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Full length article

Obstetric risk factors for levator ani muscle avulsion: A systematic review and *meta*-analysis☆

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ABSTRACT

Objectives: Women have a 11% lifetime risk of undergoing surgery for vaginal prolapse. Levator ani muscle (LAM) avulsion is one etiological factor associated with primary and recurrent pelvic organ prolapse. Pelvic organ prolapse has been shown to greatly affect the quality of life and well-being of women. Conduct a meta-analysis identifying risk factors associated with LAM avulsion recognised on transperineal ultrasound (TPUS) or magnetic resonance imaging (MRI) in primiparous women after vaginal birth.

Study design: OVID Medline, Embase and the Cochrane Library from inception to January 2021 were searched. Review Manager 5.3 (The Cochrane Collaboration) was used to analyse data. Odds ratios (OR) with 95% confidence intervals (95% CIs) were calculated. The heterogeneity among studies was calculated using the I^2 statistic.

Results: Twenty-five studies were eligible for inclusion (n = 9333 women). Major LAM avulsion was diagnosed in an average of 22 % (range 12.7–39.5 %) of cases. Twenty-two studies used TPUS and three used MRI to diagnose avulsion. Modifiable and non-modifiable risk factors were identified. Significant predictors identified were forceps (OR 6.25 [4.33 – 9.0]), obstetric anal sphincter injuries (OR 3.93 [2.85–5.42]), vacuum (OR 2.41 [1.40–4.16]), and maternal age (OR 1.06 [1.02–1.10]).

Conclusions: This is the first meta-analysis of both modifiable and non-modifiable risk factors associated with LAM avulsion. This information could be used to develop a clinically applicable risk prediction model to target postnatal women at risk of LAM avulsion with a view to prevent the onset of pelvic floor organ prolapse.

Introduction

Levator ani muscle (LAM) avulsion, defined as the detachment of the puborectalis muscle from its insertion at the pubic rami, mainly occurs during the first vaginal delivery [1] with an incidence of 10–36 % [2–8]. This detachment can be unilateral or bilateral and either complete or partial with an associated loss of muscle bulk. It is a risk factor for pelvic floor organ prolapse and may have associated symptoms such as urinary incontinence, reduced vaginal sensation, vaginal laxity and anal incontinence [9–12]. These lesions are associated with an increased risk of prolapse recurrence after reconstructive surgery [13,14].

LAM avulsion has an important role in prolapse pathophysiology, particularly major LAM [15]. Identification of risk factors for LAM avulsion could enable modification of obstetric practice, to minimise its consequences. There have been several studies investigating risk factors for LAM avulsion. Various obstetric factors have been previously reported to be associated with LAM injury including assisted vaginal birth [8], particularly forceps [3,8,16–29], lower body mass index (BMI) [6,16,17], prolonged second stage of labor [3,5,16,18,19], increased maternal age [2,17,20–23], increased birthweight [22], increased fetal head circumference [5], mediolateral episiotomy [21] and obstetric anal sphincter injury (OASI) [3,18,24]. Protective factors include epidural analgesia [7] and increased BMI [16].

Magnetic Resonance Imaging (MRI) was the first imaging technique to evaluate LAM injury [25]. MRI is non-invasive without ionising radiation. Soft tissue and pelvic muscles can be visualised by MRI in different orthogonal planes [25]. Transperineal Ultrasound (TPUS) [26] has also become a popular modality used to assess the LAM and has a

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few advantages. TPUS is easily accessible and can be used in outpatient settings. It is also widely available in obstetrics and gynaecology units and is at no additional cost after the ultrasound machine is obtained [26]. Van Gruting et al compared the accuracy of MRI and pelvic floor ultrasound for diagnosis of LAM avulsion and demonstrated that although TPUS has a high specificity, MRI has a higher sensitivity to diagnose LAM avulsion [27].

Surgical repair of LAM avulsion has been shown to be unsuccessful and its impact on prolapse recurrence and hiatal dimensions is generally underwhelming [28]. Hence, identifying risk factors for levator avulsion may be important as a way to prevent these injuries from occurring.

The aim of this systematic review and meta-analysis was to assess the current published literature to identify modifiable and non-modifiable risk factors associated with LAM avulsion diagnosed on TPUS and MRI.

