

Systematic Review

Diagnosis of Levator Ani Muscle Avulsion in Instrumented Delivery: Meta-analysis

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Abstract

Objective: The objective of this meta-analysis was to establish the rates of levator ani muscle (LAM) avulsion in patients after forceps delivery (FD) and vacuum delivery (VD) as assessed by 3D/4D transperineal ultrasound. **Methods:** A systematic search was performed in the MEDLINE, PubMed, Google Scholar, and Embase databases up to December 31, 2021. Studies that studied primiparous women diagnosed with LAM avulsion by 3D/4D transperineal ultrasound in VD or FD were included. To do the meta-analysis, the jamovi project program version 2.2 (2021) was used. **Results:** The search yielded 1225 studies that met the MeSH criteria, of which 26 were included in the review. The estimated joint OR for VD vs. normal vaginal delivery (NVD) was 1.93 (95% CI: 1.31–2.86), for FD vs. NVD was 5.33 (95% CI: 3.78–8.11), and for FD vs. VD was 2.36 (95% CI: 1.46–3.84). **Conclusions:** Instrumented delivery with forceps or vacuum favors LAM avulsion. It is not possible to establish whether this injury is attributable to the specific instrument or to the type of delivery involved in the instrumentation itself.

Keywords: assisted birth; birth; forceps; labor; operative; parturition; pelvic floor; perineum; transperineal; ultrasound; vacuum; ventouse

1. Introduction

Levator ani muscle (LAM) avulsion is defined as the disconnection of levator muscle fibers from their insertion on the inferior pubic ramus [1]. It is present in 10–35% of women after a vaginal delivery [2]. The most critical moment for the appearance of LAM avulsion is when the vertex is at station + 3 or + 4 [3], where the area of the levator hiatus acquires its greatest size [4]. LAM avulsion is a diagnostic challenge: although it is sometimes exposed by a vaginal tear [5], most often is that it goes unnoticed during childbirth. Therefore, diagnostic imaging tests have been gaining relevance for the detection of LAM avulsion, such as magnetic resonance imaging (MRI) [6,7] and three-dimensional (3D) ultrasound [8]. Of the different modes of 3D ultrasound (introital and transperineal), transperineal or translabial ultrasound has shown a correlation with the diagnosis of LAM avulsion both clinically and by MRI [5]. The abdominal probes used in transperitoneal ultrasound also have clear advantages over vaginal transducers due to their larger size and better ergonomic properties of the perineal structures [9]. MRI is a less accessible test, is more expensive, and must be done in less anatomical postures, which leads us to think that transperineal ultrasound is the most desirable imaging test for the study of LAM avulsion.

As for the risk factors for LAM avulsion, instrumented delivery promotes it more than normal vaginal delivery (NVD). However, there are very different rates of LAM avulsion under forceps delivery (FD) vs. vacuum delivery (VD), possibly due to the lack of uniformity of the different study designs. Therefore, the objective of this meta-analysis was to establish the rates of LAM avulsion in patients after instrumented delivery (FD and VD), as assessed by 3D/4D transperineal ultrasound.

2. Methods

2.1 Study Protocol

For this meta-analysis, the guidelines collected for systematic reviews and meta-analysis of PRISMA 2020 were followed. The systematic search was performed in the MEDLINE, PubMed, Google Scholar, and Embase databases up to December 31, 2021. Our search was performed using the following medical subject heading (MeSH) terms: (Delivery, Obstetric/adverse effects OR Vacuum Extraction, Obstetrical/adverse effects OR Obstetrical Forceps/adverse effects OR Extraction, Obstetrical/adverse effects OR Delivery, Obstetric/methods OR Delivery, Obstetric/instrumentation) AND (Pelvic Floor/Diagnostic imaging OR Pelvic Floor/injuries OR Pelvic Floor Disorders/diagnostic imaging OR Soft Tis-



