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ORIGINAL ARTICLE

Delivery mode and the risk of levator muscle avulsion: a meta-analysis

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Abstract

Introduction and hypothesis Female pelvic organ prolapse (POP) is a common condition, with a lifetime risk for surgery of 10–20%. Pregnancy and childbirth are the commonest modifiable risk factors for POP, and avulsion of the levator ani muscle is likely to be an etiological factor. Avulsion is more common in instrumental delivery. However, we were unable to identify a meta-analysis on this issue. Our aim was to perform a systemic review and quantitative meta-analysis of the prevalence of avulsion relative to delivery mode.

Methods Four electronic databases (MEDLINE, PubMed, Embase, and Google Scholar) were searched for studies published between 1991 and 1 October 2018 without language restrictions.

Results Twenty studies met inclusion criteria, and 14 were prospective. Seventeen used sonographic techniques; three were magnetic resonance (MR) studies. For this review, three comparisons were performed: forceps vs. vacuum (9 studies), forceps vs. normal vaginal delivery (NVD) (12 studies), and vacuum vs. NVD (12 studies). The first meta-analysis showed an increased risk for avulsion following forceps compared with vacuum, with an odds ratio (OR) of 4.57 and confidence interval (CI) 3.21–6.51, $p < 0.001$. The second showed an increased risk for avulsion following forceps compared with NVD, with an OR of 6.94 (4.93–9.78), $p < 0.001$. The third showed no significant increased risk for avulsion following vacuum compared with NVD, with an OR of 1.31 (1.00–1.72), $p = 0.051$.

Conclusions Forceps is a strong risk factor for avulsion, with an OR of 6.94 (4.93–9.78) compared with NVD and an OR of 4.57 (3.21–6.51) compared with vacuum birth.

Keywords Levator avulsion · Forceps · Meta-analysis · Pelvic organ prolapse · Risk factors

Introduction

Female pelvic organ prolapse (POP) is a common condition, associated with a significant impairment in overall quality of life (QoL) [1], with a lifetime risk for surgery of 10–20% [2, 3]. The etiology is not fully understood. A number of etiological factors may play a role, such as congenital predisposition and increased intra-abdominal pressure either due to lifestyle factors such as obesity or other medical conditions such as asthma. However, pregnancy and vaginal childbirth seem to be the commonest modifiable risk factors [4], especially for bladder and uterine prolapse, and are partly mediated through levator ani muscle (LAM) trauma [5]. LAM avulsion is a childbirth-related risk factor for POP [6]. Its prevalence is reported in 13–36% of women after vaginal delivery [6–9]. As LAM avulsion is likely to play an important role in prolapse pathophysiology, it seems important to identify risk factors. It is consistently reported that avulsion incidence is higher in instrumental deliveries [10], especially with forceps. However, a systematic review and meta-analysis has not been performed to date.

Most studies on operative vaginal delivery focus on fetal risks and maternal anal sphincter tears rather than levator trauma, because the latter has only recently been recognized as a major etiological factor in pelvic dysfunction. This meta-

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analysis aims to provide a summative association between delivery mode and LAM avulsion. The conclusions of our study should be of utility for the clinician in order to optimize obstetric practice and for researchers to facilitate future prospective studies aimed at reducing the incidence of both avulsion and POP.

Methods

Study protocol

There was no ethics approval required for this study, as it is based on published medical literature. We followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. A systematic search of the databases MEDLINE, PubMed, Google Scholar, and Embase, was performed up to 1 October 2018 to identify relevant articles. Our search items included levator OR puborectalis OR pubovisceralis OR pubococcygeal OR pelvic floor muscle AND avulsion OR injury OR defect OR lesion OR trauma OR damage OR tear AND delivery OR forceps OR vacuum. The reference lists of relevant articles were also searched for appropriate studies. No language restrictions were used in either the search or study selection. A search for unpublished literature was also performed.

Study selection

We only included studies that met the following inclusion criteria:

(1) Levator muscle avulsion was recognized after vaginal delivery
(2) Risk point estimate was reported as an odds ratio (OR), or data was presented such that an OR could be calculated
(3) The 95% confidence interval (CI) was reported, or data was presented such that the CI could be calculated
(4) Internal comparison was used when calculating the risk estimate.