Materials and methods

Eligibility criteria, information sources and search strategy

This systematic review of the literature was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guideline [29]. Meta-analysis of Observational Studies in Epidemiology (MOOSE) guidelines for reporting meta-analyses of observational studies were also followed [30] (Appendix S1). A protocol was developed and can be reviewed in the international prospective register of systematic reviews (PROSPERO) register [31]. The PRISMA statement and checklist were followed throughout the review preparation, conduct and reporting (Appendix S2). Patients were not involved in the development of this review.

Our primary review question was “What are the risk factors associated with major levator avulsion following vaginal delivery diagnosed with MRI/TPUS?”. OVID Medline, Embase and the Cochrane Library from database inception to January 2021 were searched electronically using the terms “levator ani”, “pubococcygeus”, “iliococcygeus”, “puborectalis”, “coccygeus muscle”, “risk factor”, “avulsion”, “transperineal ultrasound”, “magnetic resonance imaging”, including medical subject headings (meSH) terms, with no restriction on language or year of publication. A manual search of references from identified studies was also conducted to identify other relevant studies. Other relevant systematic reviews of risk factors for LAM avulsion and the reference lists of the eligible studies were also searched [32]. A full search strategy can be found in Appendix S3. Results were exported to the Endnote reference management system and de-duplicated.

Only studies reporting major LAM avulsion diagnosed by TPUS/MRI were included. The definition of major LAM avulsion on tomographic ultrasound imaging is if all the three central slices are abnormal [15], whilst with MRI if there is evidence of complete unilateral avulsion or If at least ≥ 50 % of the expected muscle bulk is missing bilaterally [25]. Studies reporting major LAM avulsion diagnosed by TPUS/MRI were included. Studies were included if they reported risk factors associated with major LAM avulsion using risk point estimate reported as an odds ratio (OR), or data was presented such that an OR could be calculated, the 95 % confidence interval (CI) was reported, or data was presented such that the CI could be calculated. The following additional eligibility criteria were also applied: Randomised controlled trials (RCTs), non-randomised controlled trials, prospective and retrospective observational studies analysing the risk factors associated with major LAM avulsion using MRI/TPUS. Case reports, case series, narrative reviews and conference abstracts were excluded. To avoid potential bias, only studies which evaluated primiparous women with major LAM (diagnosed with MRI/TPUS) following vaginal birth were included. No funding was required to complete this review.

Study selection

Two independent reviewers (KW and NAO) screened the titles and abstracts of all retrieved studies using the Rayyan software package [33] to obtain studies for full text assessment. Disagreement about study selection was resolved through consensus or by the senior reviewers. Two independent reviewers (KW and NAO) assessed each of the selected articles against the inclusion/exclusion criteria independently.

Any disagreements surrounding eligibility for full text assessment were resolved by the senior reviewers. Following this, the two authors assessed the full text articles which met the inclusion criteria. Authors of included studies were contacted if the full text could not be retrieved. In addition, if reported data was incomplete, unclear or published in a manner that was not extractable, these studies were excluded. Translations were sought for any study not in English.

Data extraction and synthesis

The authors (KW and NAO) independently collected data from eligible studies using a standardised electronic data extraction form in an Excel spreadsheet. Data extracted included study characteristics (first author, publication year, study design, setting, sample size, mode of delivery, imaging modality used, risk factors identified) and outcome measures (risk of LAM). Any disagreements were resolved through consensus or the senior reviewers.

Review Manager 5.3 (The Cochrane Collaboration) and Meta-Essentials (Version 1.5) was used to analyse the data. Results were pooled and a *meta*-analysis was performed if each outcome was represented in at least two studies [34], using the fixed-effects (Mantel-Haenszel) or the random-effects (DerSimonian and Laird) model. Subgroup analyses were performed to determine potential sources of methodological heterogeneity, by separating participant data by study type (prospective or retrospective) if there were at least two studies in each subgroup. A p-value of < 0.05 was considered statistically significant. The heterogeneity among studies was calculated using the I^2 statistic. An $I^2 > 50$ % was considered significant heterogeneity and $I^2 > 80$ was considered very significant heterogeneity. A random-effects model was used if heterogeneity was significant ($I^2 > 50$ %). For each outcome odds ratios (OR) with 95 % confidence intervals (95 % CIs) were calculated.