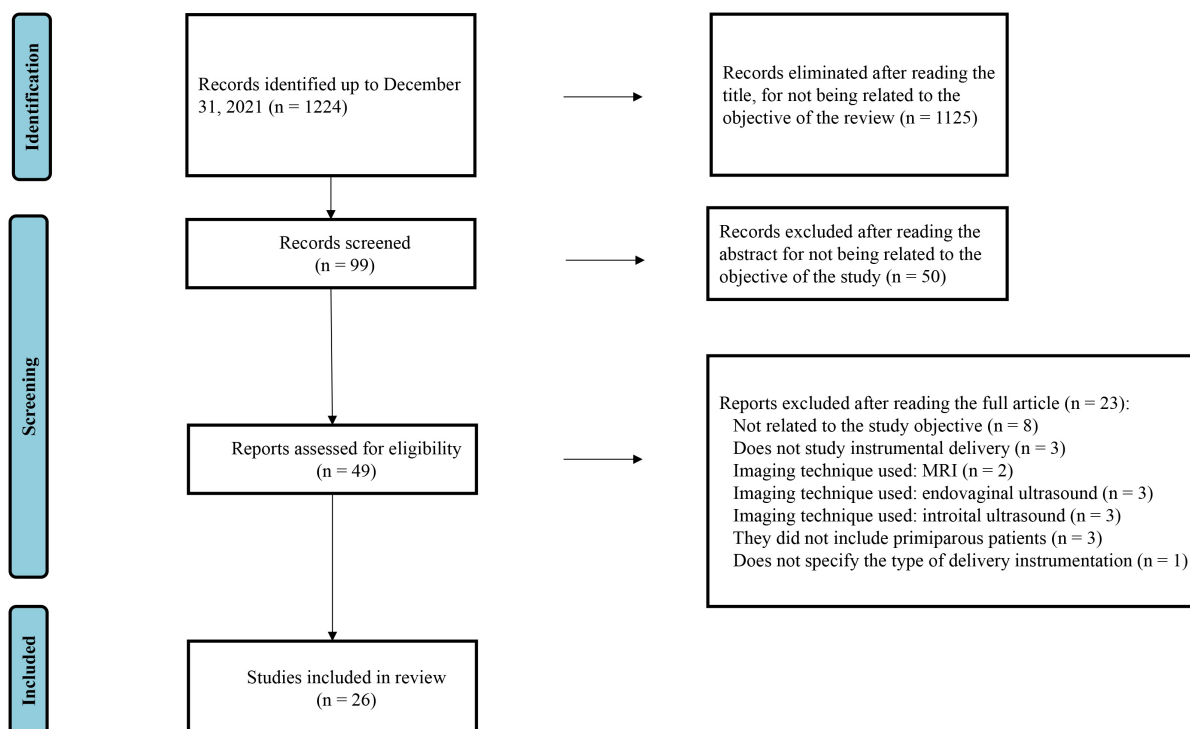


Fig. 1. PRISMA flow diagram.

sue Injuries/etiology OR Perineum/injuries OR Anal Canal/injuries. No language restrictions were applied. No ethical approval was needed since it was based on previously published medical literature.

2.2 Selection of Studies

Those studies that met the following criteria were included:

- They determined the rate of LAM avulsion with VD or FD.
- LAM avulsion was diagnosed by 3D/4D transperineal ultrasound.
- They included only primiparous patients.
- The data are presented in such a way that we could calculate the odds ratios (ORs) and the 95% confidence intervals (CIs).

2.3 Data Extraction

The information extracted from the selected articles (type of study; time of postpartum ultrasound; number of NVDs, VDs, and FDs; and the avulsion rates in NVD, VD, and FD) were included in an Excel calculation. Possible discrepancies arose in the selection of the studies as well as the information extracted from them, and a final consensus was reached between authors JAGM, AFP, and JASB. Those articles belonging to the same working group were assessed for the time periods in which the studies were carried out to verify that there was no bias due to the involuntary reanalysis of the same study.

2.4 Statistical Analysis

The statistical software jamovi version 2.2 (The jamovi project, <https://www.jamovi.org>) was used to analyze the data. The number of avulsions was summarized as incidence rates depending on the type of delivery performed (NVD, VD, or FD). A binary controlled study was done to calculate the number of LAM avulsions in the NVD group, the VD group, and the FD group. ORs, their logarithms, and their 95% CIs were determined to measure effect sizes. The results of all studies (ORs) were aggregated using a random-effects model. The ORs and prediction intervals were also obtained for the real results for the study of heterogeneity, and the estimation of τ^2 is provided, as are the Q value for heterogeneity and the I^2 statistic. Forest graphs were drawn. Results were analyzed using the logarithm of the OR. If heterogeneity was observed ($\tau^2 > 0$), the prediction interval for the real results was assessed. If the studies were atypical and/or influential in the context of the model, the studentized residuals and Cook's distances were applied. Those studies with a standard normal distribution and a studentized residual greater than the $(100 \times (1 - 0.05/(2k)) \times r)^{\text{th}}$ percentile were considered atypical. Those studies with Cook distances greater than the median plus 6 times the interquartile range of the Cook distances were considered influential. To check for asymmetry in the funnel plot, the rank correlation test and the regression test were used (the standard error of the results was used as a predictor).