Data extraction

Data extraction was performed using a standardized data extraction form after collecting information on publication year, study design, number of cases, number of controls, total sample size, temporal direction, population type, country, continent, case–control matching, mean age, number of adjusted variables, risk estimates or data used to calculate risk estimates, and CIs or data used to calculate CIs. Quality of the studies was not assessed. Several authors were contacted for missing data, which was included in our study. Adjusted ORs were extracted in preference to nonadjusted ratios; however, where adjusted ORs were not provided, unadjusted ORs and CIs were calculated. Where more than one adjusted OR was reported, we chose the ratio with the highest number of adjusted variables. Where multiple risk estimates were available in the same study—for example, due to the use of different comparator groups—they were included as separate risk estimates.

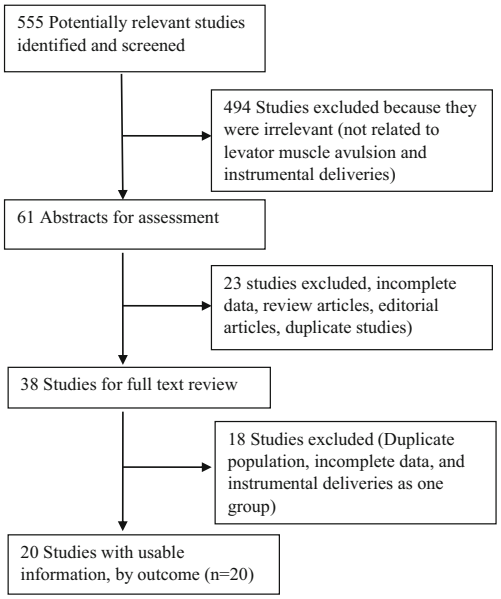

Fig. 1 Study selection

Statistical analysis

Pooled ORs and 95% CIs were calculated for the effect of type of delivery and LAM avulsion. Using a random-effects model [11], we tested heterogeneity with Cochran's Q statistic, with $P < 0.10$ indicating heterogeneity, and quantified the degree of heterogeneity using the I^2 statistic, which represents the percentage of the total variability across studies, which is due to heterogeneity. I^2 values of 25, 50, and 75% corresponded to low, moderate, and high degrees of heterogeneity, respectively [12]. We quantified publication bias using the Egger's regression model [13], with the effect of bias assessed using the fail-safe number method. The fail-safe number was the number of studies we would need to have missed for our observed result to be nullified to statistical nonsignificance at the $p < 0.05$ level. Publication bias is generally regarded as a concern if the fail-safe number is $<5n + 10$, with n being the number of studies included in the meta-analysis [14]. All analyses were performed with Comprehensive Meta-analysis (version 3.0), Biostat, Englewood, NJ, USA (2014). Quality of research articles was assessed using the Newcastle–Ottawa Scale, a tool