Assessment of risk of bias

Two independent reviewers (KW and NAO) used the relevant Joanna Briggs Institute Prevalence Critical appraisal Tool to assess the risk of bias and methodological quality of the included studies [35]. The quality assessment was used to examine the methodological adequacy of the included studies. In addition, aid in the analysis interpretation of the meta-analyses findings and potential biases due to study heterogeneity. If there was significant risk of study bias, suggesting heterogeneity within the study population, a random-effects model was used for meta-analysis. Any disagreements surrounding risk of bias assessment were resolved by the senior reviewers or through consensus-based discussion.

Results

Study selection

The search strategy identified 143 articles, five additional studies were identified for further examination after hand-searching reference lists from previous systematic reviews and included studies. After removal of duplicates, and screening of study titles and abstracts, 34 were selected for full-text review (Fig. 1). Twenty-five studies were eligible and included in the meta-analysis (Fig. 1). A full list of excluded studies is given in Appendix S4.

Study characteristics

Table 1 describes the characteristics of the included studies. Based on

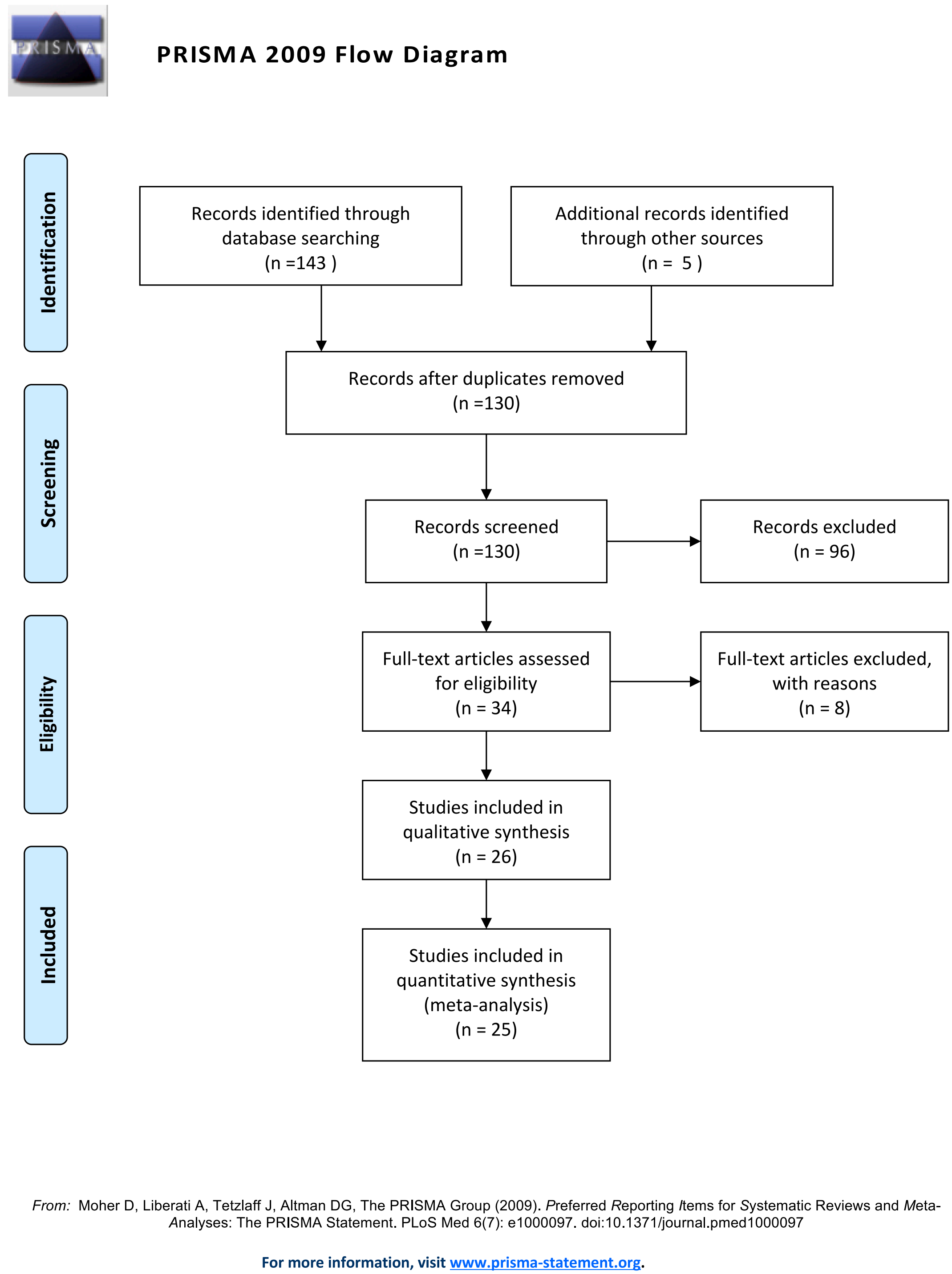

Fig. 1. PRISMA flow diagram of literature search.

