age, BMI, gestational age, epidural, active second stage length, episiotomy, neonatal birthweight.
Orejuela 2018(34)	Interventional (non-randomized) trial	USA	4D-TPUS	12-20w (protocol)	32	37.5	12.5	Intrapartum pelvic floor dilator
Ozyurt 2015(38)	Prospective cohort	Turkey	2D-TIUS	Before hospital discharge.	201	14.9	2.5	Vacuum, maternal age, maternal weight, gestational age, second stage length, shoulder dystocia, neonatal birthweight.
Pinta 2004(39)	Prospective cohort	Finland	2D-EAUS	Range 8-36w	75	22.7	26.7	Vacuum, episiotomy.
Rieger 1998(35)	Prospective cohort	Australia	2D-EAUS	Median 38d (range 20-65d)	37	40.5	24.3	Forceps, vacuum, instrumental delivery, epidural, episiotomy.
Sultan 1993(29)	Prospective cohort	UK	2D-EAUS	Median 49d (range 35-105d)	79	35.4	19.0	Forceps, vacuum, instrumental delivery, induction, augmentation, epidural, episiotomy.

Tejedor 2019(44)	Prospective cohort	Spain	3D-EAUS	3m (protocol)	47	48.9	44.7	Instrumental delivery, maternal age, induction, episiotomy, perineal trauma, neonatal birthweight.
Varma 1999(40)	Prospective cohort	UK	2D-EAUS	Within 5 days after delivery	78	11.5	6.4	Forceps, instrumental delivery.
Wickramasinghe 2016(46)	Prospective cohort	Sri Lanka	3D-EAUS	6w (protocol)	59	47.5	/	Induction, neonatal head circumference
Williams 2001(45)	Prospective cohort	UK	3D-EAUS	Median 10w (range 7-22w)	45	13.3	31.1	Episiotomy
Yassa 2018(61)*	Prospective cohort	Turkey	2D-TIUS	Before hospital discharge.	20	45.0	/	Second stage length, perineal body length.

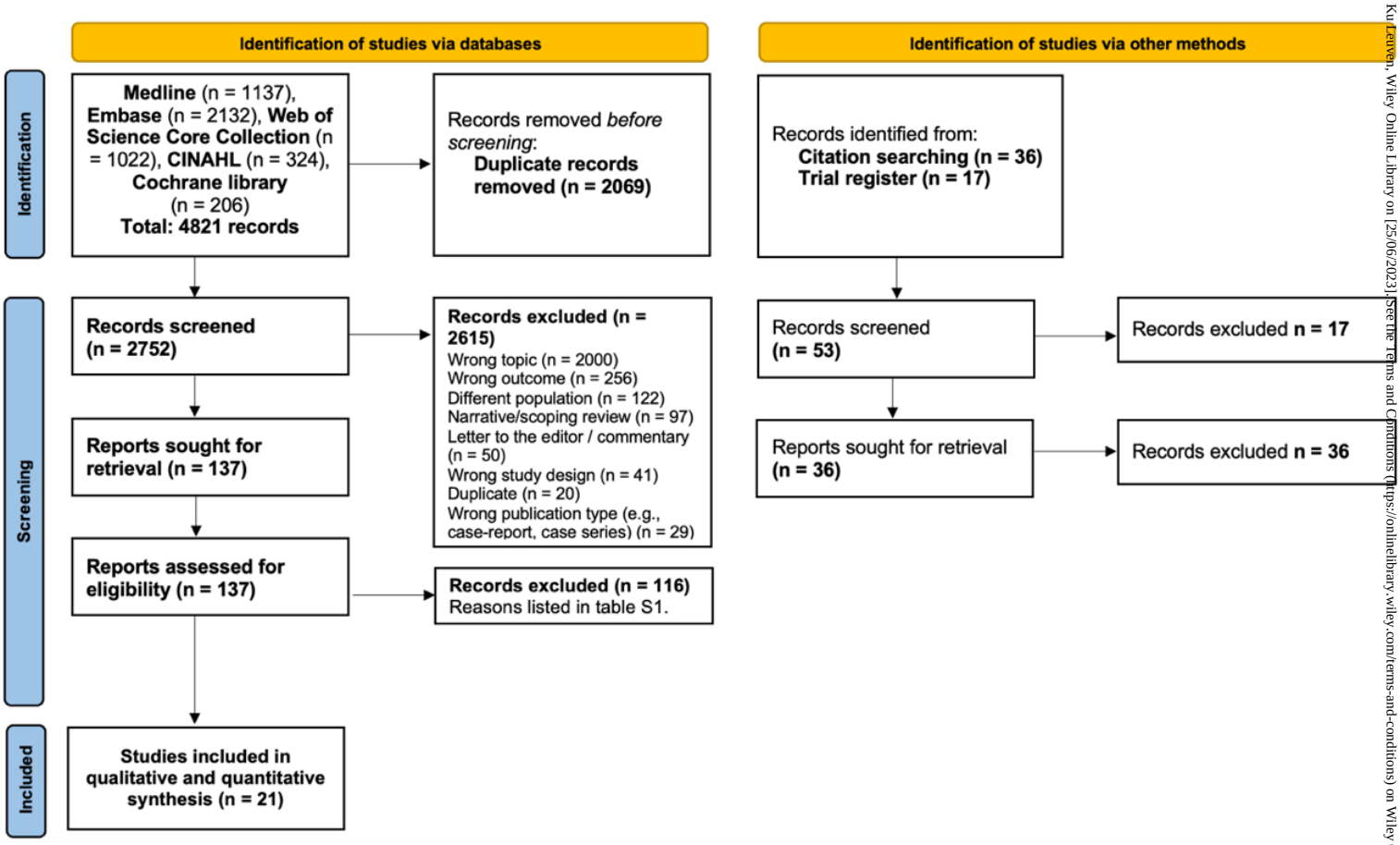
2D/3D/4D: two-, three-, four-dimensional, M: months, EAUS: endoanal ultrasound, TPUS: Trans-perineal ultrasound, TIUS: Trans-introital ultrasound, VD: number of women with vaginal delivery and outcome data. * Refers to conference proceedings, all other reports were journal articles.