Table 1. Prevalence for levator ani avulsion in FD and VD.

Author	Year	Type of Study	Follow up	Total n	n of NVD	% full avulsion in NVD	n of VD	% full avulsion in VD	n of FD	% full avulsion in FD	VD vs NVD OR (95% CI)	FD vs NVD OR (95% CI)	FD vs VD OR (95% CI)
Shek and Dietz [11]	2010	Prospective	3–4 months	367	186	13%	32	9%	20	35%	0.66 (0.18–2.39)	3.60 (1.32–9.97)	5.42 (1.19–24.78)
Albrich <i>et al.</i> [12]	2012	Prospective	2–3 days	157	70	38.5%	10	40%	1	100%	1.06 (0.28–4.14)	4.76 (0.19–121.51)	4.35 (0.14–132.95)
Chan <i>et al.</i> [13]	2012	Prospective	8 weeks	339	201	15.4	48	33.3%	14	71.4%	2.75 (1.35–5.58)	13.74 (4.06–46.53)	5.00 (1.35–18.36)
Araujo <i>et al.</i> [14]	2013	Prospective	24–48 hours	35	16	6.3%	-	-	9	22%	-	4.18 (0.32–54.05)	-
Van Deyt <i>et al.</i> [15]	2014	Prospective	3 months	191	92	9.8%	30	13%	21	48%	1.38 (0.39–4.90)	8.50 (2.83–25.53)	6.17 (1.58–24.29)
Thibault.Gagnon <i>et al.</i> [16]	2014	Prospective	5.2 months	294	160	14.4%	47	19.1%	22	40.9%	1.40 (0.6–3.29)	4.10 (1.58–10.70)	2.94 (0.96–8.94)
Michalec <i>et al.</i> [17]	2015	Retrospective	6–12 months	103	52	7.7%	51	11.8%	-	-	1.60 (0.42–6.05)	-	-
Memon <i>et al.</i> [18]	2015	Retrospective	10 years	73	-	-	28	18%	45	49%	-	-	4.39 (1.42–13.60)
Chung <i>et al.</i> [19]	2015	Prospective	2 months	289	-	-	247	16.6%	42	40.5%	-	-	3.42 (1.70–6.89)
Guedea <i>et al.</i> [20]	2015	Prospective	6 months	82	11	0%	14	50%	-	-	23.10 (1.14–464.05)	-	-
Durnea <i>et al.</i> [21]	2015	Prospective	1.8 years	202	-	6%	-	18%	-	55%	-	-	-
Michalec <i>et al.</i> [22]	2015	Retrospective	6 months	184	92	10%	92	12%	-	-	1.22 (0.49–3.10)	-	-
Caudwell-Hall <i>et al.</i> [23]	2017	Retrospective	5.1 months	844	452	13%	102	13%	55	44%	1.00 (0.53–1.90)	5.26 (2.89–9.58)	5.26 (2.39–11.47)
García-Mejido <i>et al.</i> [24]	2017	Prospective	36 months	105	51	9.8%	54	35.2%	-	-	6.00 (1.7–14.73)	-	-
García-Mejido <i>et al.</i> [25]	2017	Prospective	6 months	146	73	9.6%	73	34.2%	-	-	4.90 (1.95–12.18)	-	-
García-Mejido <i>et al.</i> [26]	2018	Prospective	6 months	79	-	-	79	34.1%	-	-	-	-	-
Abdool <i>et al.</i> [27]	2018	Prospective	4.8 months	84	51	11.8%	4	25%	5	40%	2.48 (0.22–27.94)	5.00 (0.68–36.23)	1.99 (0.11–35.87)
García-Mejido <i>et al.</i> [28]	2018	Prospective	6 months	89	-	-	-	-	89	38.2%	-	-	-
García-Mejido <i>et al.</i> [29]	2019	Prospective	6 months	263	-	-	162	41.4%	101	38.6%	-	-	0.89 (0.54–1.48)
García-Mejido <i>et al.</i> [30]	2019	Prospective	6 months	97	-	-	69	33.3%	28	21.4%	-	-	0.54 (0.19–1.54)
Sainz <i>et al.</i> [31]	2019	Prospective	3–6 months	255	-	-	-	-	255	40.4%	-	-	-
González-Díaz <i>et al.</i> [32]	2020	Prospective	6 months	184	-	-	184	32.1%	-	-	-	-	-
García-Mejido <i>et al.</i> [33]	2020	Prospective	3–6 months	414	-	-	212	32.5%	202	49.5%	-	-	2.03(1.36–3.03)
García-Mejido <i>et al.</i> [34]	2020	Prospective	6 months	100	-	-	56	39.3%	44	36.4%	-	-	0.89 (0.39–1.99)
Halle <i>et al.</i> [35]	2020	Prospective	6 weeks	212	168	14.9%	40	42.5%	-	-	4.22 (1.97–9.03)	-	-
			1 year	212	168	7.1%	40	20%	-	-	3.29 (1.23–8.67)	-	-
Ortega <i>et al.</i> [36]	2021	Retrospective	18 months	165	-	-	-	-	165	41.8%	-	-	-
All studies				5565	1843	6% to 38.5%	1674	9% to 50%	1118	22% to 71%	2.02 (1.34–3.03)	5.33 (3.78–8.11)	2.36 (1.46–3.84)
											1.93 (1.31–2.86)		