the inclusion criteria, 9333 women were included in this review (range = 42–1125) from 21 prospective observational studies and 4 retrospective observational studies. All articles included an evaluation of major LAM injuries. Twenty-two studies used TPUS for the diagnosis of major LAM avulsion, and three diagnosed major LAM avulsion based on MRI. All 25 studies identified one or more risk factors.

Synthesis of results

Major LAM avulsion was diagnosed in an average of 22 % (range 12.7–39.5 %) of cases. The modifiable and non-modifiable risk factors for major LAM avulsion are described in Table 2. Risk factors associated with levator avulsion were compared between spontaneous vaginal birth and assisted vaginal birth. Meta-analyses demonstrated that the odds of major LAM avulsion following forceps-assisted birth increased six-fold when compared with spontaneous vaginal birth (OR 6.25 [95 % CI: 4.33–9.0]) (Fig. 2). No statistically significant subgroup effect was found between studies prospective ($n = 9$) or retrospective ($n = 3$) in design ($p = 0.49$) and heterogeneity remained low within each subgroup.

Vacuum-assisted birth doubled the odds of major LAM avulsion when compared with spontaneous vaginal birth (OR 2.41 [95 % CI

Table 1
Overview of included studies.

Authors (year)	Study type	Imaging type	Sample size	Follow up period post delivery	Risk factors
Cassado (2020) [48]	Prospective	TPUS	322	12 months	Forceps 12.31 (5.65–26.80) Vaccum 4.784 (2.153–10.631)
Halle (2020) [49]	Prospective	TPUS	300	12 months	Vaccum 3.0 (1.0–9.0) Length of second stage 1.004 (0.993–1.014) Birth weight 1.004 (0.993–1.014)
Yousef (2019) [50]	Prospective	TPUS	262	6 months	Fundal pressure 2.5 (1.29–4.51)
Volloyhaug (2019) [51]	Prospective	TPUS	250	3 months	Forceps 4.35 (2.56–7.39)
Urbankova (2019) [52]	Prospective	TPUS	987	12 months	Forceps 3.22 (1.54–8.22) Prolonged second stage 0.992 (0.986–0.998) BMI Index 1.066 (1.010–1.125)
Kamisan (2019) [53]	Retrospective	TPUS	502	6 months	Forceps 5.24 (2.27–12.08) Vaccum 1.0038 (0.5049 to 1.9957)
Martinho (2018) [54]	Prospective	TPUS	1125	3 years	Birthweight 1.36 (1.04–1.78)
Caudwell-Hall (2018) [55]	Retrospective	TPUS	844	6 months	Maternal age 1.05 (1.01–1.1) Body Mass Index 0.94 (0.89–0.99)
Caudwell-Hall (2017) [56]	Retrospective	TPUS	844	3 months	Forceps 2.9 (1.3–6.7) Prolonged second stage 1.03 (1.02–1.05) OASIs 3.2 (1.5–6.4)
Gonzalez (2017) [57]	Prospective	MRI	75	12 months	OASI is not a risk factor for LAM avulsion
Garcia-Mejido (2017) [58]	Prospective	TPUS	146	6 months	Vaccum 3.99 (1.53–10.42)
Shek (2016) [59]	Retrospective	TPUS	796	5 months	OASIs 3.44 (1.47–8.03) Vaginal sidewall tear 3.35 (1.30–8.61)
Valsky (2016) [60]	Prospective	TPUS	558	18 months	Length of second stage 3.05 (1.5–6.1) OASIs 4.12 (2.1–8.1)
Chung (2015) [61]	Prospective	TPUS	289	8 weeks	Forceps 3.54 (1.72–7.26)
Durnea (2015) [62]	Prospective	TPUS	202	1 year	Forceps 4.9 (1.44–16.97 Prolonged second stage 1.01 (1.00–1.02)
van Delft (2014) [63]	Prospective	TPUS	191	3 months	Forceps 6.6 (2.5–17.2) Second stage of labour 2.2 (1.4–3.3) OASIs 4.4 (1.6–12.1)
Low (2014) [64]	Retrospective	MRI	90	6 months	Maternal age 1.093 [1.012–1.180] Length of second stage 1.089 [1.005–1.180] OASIs 2.708 [0.986–7.433] Episiotomy 2.71 [1.0–1.34]
Chan (2012) [65]	Prospective	TPUS	339	2 months	Forceps 5 [1.13–22.04]
Cassado (2011) [66]	Prospective	TPUS	180	4 months	Forceps 10.3 [3–35.36]
Albrich (2011) [67]	Prospective	TPUS	157	3 days	Vaccum 1.6905 [0.4432–6.4473]
Cassado (2011) [68]	Prospective	TPUS	164	9 months	Forceps 10.3 [3–37.4]
Kearney (2010) [69]	Retrospective	MRI	37	1 year	Forceps 11 [3.5–35] Prolonged second stage 2.3 [0.64–8.7]
Shek (2010) [70]	Prospective	TPUS	488	4 months	Forceps 3.83 [1.34–10.94] OP 3.86 [0.95–15.7]
Valsky (2009) [71]	Prospective	TPUS	210	3 days	Birth weight (when > 90th centile) 3.66 [1.49–8.99] Length of second stage of labour 3.55 [1.39–9.02] Head circumference 3.343 [1.33–8.42]
Kearney (2006) [72]	Prospective	MRI	160	12 months	Forceps 14.7 [4.9–44.2] OASIs 8.1 [3.3–19.5] Episiotomy 3.1 [1.4–7.2]