Table 2: Summary of findings

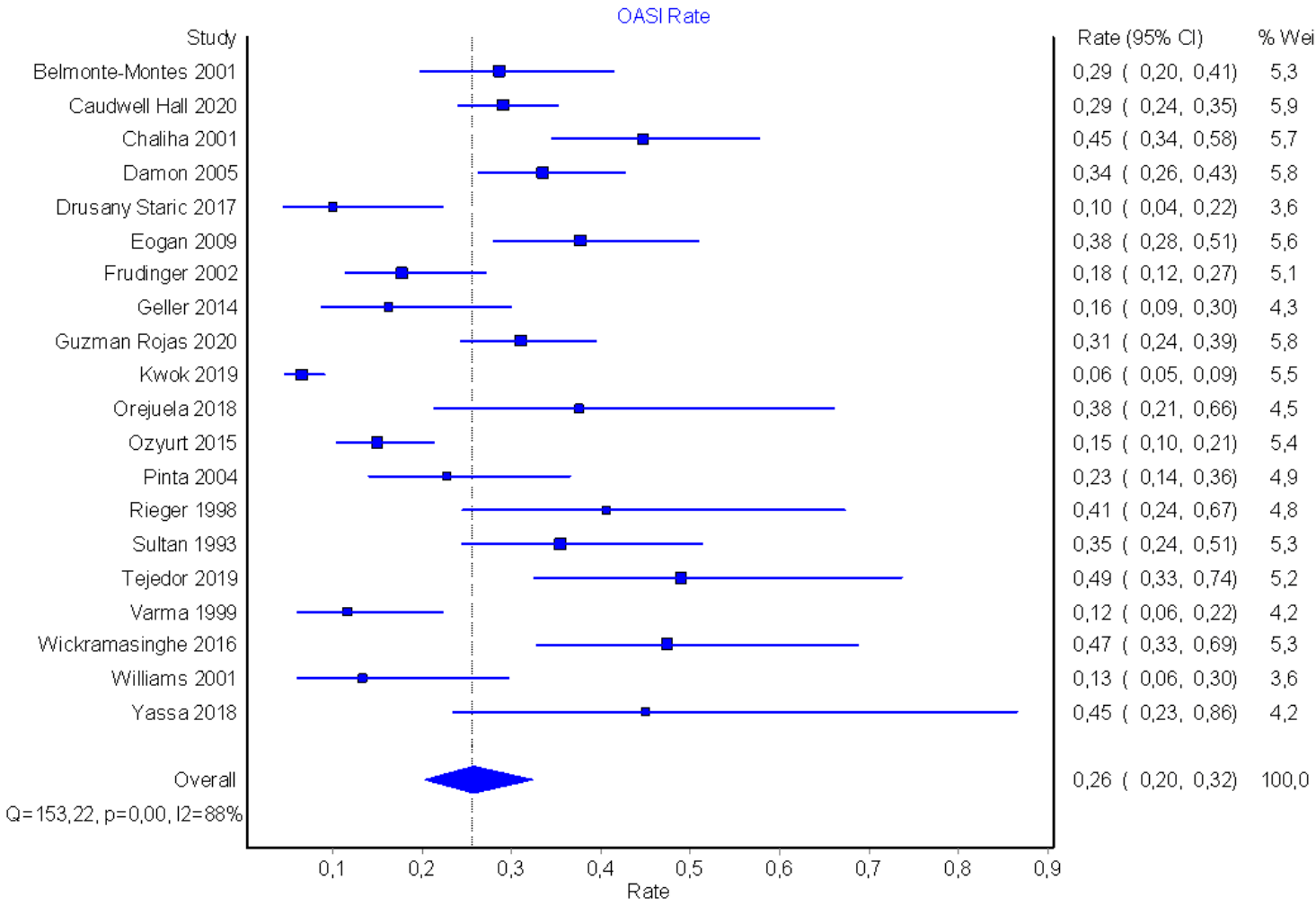
Predictive factor	Number of studies	(Summary) Statistic	Method	Effect estimate (95% CI)	Heterogeneity (I^2)
Baseline demographics					
Maternal age (years)	4	MD	IV / RE	0.78 [-0.02, 1.58]	0%
Maternal BMI (kg/m²)	2	MD	IV / RE	-0.37 [-1.25, 0.51]	0%
Maternal weight (kg)	1	MD	NA	0.72 [-2.12, 3.56]	NA
Gestational age at delivery (weeks)	3	MD	IV/ RE	0.34 [0.04, 0.64]	0%
Narrow vs. Broad SAA (90° cut off)	1	OR	NA	1.30 [0.45, 3.75]	NA
Antepartum perineal body length (cm)	1	MD	NA	-0.60 [-1.09, -0.11]	NA
Labour characteristics					
Labour induction (binary)	3	OR	GIV / RE	1.36 [0.15, 12.64]	83%
Labour augmentation (binary)	3	OR	GIV / RE	1.81 [1.21, 2.71]	0%
Epidural analgesia (binary)	5	OR	GIV / RE	1.50 [0.83, 2.68]	55%
First stage length (min)	1	MD	NA	78 [-42, 199]	NA
Second stage length (min)	4	MD	GIV/ RE	12.96 [-3.96, 29.87]	52%
Active second stage length (min)	2	MD	GIV / RE	-0.92 [-11.09, 9.26]	25%
Delivery characteristics					
Forceps (vs. SVD)	8	OR	IV / RE	3.56 [1.31, 9.67]	77%
Vacuum (vs. SVD)	8	OR	IV / RE	1.32 [0.66, 2.63]	52%
Instrumental (vs. SVD)	11	OR	IV / RE	2.13 [1.13, 4.01]	74%
Shoulder dystocia (binary)	1	OR	NA	12.07 [1.06, 137.60]	NA
Episiotomy (vs. no episiotomy)	9	OR	GIV / RE	1.85 [1.11, 3.06]	42%
Episiotomy angle (°)	1	MD	NA	-1.00 [-3.70, 1.70]	NA
Episiotomy length (cm)	1	MD	NA	-0.40 [-0.75, -0.05]	NA
Neonatal characteristics					
Neonatal weight (grams)	4	MD	IV / RE	199.57 [-9.32, 408.45]	73%