OR, odds ratio; CI, confidence interval; NVD, normal vaginal delivery, VD, vacuum delivery, FD, forceps delivery.

2.5 Assessment of Risk of Bias

The data on the study design, the patients included, the selection process, the characteristics of the patients, and the statistical method were analyzed. Two independent reviewers (JAGM and AFP) assessed the risk of bias and the quality of the included studies, interpreted the findings of the systematic review, and determined the potential bias resulting from the heterogeneity of the study.

3. Results

The search included 1225 studies that met the MeSH criteria, of which 26 were included in the review because they met the inclusion criteria (Fig. 1). Of all the excluded studies, we highlight the study by Greenbaum *et al.* [10] which, although it met the inclusion criteria, was excluded because it did not mention the type of instrumentation performed during vaginal delivery.

The results extracted from the different studies are shown in Table 1 (Ref. [11–36]). Five studies were retrospective and the rest prospective. The ultrasound examination was performed in most studies within 6 months after delivery [11–17,19,20,22,23,25–35], though some performed an ultrasound examination only or also after this period [17,18,21,24,35,36]. Some papers included a small number of VDs [12,20,27] and FDs [12–14,27], a possible source of bias.

Twenty-three studies determined the LAM avulsion rate after VD and 19 after FD. The rates of LAM avulsion in the VD group ranged between 9% and 50% and in the FD group between 22% and 71%. Albrich *et al.* [12] was excluded because presented a single case of LAM avulsion in one patient with FD. The estimated joint OR for VD vs. NVD was 2.02 (95% CI: 1.34–3.03), including the exploration of Halle *et al.* [35] at 6 weeks postpartum (Fig. 2, Ref. [35]). If we include the exploration performed by Halle *et al.* [35] at one year, the joint OR was 1.93 (95% CI: 1.31–2.86) (Fig. 3, Ref. [35]). The estimated joint OR for FD vs. NVD was 5.33 (95% CI: 3.78–8.11) (Fig. 4, Ref. [23]). Finally, the joint OR for FD vs. VD was 2.36 (95% CI: 1.46–3.84) (Fig. 5).

The type of instrument used during delivery was not reported in 13 studies with VD [11–13,15–18,20–23,27,35] and in 10 with FD [11–16,18,21,23,27]. The majority of articles that specified the type of vacuum used in the RV reported that a metal vacuum bird’s cup was 50 mm [19,24–26,29,30,32–34], although one of them also assessed LAM avulsion after a Kiwi vacuum was used [32]. The majority of studies on FD described the rates of LAM avulsion with Kielland’s forceps [28–31,33,34,36], though one of them studied Anderson forceps and Wrigley forceps [19].