Table 2
Modifiable and non-modifiable risk factors for levator ani muscle avulsion.

Risk factors (number of studies)	OR [95 % CI]
Modifiable risk factors	
Forceps delivery (compared with normal vaginal delivery) (n = 12) [18,52,53,72–78,7,8]	6.25 [4.33 – 9.0]
Vaccum delivery (compared with normal vaginal delivery) (n = 5) [58,73,79,80,8]	2.41 [1.40–4.16]
Non-modifiable risk factors	
Obstetric anal sphincter injuries (n = 5) [18,19,21,63,81]	3.93 [2.85–5.42]
Maternal age (n = 2) [17,43]	1.06 [1.02–1.10]

1:40–4.16]) (Fig. 3). The studies reporting the risk of LAM avulsion with vacuum-assisted birth were all prospective in design.

Other factors associated with major LAM avulsion included OASIs (n = 5 studies) (OR 3.93, 95 % CI: 2.85–5.42) and maternal age (n = 2 studies) (OR 1.06, 95 % CI: 1.02–1.10). With OASIs, the test for subgroup differences indicated there is no statistically significant subgroup effect between studies prospective (n = 3) or retrospective (n = 2) in design (p = 0.42) and heterogeneity remained low within each subgroup.

No significant association found between Major LAM avulsion and birth weight or length of second stage (Figs. 4 and 5). Other risk factors identified from the literature, but reported in fewer than two studies included episiotomy, head circumference, occiput posterior position, lateral vaginal wall tear and fundal pressure.

Risk of bias of included studies

Fig. 4 described the results of the risk of bias assessment. Assessment of the included studies exposed inadequacies in several methodological areas. 44 % (n = 11) of the studies had a high or unclear risk of bias across one or more assessed element.

Discussion

This meta-analysis showed that major LAM avulsion was diagnosed in an average of 22 % (range 12.7–39.5 %) of cases. We only included major LAM avulsions in the meta-analysis as these are the type of defects that were more significantly associated with symptoms and signs of female pelvic organ prolapse [15]. Forceps- assisted birth was found to be the strongest modifiable risk factor for major LAM avulsion. Compared