Neonatal head circumference (cm)	1	MD	NA	0.00 [-1.84, 1.84]	NA
Intrapartum / antenatal interventions					
Intrapartum PFM dilator (binary)	1	OR	NA	0.53 [0.11, 2.49]	NA
Antenatal perineal massage (binary)	1	OR	NA	0.96 [0.44, 2.07]	NA

BMI: body mass index, SAA: subpubic arch angle, OR: odds ratio, MD: mean difference, IV: inverse variance, GIV: generic inverse variance, NA: non-applicable, CI: confidence interval, SVD: spontaneous vaginal delivery.



UOG_26292_UOG-2023-0285.R1_Figure 1.png



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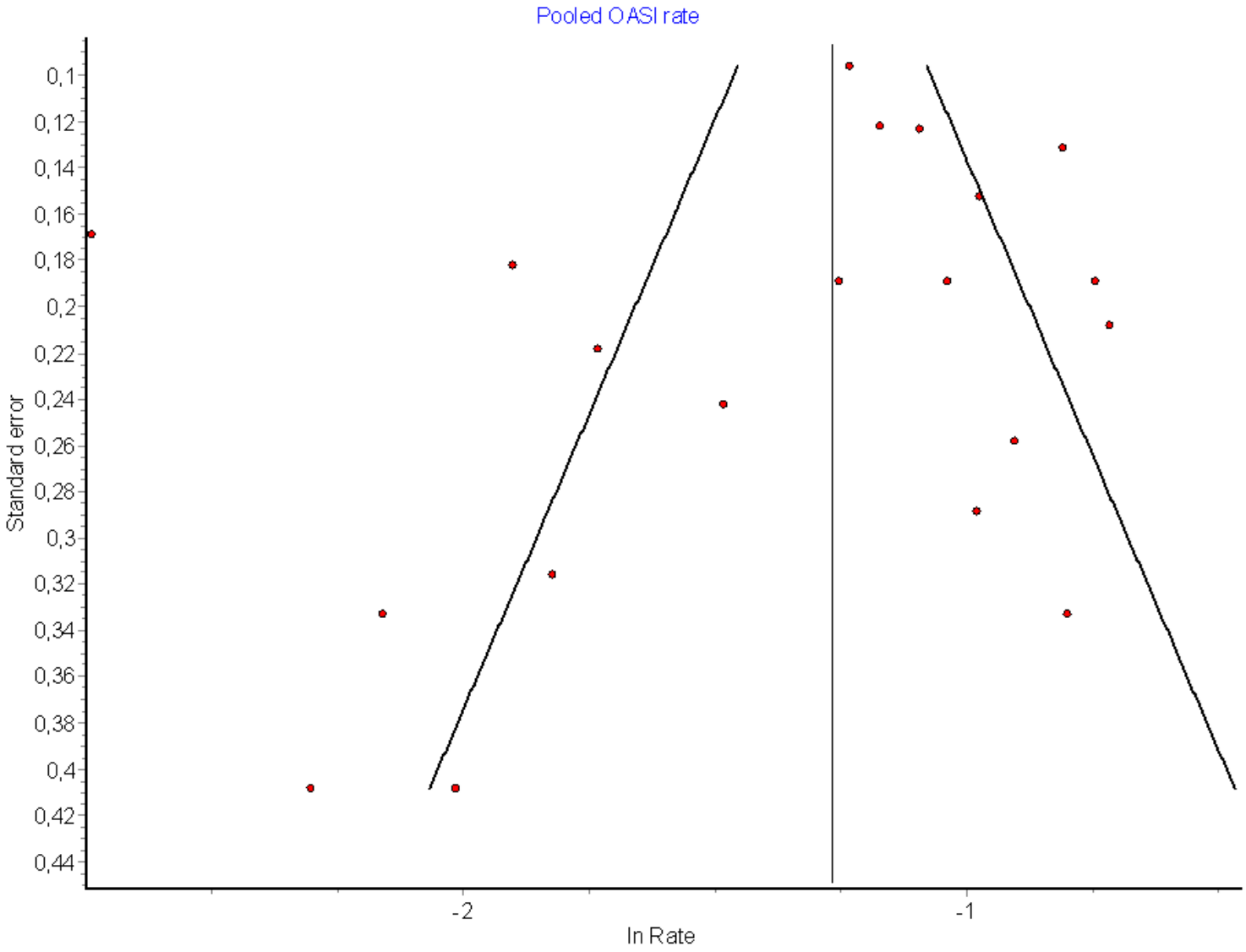