4. Discussion

Disparate rates of LAM avulsion are described in VD (between 9% and 50%) and FD (between 22% and 71%),

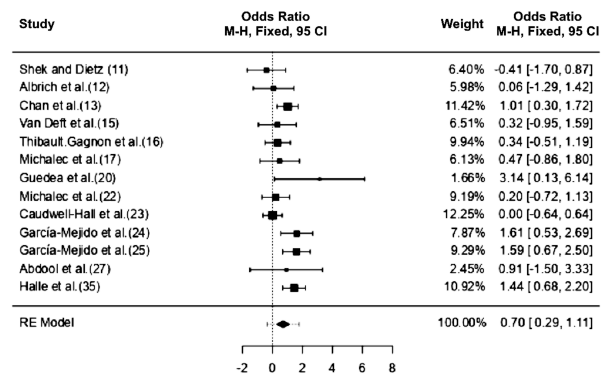


Fig. 2. Analysis of the general levator ani muscle (LAM) avulsion rates between vacuum delivery (VD) (including the exploration of Halle *et al.* [35] at 6 weeks postpartum) and normal vaginal delivery (NVD). Of the 13 studies included, log odds ratios ranged between -0.41 and 3.14 , the majority being positive (85%). The estimated average log OR was 0.70 (95% CI: 0.29 – 1.11), the mean being different from 0 ($z = 3.37$, $p = 0.0008$). The Q test showed heterogeneous results ($Q = 23.87$, $p = 0.02$, $\tau^2 = 0.25$, $I^2 = 48.53\%$), with a prediction interval of 95% from -0.36 to 1.76 . Therefore, although the average result is estimated to be positive, in some studies the true result may be negative. The studentized residuals were all within ± 2.89 (without indications of outliers). Evaluating Cook’s distances, none of the studies could be considered too influential. There was no asymmetry in the funnel plot in the rank correlation ($p = 0.95$) or in the regression test ($p = 0.54$).

with a joint OR for FD vs. VD of 2.36 (95% CI: 1.46 – 3.84). Based on our findings, we agree with the results of a previous systematic review [37], where it was specified that FD was associated with a higher incidence rate and severity of LAM avulsion compared to NVD [37]. However, there is controversy about whether FD presents higher rates of LAM avulsion than VD. In fact, a recent meta-analysis found Kielland’s forceps to be safe and favored their use over vacuum-assisted delivery [38]. However, that meta-analysis did not study LAM. One of the main problems that we found in the previous reviews is that they included and compared different imaging techniques for the study of LAM avulsion [39,40], such as MRI and 3D introital ultrasound. In addition, the vast majority of studies included in those reviews did not specify the type of instrument used (the type of forceps or vacuum) or how it was applied during delivery.

In this meta-analysis, we analyzed the type of instrument specified in the study. The most commonly used vacuum was the 50 mm bird’s cup [19,24–26,29,30,32–34]. Only one study made reference to the rate of LAM avulsion in deliveries with another type of vacuum (Kiwi vacuum) [32], so there were no differences in the LAM avulsion rates compared to those produced by Malmstrom’s vac-

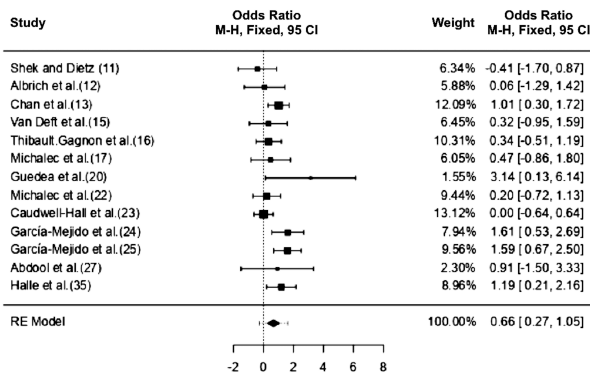


Fig. 3. Analysis of the general levator ani muscle (LAM) avulsion rates between vacuum delivery (VD) (including the exploration of Halle *et al.* [35] 1 year after delivery) and normal vaginal delivery (NVD). Of the 13 studies included, log odds ratios ranged between -0.41 and 3.14 , with the majority being positive (85%). The estimated average log OR was 0.66 (95% CI: 0.27 to 1.05), the mean being different from zero ($z = 3.31$, $p = 0.0009$). The Q test showed nonsignificant heterogeneous results ($Q = 20.91$, $p = 0.05$, $\tau^2 = 0.19$, $I^2 = 41.36\%$), with a prediction interval of 95% from -0.29 to 1.61 . Therefore, although the average result is estimated to be positive, in some studies the true result may be negative. The studentized residuals were all within ± 2.89 (without indications of outliers). Evaluating Cook's distances, none of the studies could be considered too influential. There was no asymmetry in the funnel plot in the rank correlation ($p = 0.59$) or in the regression test ($p = 0.39$).