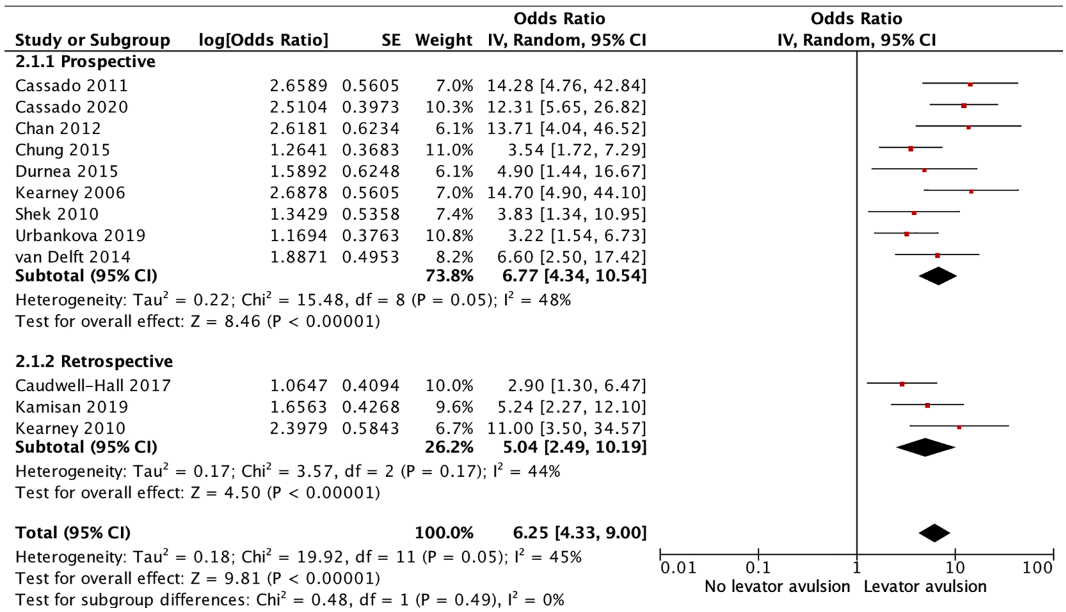

Fig. 2. Meta-analysis of the association between mode of delivery and avulsion: forceps versus normal vaginal delivery. The size of the square correlates with study sample size. Test for heterogeneity $I^2 = 0.00$, p value = 0.98. Each study is shown by an odds ratio estimate with corresponding 95 % confidence interval.

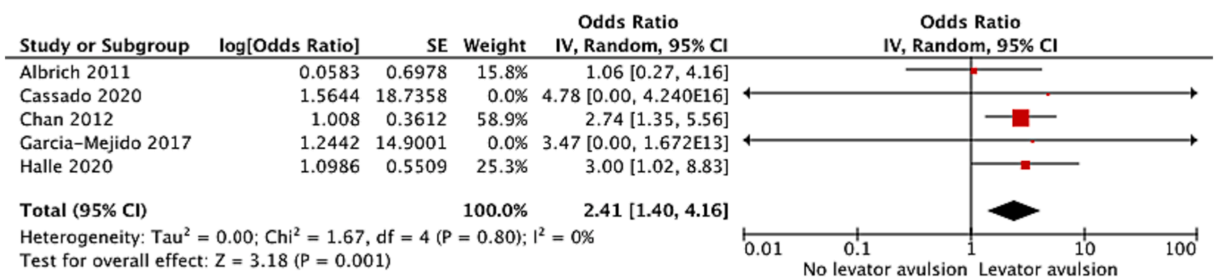

Fig. 3. Meta-analysis of the association between mode of delivery and avulsion: ventouse versus normal vaginal delivery. The size of the square correlates with study sample size. Test for heterogeneity $I^2 = 0.00$, p value = 0.98. Each study is shown by an odds ratio estimate with corresponding 95 % confidence interval.

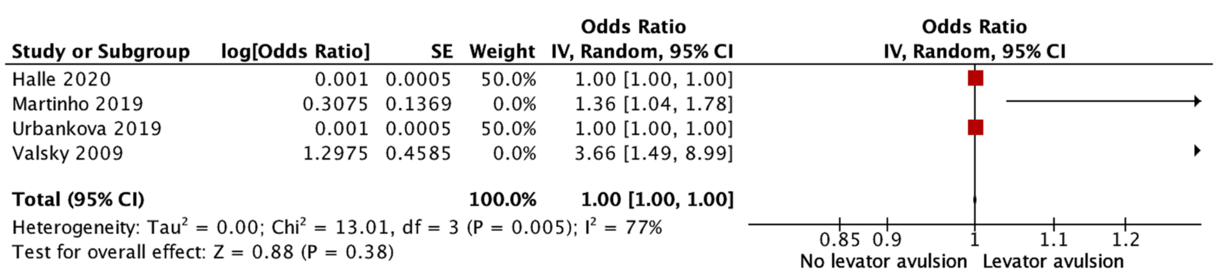

Fig. 4. Meta-analysis of the association between birth weight and avulsion:. The size of the square correlates with study sample size. Test for heterogeneity $I^2 = 0.00$, p value = 0.98. Each study is shown by an odds ratio estimate with corresponding 95 % confidence interval.

to a spontaneous birth, the odds of having a major LAM avulsion following a forceps-assisted birth increased 6-fold but doubled following a vacuum-assisted birth. Other associated factors were OASIs, and increased maternal age.