Table 1 Studies in this systematic review and meta-analysis

Study	No. patients	Description	Avulsion	Imaging	Postpartum	Population	Location	Quality	Comparison		
									FD–NVD	FD–VAC	VAC–NVD
Kearney et al. 2006 [15]	145	Prospective observational	Subjective scoring (normal, minor, major defect)	MRI	9–12 months	80 nulliparous continent, 80 with de novo incontinence	America	8	1	1	1
Dietz and Simpson[a] 2007 [16]	278	Prospective observational	Loss of continuity between muscle and pelvic sidewall (axial plane)	3/4D TUS	Mean >30 years	Urogynecological clinic	Australia	6			
Valsky et al. 2009 [17]	224	Prospective observational	Discontinuity and distortion in anteromedial pubovesical muscle	3/4D TUS	24–72 h	Singleton births postpartum	Asia	9			1
Kearney et al. 2010 [18]	167	Prospective cross sectional	Subjective scoring (normal, minor, major defect)	MRI	1 year	After forceps + NVD	UK	8	1		
Dietz and Kirby[a] 2010 [19]	983	Retrospective review	3 central slices on TUI	3/4D TUS	Mean >30 years	Urogynecological clinic	Australia	7			
Garriga et al. 2011 [20]	122	Prospective observational	Discontinuity between puborectalis and pubic ramus	3/4D TUS	1 and 9 months	After first birth	Europe	8	1		
Cassadó Garriga et al. 2011 [21]	180	Prospective observational	Discontinuity between puborectalis and pubic ramus	3/4D TUS	40–120 days	60 of each delivery mode, postpartum	Europe	8	1		
Albrich et al. 2011 [22]	157	Prospective observational	3 central slices on TUI, LUG >25 mm	3/4D TUS	48–72 h	After first vaginal or cesarean	Europe	7	1	1	1
Eisenberg et al. 2011 [23]	73	Cross-sectional	3 central slices on TUI, LUG >25 mm	3/4D TUS	Mean 21 months	After first instrumental delivery, NVD, or cesarean	Asia	9	1	1	1
Chan et al. 2012 [8]	339	Prospective observational	3 central slices on TUI, LUG >23.65 mm	3/4D TUS	8 weeks	Recruitment during pregnancy	Asia	8	1	1	1
Araujo Junior et al. 2013 [24]	35	Prospective cross-sectional	Loss of continuity between muscle and pelvic sidewall (axial plane)	3/4D TUS	Second day	After first delivery	America	8	1		
Van Delft et al. 2014 [25]	191	Observational longitudinal cohort	MRI-equivalent score 4–6 or 3 central slices on TUI, LUG >25 mm	3/4D TUS	3 months	Recruitment during pregnancy	UK	9	1	1	1
Low et al. 2014 [26]	90	Observational longitudinal cohort	Subjective scoring (normal, minor, major defect)	MRI	Mean 49 days	After first delivery with risk factor for avulsion	America	7			1
Chung et al. 2014 [27]	289	Prospective observational	3 central slices on TUI, LUG >23.65 mm	3/4D TUS	8 weeks	After first instrumental delivery	Asia	8		1	
Durnea et al. 2014 [28]	202	Prospective cohort	3 central slices on TUI, LUG >25 mm	3/4D TUS	1 year	Secondary analysis of perinatal study	UK	9	1		1
Caudwell-Hall et al. 2014 [29]	844	Prospective observational	3 central slices on TUI, LUG >25 mm	3/4D TUS	3 months	After first delivery. secondary analysis of 2 perinatal studies	Australia	8	1	1	1
Memon et al. 2015 [30]	73	Retrospective cohort	3 central slices on TUI, LUG >25 mm	3/4D TUS	Mean 10 years	5–15 years after instrumental delivery	America	9		1	
Volloyhaug et al. 2015 [31]	608	Cross-sectional	3 central slices on TUI, LUG >25 mm	3/4D TUS	16–24 years	After first birth	Europe	9	1	1	1
Michalec et al. 2015 [32]	184	Retrospective observational	3 central slices on TUI, LUG >25 mm	3/4D TUS	6 months	After first vacuum delivery and NVD	Europe	8			1
Valsky et al. 2016 [33]	558	Prospective	3 successive slices on TUI	3/4D TUS	3–18 months	After 3rd–4th degree OASIS and control group with intact sphincter	Asia	7			1

MRI magnetic resonance imaging, *TUI* tomographic ultrasound imaging, *LUG* levator–urethra gap, *FD* frceps delivery, *NVD* normal vaginal delivery, *VAC* vacuum delivery

[a] Included in systematic review; not included in meta-analysis due to lack of data

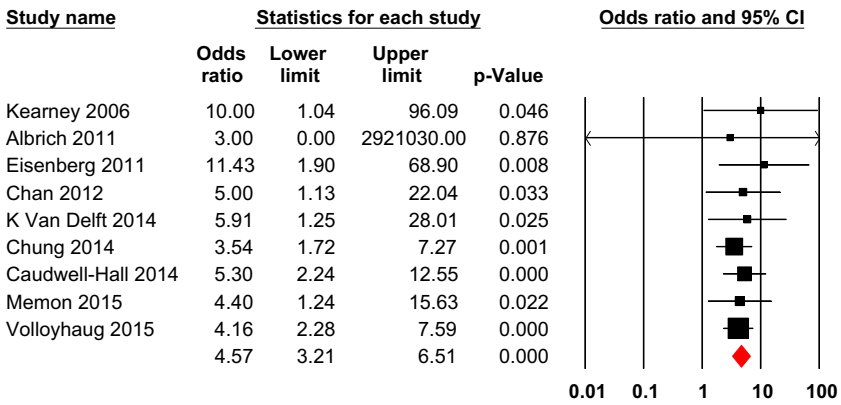

Fig. 2 Meta-analysis of the association between mode of avulsion and delivery: forceps versus vacuum. The size of the *square* correlates with study sample size. Test for heterogeneity $I^2 = 0.00$, p value = 0.98. Each study is shown by an odds ratio estimate with corresponding 95% confidence interval

developed for the purposes of evaluating nonrandomized studies used in systematic reviews and meta-analyses. One author (TF) conducted the quality assessments. A total score of ≤5 was considered low, 6 or 7 moderate, and 8 or 9 as high quality.