uum, with an OR of 0.977 (0.426 ; 2.241 ; $p = 0.957$) and an adjusted OR of 2.90 (0.691 ; 12.20 ; $p = 0.146$). Something similar was true of the studies that specified the type of forceps used during the FD, as most describe the rate of LAM avulsion caused by only one type of forceps (Kielland's forceps) [28–31,33,34,36]. Only one study included different forceps [19], with a small number of participants (20 Anderson forceps and 22 Wrigley forceps), and did not compare the rate of LAM avulsion between the two types.

Only five studies studied the rate of LAM avulsion according to the way in which the instrument was applied during instrumented delivery [26,28,29,33,36]. It was determined that the number of vacuum tractions necessary to complete the fetal extraction was not associated with a higher rate of LAM avulsion [26], nor was the position of the fetal head (anterior, posterior, or transverse) at the time of vacuum application [26]. In the case of FD, there are controversies. It has been described that the rate of LAM avulsion is not increased when rotational forceps are used (OR: 1.5 [0.6 – 3.6]; p : not significant), in the correction of asynclitism (OR: 0.8 [0.3 – 1.9]; p : not significant), or according to the station of the fetal head at the time of placement of the forceps (OR: 2.0 [0.8 – 5.1]; p : not significant) [28]. However, another study established that rotational forceps were associated with avulsion, with an OR of 2.45 (95% CI 1.22 –

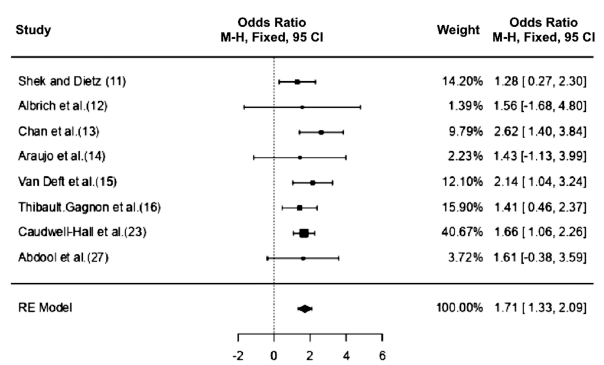


Fig. 4. Analysis of the general levator ani muscle (LAM) avulsion rates between FD (forceps delivery) and normal vaginal delivery (NVD). Of the 8 studies included, log odds ratios ranged between 1.28 and 2.62 , the majority being positive (100%). The estimated average log OR was 1.71 (95% CI: 1.33 to 2.09), the mean being different from zero ($z = 8.78$, $p < 0.0001$). The Q test showed that there was no significant amount of heterogeneity ($Q = 3.86$, $p = 0.796$, $\tau^2 = 0.00$, $I^2 = 0.00\%$). The study by Caudwell-Hall *et al.* [23] had a relatively large weight compared to the rest. The studentized residuals were all within ± 2.73 (without indications of outliers). Evaluating Cook's distances, none of the studies could be considered too influential. There was no asymmetry in the funnel plot in the rank correlation ($p = 0.39$) or in the regression test ($p = 0.86$).

4.93] [36]. One study analyzed whether the disarticulation of the forceps before the delivery of the fetal head could benefit the rate of LAM, and it found a crude OR (without disengagement vs. disengagement) for avulsion of 0.90 (95% CI 0.49 – 1.67 ; $p = 0.757$) and an adjusted OR (adjusted for maternal age, induced labor, epidural period, second stage of labor, perineal tear, and fetal head circumference) of 0.82 (95% CI 0.40 – 1.69 ; $p = 0.603$) [31]. However, when comparing the rates of LAM avulsion between VD and FD considering the position (anterior or other) and the station (low or medium instrumentation) of the fetal head at the time of instrument placement, no differences were found [29,33].