As forceps have been identified as an independent risk factor for LAM injury [32,36] the burden of associated pelvic floor dysfunction needs to be appraised. Our review corroborates previous evidence that LAM avulsion is associated with forceps-assisted births at a higher rate than other modes of birth [36]. The mechanism whereby forceps cause LAM avulsion is not fully understood. The association between LAM avulsion and forceps-assisted births may be due to many factors. Firstly, the forceps blades increase the size of the pelvic outlet by 12 %, increase delivery speed and so distension of the pelvic floor and perineum is faster compared to the vacuum or spontaneous vaginal birth. As less maternal effort is required [37], clinicians can inadvertently exert excessive traction force on the forceps resulting in pelvic floor and perineal trauma [38], which can also contribute to pudendal nerve damage [39]. Friedman et al. [32] conducted a meta-analysis to evaluate the association between mode of birth and the risk of LAM avulsion. They demonstrated that in comparison to spontaneous vaginal births, forceps-assisted birth increased the odds of LAM avulsion six-fold (OR 6.94 (4.93–9.78)). In addition, vacuum-assisted birth increased the odds of LAM avulsion by 31 % (OR 1.31 (1.00–1.72)). These findings were similar to the results of Rusavy et al whose meta-analysis showed that

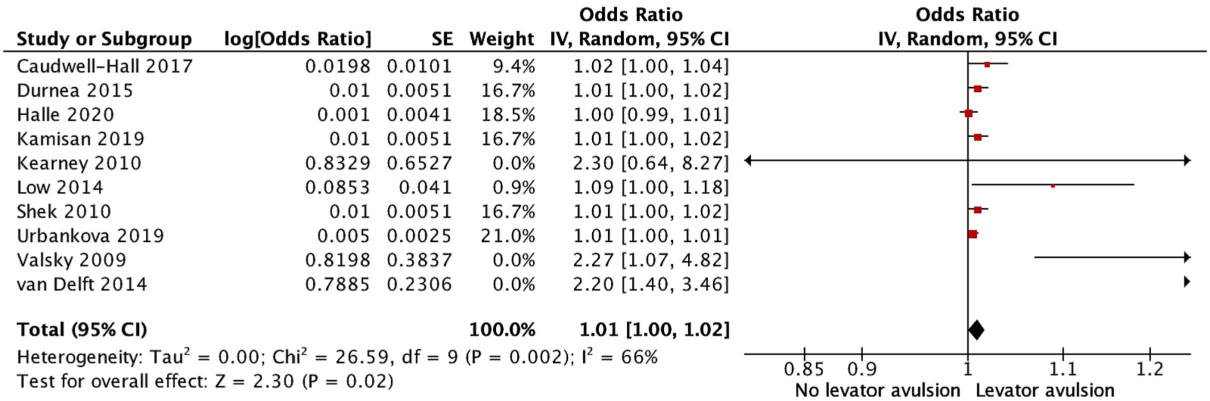

Fig. 5. Meta-analysis of the association between prolonged second stage and avulsion:. The size of the square correlates with study sample size. Test for heterogeneity $I^2 = 0.00$, p value = 0.98. Each study is shown by an odds ratio estimate with corresponding 95 % confidence interval.

assisted vaginal birth is also associated with LAM avulsion [36]. The author's demonstrated that the odds of LAM following vacuum-assisted and forceps birth compared with spontaneous vaginal birth were increased approximately two (OR 1.66 (0.99–2.79)) and six-fold (OR 6.32 (4.56–8.76)) respectively. Our meta-analysis and that performed by Rusavy's [36] only included studies evaluating LAM avulsion after first vaginal birth thereby ensuring that the LAM avulsion was directly attributable to that vaginal birth.