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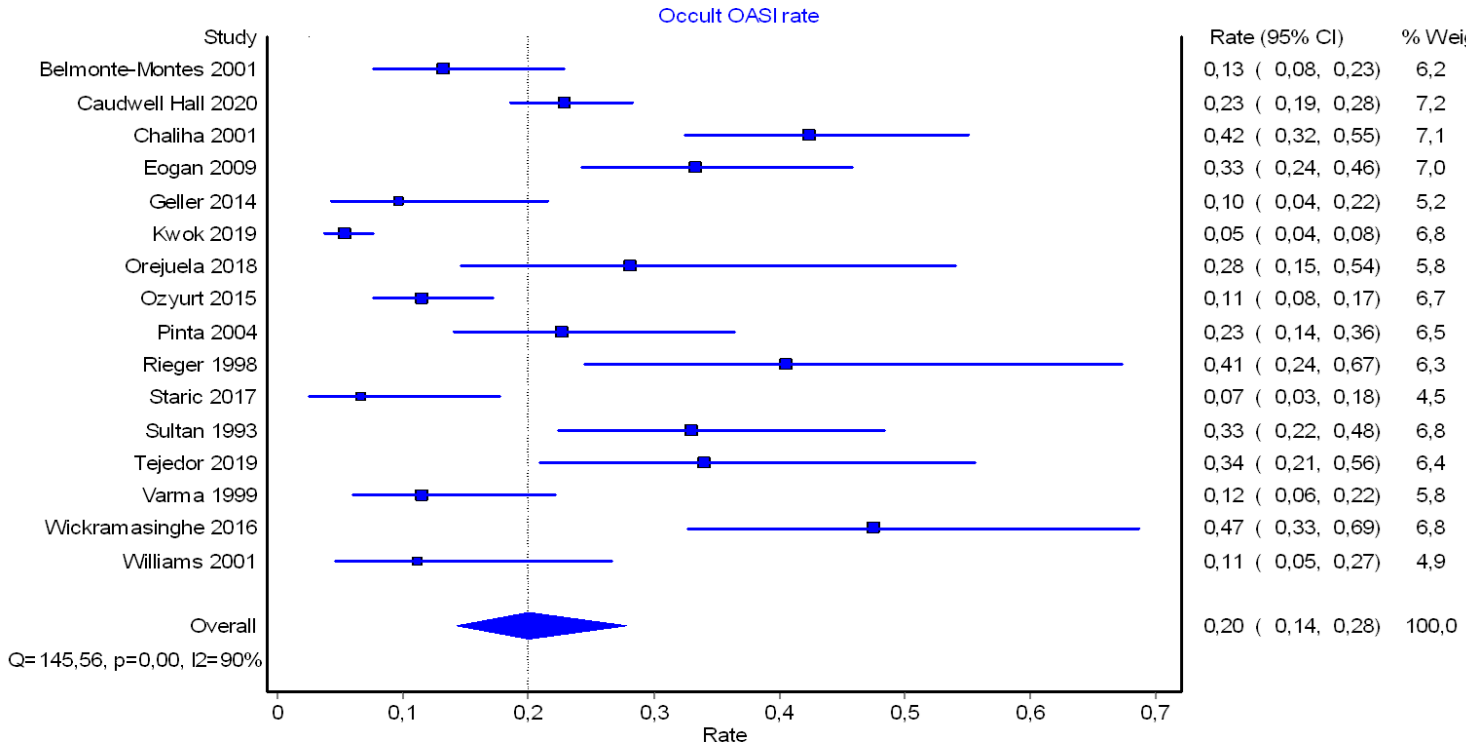