Results

From 555 citations screened, we identified 20 studies that met our inclusion criteria (Fig. 1). Table 1 shows selected characteristics of the identified studies, with a sum of 5067 patients. Categories cited and retrieved include publication year, study type, continent, total number of patients, imaging technique, definition of avulsion used, and timing of imaging postdelivery. Five studies were conducted in Europe, for in the USA, five in Asia, three in the UK, and three in Australia. The average timing of avulsion assessment was 4.89 years postpartum (2 days to 30 years). Seventeen studies used ultrasound (US) for the diagnosis of avulsion, whereas three diagnosed avulsion based on magnetic resonance imaging (MRI). Meta-analysis was performed for patients who had either a normal vaginal delivery (NVD), a vacuum delivery (VD), or a forceps delivery (FD). For each type of delivery, avulsion rate was recorded, and ORs and CIs were either given or calculated. Details are shown in Table 1, as are Newcastle–Ottawa Scale quality scores: five studies were considered as moderate and 15 as high quality based on total scores. .

Three types of comparisons were performed according to data availability: forceps versus vacuum (Fig. 2) (9 studies), forceps versus NVD (Fig. 3) (12 studies), and vacuum versus NVD (Fig. 4) (12 studies). The first meta-analysis showed an increased risk for avulsion following forceps compared with vacuum, with an OR of 4.57 and 95% CI 3.21–6.51, $p < 0.001$. The second showed an increased risk for avulsion following forceps compared with NVD, with an OR of 6.94 and 95% CI 4.93–9.78, $p < 0.001$. The third showed an increased risk for avulsion following vacuum compared with NVD, with an OR of 1.31 and 95% CI 1.00–1.72, $p = 0.051$.

There was no evidence of publication bias based on Egger's regression analysis for risk of avulsion for all assessed parameters: for FD versus NVD, $p = 0.11$; for FD versus vacuum, $p = 0.09$; for vacuum versus NVD, $p = 0.68$ (Fig. 5).

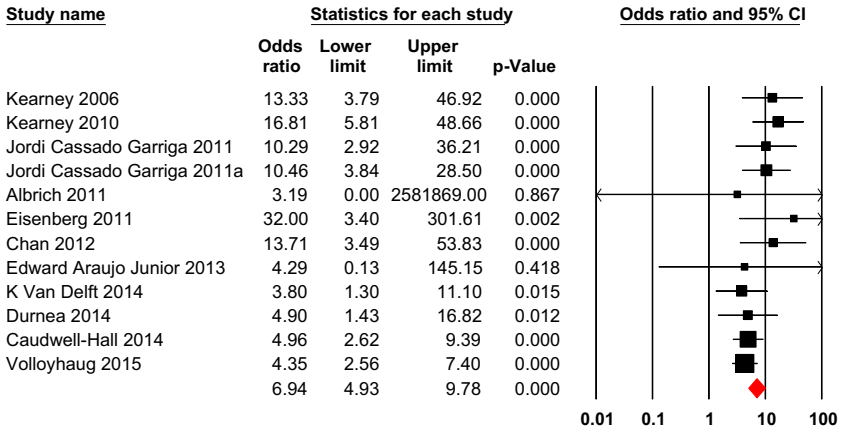

Fig. 3 Meta-analysis of the association between avulsion and mode of delivery: forceps versus normal vaginal delivery. The size of the *square* correlates with study sample size. Test for heterogeneity $I^2 = 14.72$, p value = 0.30. Each study is shown by an odds ratio estimate with corresponding 95% confidence interval