As we demonstrated that vacuum-assisted birth is associated with a lower risk of LAM avulsion than forceps, training in vacuum cup selection (soft or rigid cup) and correct cup placement to reduce failure is paramount, thereby avoiding the need for a second instrument (forceps). However, there are some instances that forceps may be the more appropriate choice of instrument, such as gestations below 32 weeks, fetal bleeding disorders and breech presentation [40]. Clinicians, therefore, need to be versatile in the use of both instruments. Obstetricians should also be made aware of the potential adverse effect a forceps-assisted birth can have on the pelvic floor. This will allow clinicians to counsel women appropriately so they are fully informed of the LAM avulsion risk, which may cause irreversible damage to the pelvic floor and potentially significantly impact their quality of life [41]. The optimal time to inform women is during the antenatal period, as the counseling process during the second stage of labor is limited due to maternal exhaustion and pain. This is particularly the case in an emergency situation there is not enough time for the woman to process the information and make an informed decision.

However, some risk factors are not modifiable, such as birthweight, OASIs, maternal age and body mass index. The anal sphincter and LAM are the two main pelvic floor structures that are involved during obstetric pelvic floor trauma. This meta-analysis showed that OASI is also associated with an increased risk of LAM avulsion. One of the plausible reasons to explain this association is that OASIs and levator avulsion share common risk factors, such as primiparity and forceps-assisted birth [18,21,22,42].

Maternal age [17,43] is associated with LAM avulsion. Changes in the biomechanical properties of pelvic floor connective tissues with age may explain the association between increased maternal age and trauma to the pelvic floor muscle [44–46]. Connective tissue may become less elastic and more susceptible to trauma during ageing [44], due to the lack of collagen and estrogen, which may explain the association we demonstrated..

Strengths and limitations

In this meta-analysis we evaluated modifiable and non-modifiable obstetric risk factors for LAM avulsion. The strengths of this meta-analysis firstly include its thorough and systematic approach. Moreover, we included a large sample size of 25 studies, published over a time span of 14 years, including over 9000 patients. In addition, a comprehensive search of studies was conducted with no language or date restrictions.

However, we acknowledge that there are some limitations to our review. Firstly, only non-randomised studies were included, of which many did not perform multivariate regression analysis. This meant that as the crude data was not available for most studies, the reported unadjusted odd-ratios were used when pooling effects for *meta*-analysis. Therefore causality cannot be established and confounding factors cannot be accounted for. Various risk factors have been identified to be associated with LAM avulsion. We understand that these factors are interrelated. For example, the indication for assisted vaginal birth could be secondary to a combination of factors, including a delayed second stage of labor and fetal birth weight. Therefore, isolating the accountable individual risk factor becomes difficult.

Furthermore, there was evidence of significant heterogeneity and risk of bias between studies in some of our analyses. This may a reflection of variation in obstetric practice between the studies, but also could be due to differences in the degree of expertise between the clinicians diagnosing the LAM avulsion. However our meta-analysis minimised this risk by only including major LAM avulsions where less discrepancies occur. We also acknowledge the potential effect heterogeneity has on the confidence in the outcome effect sizes, however this was controlled for by using a random-effects model when pooling data for meta-analysis.

Conclusions

This meta-analysis identified both modifiable and non-modifiable risk factors associated with LAM avulsion. We demonstrated that forceps-assisted births, vacuum-assisted births, maternal age and OASI are risk factors. However, assisted births convey the greatest risk for LAM avulsion. This information could help clinicians counsel women regarding the risk factors associated with LAM avulsion. Understanding these risk factors can inform intrapartum decision making with the goal of minimising the risk of LAM avulsion. This information can also allow clinicians to target women at risk of LAM avulsion postnatally and offer them focused pelvic floor muscle training which might prevent or at least delay the onset of pelvic floor organ prolapse [47]. The use of forceps carries a higher risk than vaccum-assisted birth, therefore training should focus on the choice and technique of this instrument to enhance the risk of success and minimise the use of forceps. Future studies should focus on identifying antepartum risk factors for levator avulsion and on modification of current obstetric practices to prevent levator trauma.

Brief summary

This meta-analysis demonstrated the modifiable and non-modifiable risk factors that are associated with LAM including forceps, obstetric anal sphincter injuries, vacuum and maternal age.

Author's contributions

K.W. Wong: Protocol/project development, data collection and management, data analysis, manuscript writing. **N. Okeahialam:** data analysis, manuscript editing. **A.H. Sultan:** Protocol/project development, manuscript editing. **R. Thakar:** Protocol/project development, manuscript editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ejogrb.2024.02.044.

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