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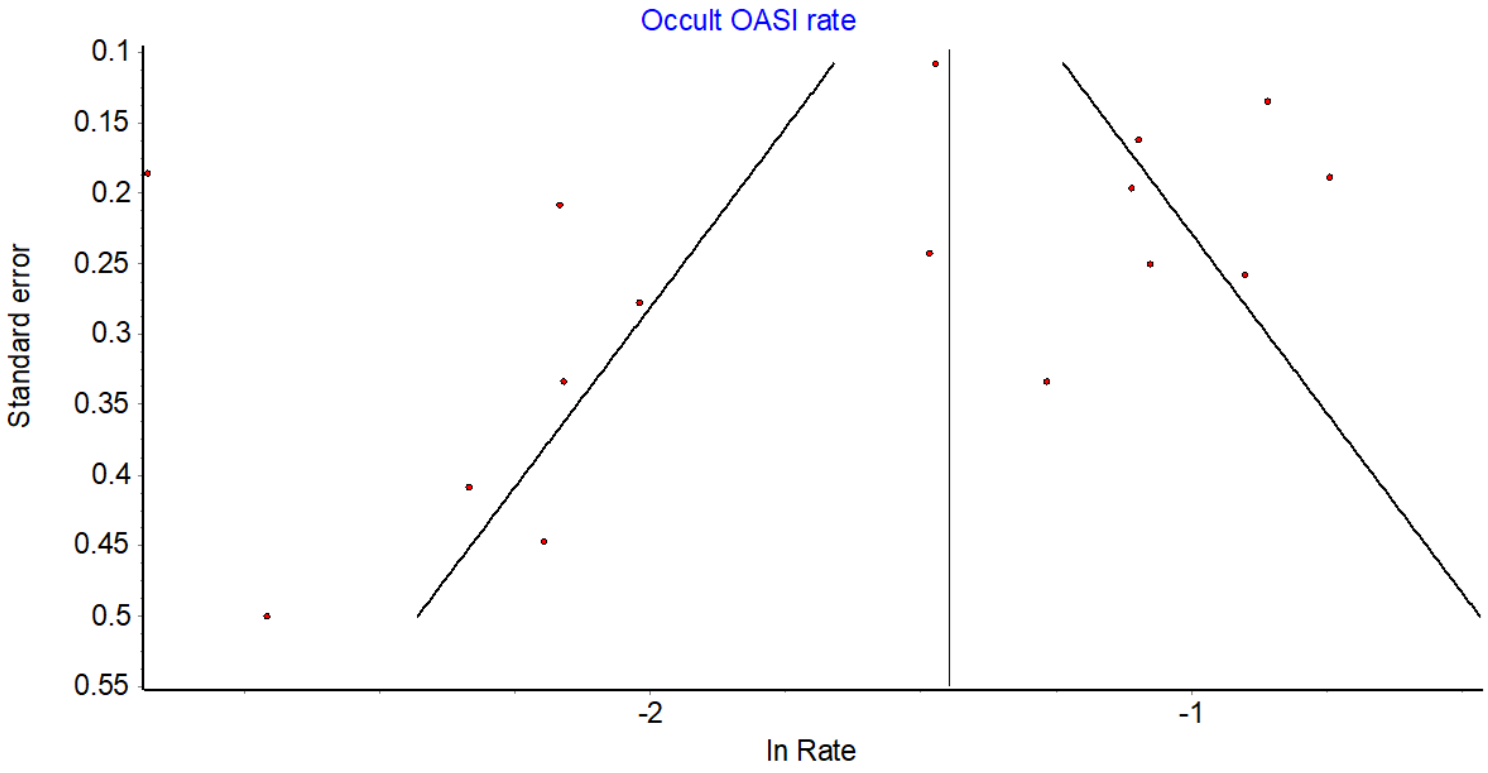