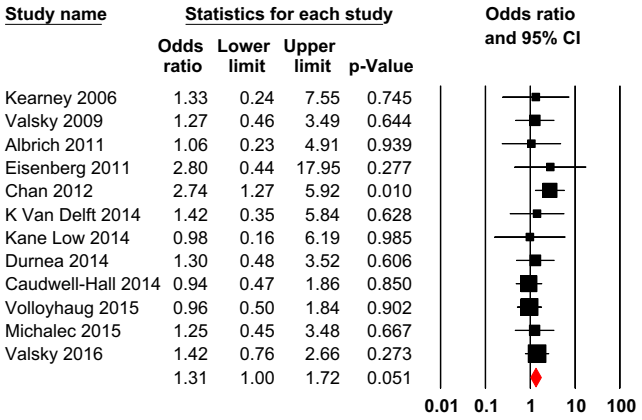

Fig. 4 Meta-analysis of the association between avulsion and mode of delivery: vacuum versus normal vaginal delivery. The size of the *square* correlates with study sample size. Test for heterogeneity $I^2 = 0.00$, p value = 0.86. Each study is shown by an odds ratio estimate with corresponding 95% confidence interval

Discussion

This meta-analysis suggests there is a substantial contribution of delivery mode to levator avulsion rates. It is evident that forceps delivery conveys the greatest risk for LAM avulsion when compared with both NVD (OR 6.94, 95% CI 4.93–9.78) and to vacuum delivery (OR 4.57, 95% CI 3.21–6.51), and both comparisons were statistically highly significant. There was also a trend for vacuum delivery as a risk factor for avulsion compared with NVD; however, this did not reach significance (OR 1.31, 95% CI 1.00–1.72).

This meta-analysis involved 20 studies in which >5000 postdelivery women were assessed for LAM avulsion over a period of 11 years, with the diagnosis by either MRI or 3/4D perineal US (see Table 1). It is acknowledged that, mainly due to rapid technological development in this field, the diagnosis of avulsion in our meta-analysis was obtained by two different imaging modalities. MRI was the first method used to assess the LAM [15, 34], although 3/4D US imaging was introduced almost simultaneously [35]. The sonographic method is much cheaper and simpler and has been shown to be repeatable [36] and equivalent to MRI [37].

Included studies used two different imaging modalities and several different definitions of avulsion, although most recent papers define this abnormality by a standardized technique first published in 2007 [38]. Despite this heterogeneity in methodologies, however, conclusions and risks estimated for avulsion after vaginal delivery and more significantly after forceps delivery are shared by all studies. This is consistent with the low heterogeneity of the statistical analysis, which reflects uniformity.

Several plausible explanations have been suggested to explain the increased risk of pelvic floor trauma with forceps compared with both NVD and vacuum delivery [10], such as greater space requirement [39], faster distension, and higher-traction forces involved [40]. Our findings are in accordance with results of a large study in the UK that identified forceps delivery as an independent risk factor for pelvic floor surgery, whereas delivery by cesarean section was found to be protective [41]. They were also consistent with results of a US