Another noteworthy aspect of the current literature is the time when transperineal ultrasound is performed to diagnose LAM avulsion. It is advisable not to make a diagnosis of LAM avulsion until 3 months after delivery to avoid diagnostic errors [41], and this recommendation was qualified by a recent meta-analysis: Rusavy *et al.* [37] advised that the diagnosis of LAM avulsion be made 6 months after delivery, or 12 months after FD. On the other hand, different authors have mentioned that LAM avulsion can disappear over time [42–45]. In fact, we recently reported that partial avulsions can present an improvement toward an intact LAM within 9 months postpartum [46]. There are two types of avulsions: Type I LAM avulsion is a lesion that can recover over time, and type II LAM avulsion

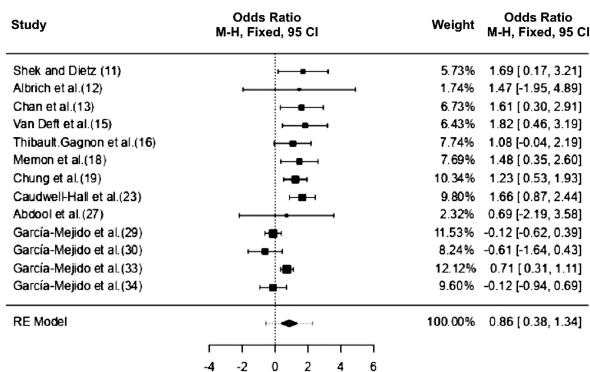


Fig. 5. Analysis of the general levator ani muscle (LAM) avulsion rates between forceps delivery (FD) and vacuum delivery (VD). Of the 13 studies included, log odds ratios ranged from -0.61 to 1.82 , the majority being positive (77%). The estimated average log OR was 0.86 (95% CI: 0.38 to 1.34), where the average was different from 0 ($z = 3.49$, $p = 0.0005$). The Q test showed heterogeneous results ($Q = 36.44$, $p = 0.0003$, $\tau^2 = 0.46$, $I^2 = 70.52\%$), with a prediction interval of 95% of -0.55 to 2.28 . Therefore, although the average result is estimated to be positive, in some studies the true result may be negative. The studentized residuals were all within ± 2.89 (without indications of outliers). Evaluating Cook's distances, none of the studies could be considered too influential. There was no asymmetry in the funnel plot in the rank correlation ($p = 0.68$) or in the regression test ($p = 0.28$).

is not recoverable [47]. This aspect has not only been described by transperineal ultrasound [47] but has also been established in anatomical studies and by MRI [48]. In this meta-analysis, the vast majority of studies performed ultrasound examinations up to 6 months after delivery [11–17,19,20,22,23,25–35], but they did not assess its evolution over time. LAM avulsion produces an alteration in the support of the pelvic floor structures, however this fact should not influence the decision to implement a delivery. In fact, a recent Cochrane review establishes that there is no instrumentation that guarantees maternal and fetal safety [49]. However, instrumentation at delivery will depend on the skill of the operator, the selection of available instruments, and the clinical setting [49].

The main strength of this meta-analysis lies in its inclusion criteria: Only those studies with primiparous women after instrumented deliveries were included, and LAM avulsion was diagnosed only by 3D/4D transperineal ultrasound. One shortcoming is that the time of the ultrasound exam was not the same in all the articles, and most studies do not specify the type of instrument and the techniques used. In addition, there are no clinical trials that could provide solid evidence for the question that motivated this meta-analysis.

5. Conclusions

In conclusion, delivery instrumented with forceps or vacuum favors LAM avulsion. Current data cannot establish whether this injury is attributable to the specific instrument or to the type of delivery involved in the instrumentation itself.

Abbreviations

LAM, Levator ani muscle; 3D, Three-dimensional; MRI, Magnetic resonance imaging; NVD, Normal vaginal delivery; FD, Forceps delivery; VD, Vacuum delivery.

Author Contributions

JAGM and JASB designed the research study. JAGM performed the research. AFP analyzed the data. CLP, AFP and JAGM wrote the manuscript. All authors contributed to editorial changes in the manuscript. All authors read and approved the final manuscript.

Ethics Approval and Consent to Participate

Not applicable.

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Conflict of Interest

The authors declare no conflict of interest. JAGM and JASB are serving as the Guest editors of this journal. We declare that JAGM and JASB had no involvement in the peer review of this article and have no access to information regarding its peer review. Full responsibility for the editorial process for this article was delegated to SM.

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