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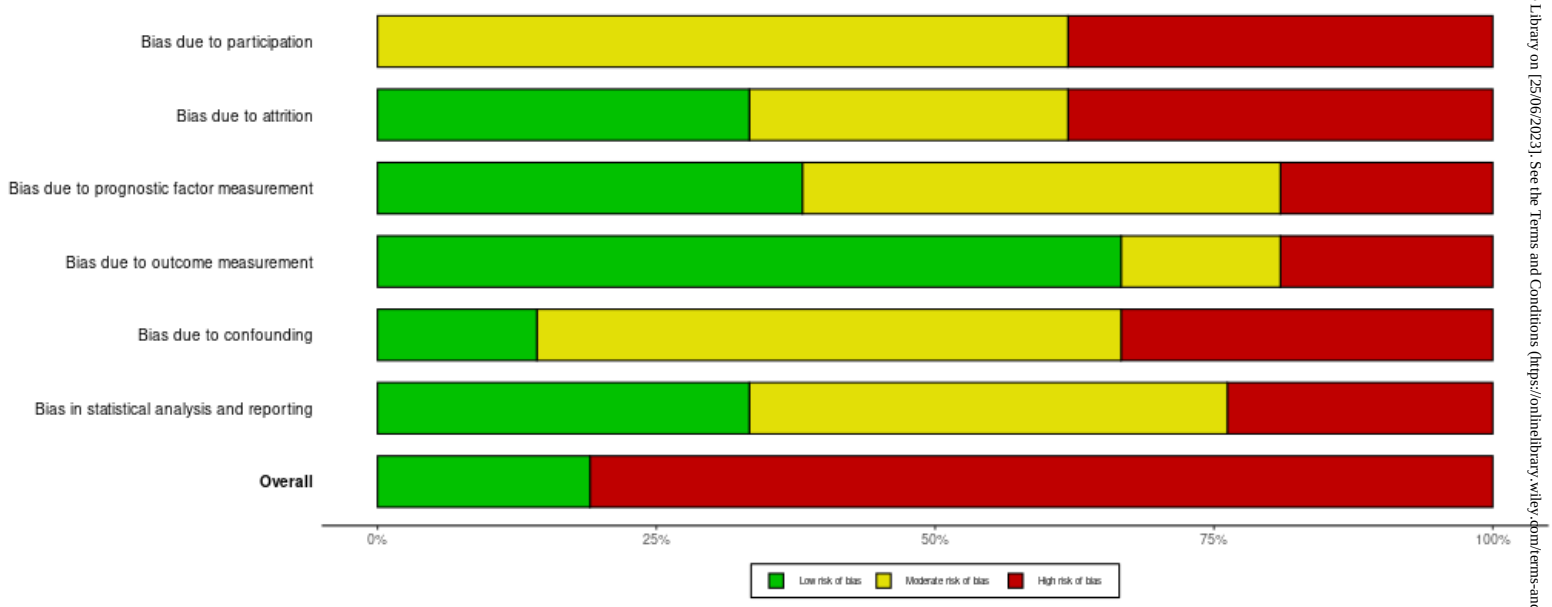
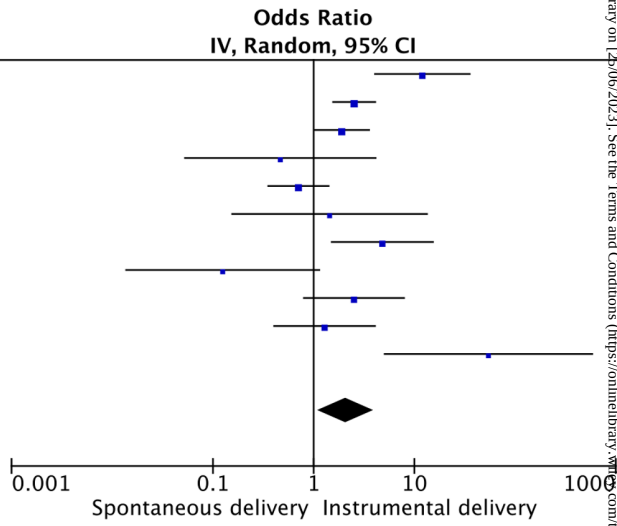


UOG_26292_UOG-2023-0285.R1_Figure 6.png

Study or Subgroup	IVD Events	IVD Total	SVD Events	SVD Total	Weight	Odds Ratio IV, Random, 95% CI
Belmonte-Montes 2001	16	23	12	75	10.3%	12.00 [4.07, 35.39]
Caudwell Hall 2020	45	103	63	268	13.6%	2.52 [1.56, 4.08]
Damon 2005	27	62	39	135	12.9%	1.90 [1.02, 3.55]
Geller 2014	1	11	9	51	5.4%	0.47 [0.05, 4.12]
Kwok 2019	19	337	16	205	12.6%	0.71 [0.35, 1.41]
Ozyurt 2015	1	5	29	196	5.2%	1.44 [0.16, 13.34]
Pinta 2004	9	20	8	55	9.9%	4.81 [1.51, 15.28]
Rieger 1998	1	9	14	28	5.3%	0.13 [0.01, 1.14]
Sultan 1993	8	15	20	64	10.0%	2.51 [0.80, 7.89]
Tejedor 2019	11	21	12	26	9.9%	1.28 [0.41, 4.06]
Varma 1999	4	5	5	73	4.8%	54.40 [5.07, 583.13]
Total (95% CI)		**611**		**1176**	**100.0%**	**2.13 [1.13, 4.01]**
Total events	142		227			

Heterogeneity: $Tau^2 = 0.71$; $Chi^2 = 38.45$, df = 10 ($P < 0.0001$); $I^2 = 74\%$

Test for overall effect: Z = 2.33 (P = 0.02)