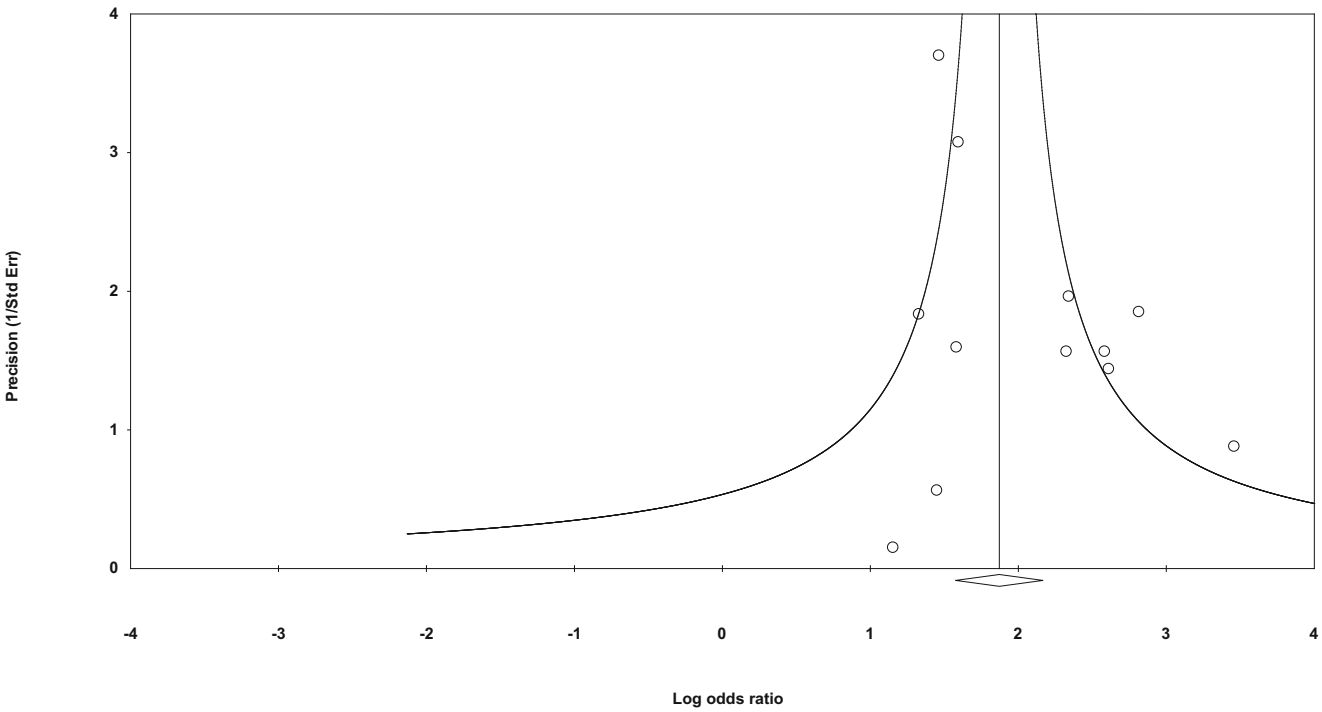

Fig. 5 Funnel plot showing no evidence of publication bias for mode of delivery (forceps versus normal vaginal delivery) and avulsion ($p = 0.11$)

study that found forceps delivery almost doubled the odds for prolapse [42]. The disappearance of forceps use in Denmark between the 1970s and 2000 [43] may well be the primary reason for a substantial reduction in the lifetime risk of prolapse surgery in that country [44].

Strengths and limitations

The primary strength of any meta-analysis lies in its ability to overcome power issues commonly inherent in published studies, and in this regard, we believe we reached valid and plausible conclusions. The strengths of this review include its thorough and systematic review, the large population size due to the inclusion of 20 studies published over a time span of >11 years, from five continents, with a total ≥5000 patients. Though the definition of LAM avulsion has changed over this period, as described above, all studies shared similar outcomes; hence, no heterogeneity was found, which is another strength of the study. It is reassuring that similar effects were noted in studies performed in different ethnic groups. The same is true regarding the different imaging modalities and definitions of LAM avulsion, as an increased risk of avulsion with forceps use was found regardless of modality or diagnostic definition. On the other hand, the fact that the definition of avulsion differs among studies is a limitation, as is the variation in the timing of diagnosis, which ranged from 2 days to 30 years postpartum. In addition, data was largely obtained from retrospective studies. The fact that most studies were carried out in developed countries with similar population profiles and largely similar obstetric management, however, is clearly an additional limitation, especially considering emerging data regarding interethnic variations in pelvic organ support in general and POP in particular. It also appears that reproductive behavior and obstetric management may play a larger role than anticipated, given that LAM avulsion rates in traditional societies with lower maternal age at first birth may be substantially lower [45]. Combining adjusted and unadjusted odds ratios is another limitation that may over emphasize results from unadjusted OR which will typically be larger than adjusted values.

In conclusion, our meta-analysis has demonstrated substantial associations between delivery mode and LAM avulsion. Forceps delivery was the most significant risk factor for LAM avulsion, with a statistically highly significant OR of 6.94 when compared with NVD and 4.57 when compared with vacuum delivery. Vacuum delivery may be a weak risk factor, with an OR of 1.3, which did not reach statistical significance. The risk factors identified in this meta-analysis may serve to inform patients and help select mode of delivery. Careful consideration of the risks and benefits should be weighed and discussed with the patient prior to the use of forceps.

Compliance with ethical standards

Conflicts of interest H.P. Dietz has received unrestricted educational grants from GE Medical. T. Friedman and G.D. Eslick have no conflict of interest to declare.

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