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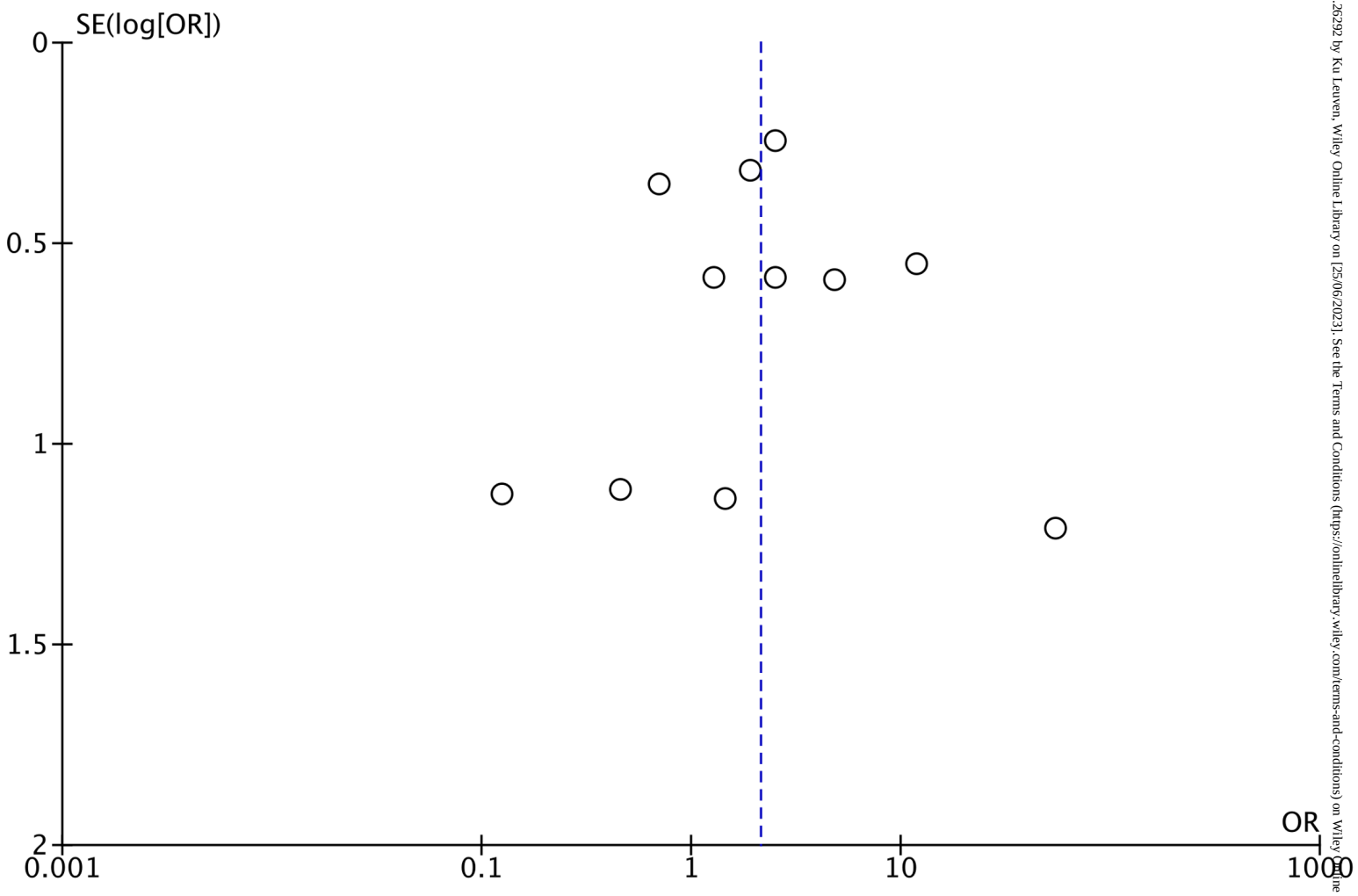
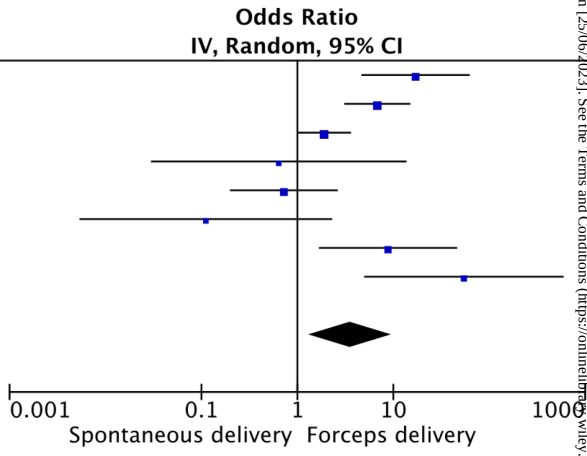


UOG_26292_UOG-2023-0285.R1_Figure 8.png

Study or Subgroup	IVD Events	IVD Total	SVD Events	SVD Total	Weight	Odds Ratio IV, Random, 95% CI
Belmonte-Montes 2001	13	17	12	75	14.6%	17.06 [4.75, 61.33]
Caudwell Hall 2020	23	34	63	268	17.2%	6.80 [3.14, 14.72]
Damon 2005	27	62	39	135	17.8%	1.90 [1.02, 3.55]
Geller 2014	0	3	9	51	6.9%	0.64 [0.03, 13.43]
Kwok 2019	3	52	16	205	14.6%	0.72 [0.20, 2.58]
Rieger 1998	0	4	14	28	7.0%	0.11 [0.01, 2.26]
Sultan 1993	8	10	20	64	12.7%	8.80 [1.71, 45.24]
Varma 1999	4	5	5	73	9.2%	54.40 [5.07, 583.13]
Total (95% CI)		**187**		**899**	**100.0%**	**3.56 [1.31, 9.67]**
Total events	78		178			

Heterogeneity: $Tau^2 = 1.36$; $Chi^2 = 30.89$, df = 7 ($P < 0.0001$); $I^2 = 77\%$

Test for overall effect: Z = 2.49 (P = 0.01)

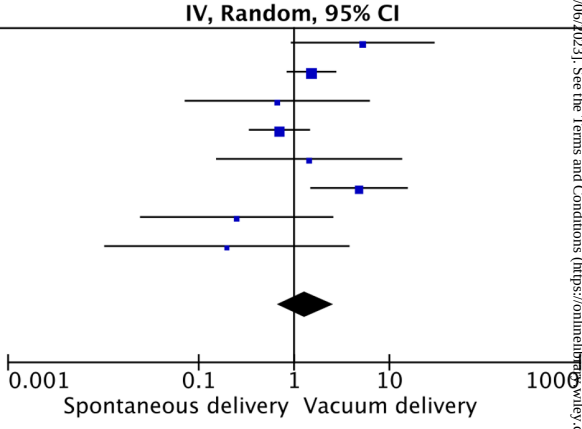


UOG_26292_UOG-2023-0285.R1_Figure 9.png

Study or Subgroup	IVD Events	IVD Total	SVD Events	SVD Total	Weight	Odds Ratio IV, Random, 95% CI
Belmonte-Montes 2001	3	6	12	75	10.5%	5.25 [0.94, 29.18]
Caudwell Hall 2020	22	69	63	268	24.7%	1.52 [0.85, 2.72]
Geller 2014	1	8	9	51	7.3%	0.67 [0.07, 6.11]
Kwok 2019	16	285	16	205	22.6%	0.70 [0.34, 1.44]
Ozyurt 2015	1	5	29	196	7.2%	1.44 [0.16, 13.34]
Pinta 2004	9	20	8	55	16.2%	4.81 [1.51, 15.28]
Rieger 1998	1	5	14	28	6.8%	0.25 [0.02, 2.53]
Sultan 1993	0	5	20	64	4.6%	0.20 [0.01, 3.74]
Total (95% CI)		**403**		**942**	**100.0%**	**1.32 [0.66, 2.63]**
Total events	53		171			

Heterogeneity: $Tau^2 = 0.41$; $Chi^2 = 14.45$, df = 7 (P = 0.04); $I^2 = 52\%$

Test for overall effect: Z = 0.80 (P = 0.43)

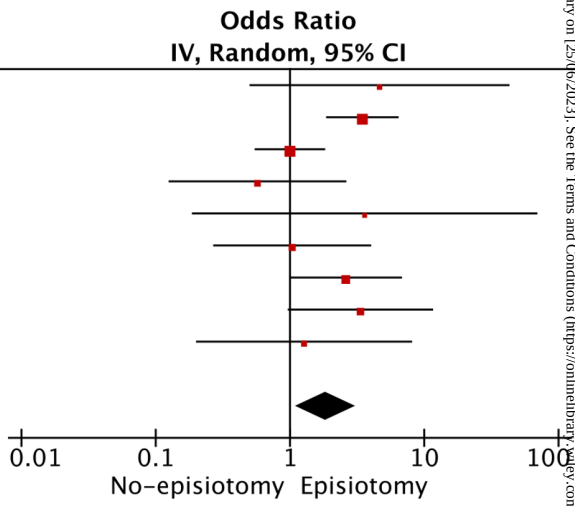


UOG_26292_UOG-2023-0285.R1_Figure 10.png

Study or Subgroup	log[Odds Ratio]	SE	Weight	Odds Ratio IV, Random, 95% CI
Drusany Staric 2017	1.5353	1.1288	4.5%	4.64 [0.51, 42.42]
Guzman Rojas 2013	1.2413	0.3085	21.4%	3.46 [1.89, 6.33]
Guzman Rojas 2020	-0.0012	0.2999	21.7%	1.00 [0.55, 1.80]
Kwok 2019	-0.5578	0.7689	8.2%	0.57 [0.13, 2.58]
Pinta 2004	1.2804	1.5025	2.7%	3.60 [0.19, 68.39]
Rieger 1998	0.0377	0.6825	9.7%	1.04 [0.27, 3.96]
Sultan 1993	0.9566	0.4833	14.8%	2.60 [1.01, 6.71]
Tejedor 2019	1.2085	0.6272	10.9%	3.35 [0.98, 11.45]
Williams 2001	0.2412	0.9363	6.1%	1.27 [0.20, 7.98]
Total (95% CI)			**100.0%**	**1.85 [1.11, 3.06]**

Heterogeneity: $Tau^2 = 0.22$; $Chi^2 = 13.80$, df = 8 (P = 0.09); $I^2 = 42\%$

Test for overall effect: Z = 2.38 (P = 0.02)



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