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ORIGINAL ARTICLE

The impact of variations in obstetric practice on maternal birth trauma

Ixora Kamisan Atan[1,2] · Shek Ka Lai[1,3] · Suzanne Langer[1] · Jessica Caudwell-Hall[1] · Hans Peter Dietz[1]

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Abstract

Introduction and hypothesis Forceps delivery and length of second stage are risk factors of maternal birth trauma, i.e., levator ani muscle (LAM) avulsion and anal sphincter trauma. The cesarean section (CS) rate has recently become the key performance indicator because of its increase worldwide. Attempts to reduce CS rates seem to have led to an increase in forceps deliveries and longer second stages. This study aimed to determine the association between variations in obstetric practice (between hospitals) and maternal birth trauma.

Methods This was a retrospective ancillary analysis involving 660 nulliparous women carrying an uncomplicated singleton term pregnancy in a prospective perinatal intervention trial at two Australian tertiary obstetric units. They had been seen antenatally and at 3–6 months postpartum for a standardized clinical assessment between 2007 and 2014. Primary outcome measures were sonographically diagnosed LAM and external anal sphincter (EAS) trauma.

Results The incidence of LAM avulsion (11.5% vs. 21.3%, $P = 0.01$) and composite trauma, i.e., LAM avulsion ± EAS injury (29.2% vs. 39.7%, $P = 0.03$) were higher in one of the two hospitals, where the forceps delivery rate was also higher (10.9% vs. 2.6%, $P < 0.001$). BMI (OR 0.9, $P = 0.02$), length of second stage (OR 1.01, $P = 0.02$) and forceps delivery (OR 5.24, $P < 0.001$) were significant predictors of the difference in LAM avulsion incidence between the hospitals. Maternal age (OR 1.06, $P < 0.04$) and forceps delivery (OR 8.66, $P < 0.001$) were significant predictors for composite trauma.

Conclusions A higher incidence of LAM avulsion and composite trauma in one of the two hospitals was largely explained by a higher forceps delivery rate.

Keywords Maternal birth trauma · Levator trauma · Levator avulsion · OASIS · Anal sphincter trauma · Forceps delivery

Introduction

Maternal birth trauma has attracted growing attention in recent years [1]. It includes not only perineal and anal sphincter tears, but also levator ani muscle (LAM) injury, which has a quoted incidence of 10–36% [2, 3]. Maternal birth trauma may result in long-term morbidity such as pelvic organ prolapse (POP), anal incontinence, perineal pain, dyspareunia, sexual dysfunction and post-traumatic stress disorder, affecting women's quality of life [4–7]. Levator trauma, in the form of avulsion (macrotrauma) or hiatal overdistension (microtrauma), is associated with an increased risk of prolapse recurrence after reconstructive surgery [8]. Risk factors for levator trauma include advanced maternal age at first delivery, prolonged second stage of labor, macrosomia, episiotomy, major perineal tears and forceps delivery [2].

In recent years, the cesarean section (CS) rate has become a key performance indicator (KPI) of obstetric units in many countries [1, 9]. The World Health Organization (WHO) has set the CS rate as 1 of its 24 core indicators of performance assessment in hospitals (PATH) [10]. This is the consequence of increasing CS rates worldwide, being as high as 35–40% in some regions [11]. In 2011, one in three women in the US were delivered by CS [12]. Needless to say, the CS rate is perceived as a negative measure of the quality of an obstetric service. Attempts to reduce CS rates have led to an increase in the use of forceps and tolerance of longer second stages [13, 14].

✉ Ixora Kamisan Atan
dr_ixoratan@hotmail.com; dr.ixorakamisan@gmail.com

[1] Sydney Medical School Nepean, The University of Sydney, Sydney, Australia

[2] Department of Obstetrics & Gynecology, Universiti Kebangsaan Malaysia Medical Centre (UKMMC), Jalan Yaacob Latiff, Bandar Tun Razak, Cheras, 56000 Kuala Lumpur, Malaysia

[3] Liverpool Clinical School, University of Western Sydney, Sydney, Australia

With our increasing knowledge of maternal birth trauma and its risk factors, it is reasonable to envisage that variation in obstetric practice may be associated with variable risks of maternal birth trauma. We have hence undertaken a study to determine the association between variations in obstetric practice at two tertiary hospitals in Sydney, Australia, and maternal birth trauma. Primary outcome measures were sonographically diagnosed levator ani muscle (LAM) avulsion, external anal sphincter (EAS) trauma, and significant LAM microtrauma/overdistension. Composite trauma, i.e., LAM avulsion ± EAS trauma, was analyzed as a secondary outcome measure. The null hypothesis was: 'There is no association between variations in obstetric practice and sonographically diagnosed maternal birth trauma.'

Methods

This was a retrospective observational study (an ancillary analysis) utilizing data sets of 660 nulliparous women carrying an uncomplicated singleton term pregnancy, recruited in a prospective perinatal intervention trial at two tertiary obstetric units in Sydney. These two hospitals were chosen as they were accessible to our research staff and similar logistically, i.e., in staffing, number of deliveries and facilities (NSW Level 6 Maternity Services) [24]. The parent trial was approved by the Sydney West and Sydney South Area Health Service Human Research Ethics Committees (SWAHS HREC 07–022 and SSAHS HREC X09–0384) on 30th April 2007. The inclusion criteria for the parent trial were (1) uncomplicated singleton pregnancy between 33 and 35 weeks; (2) maternal age ≥ 18 years; (3) no previous pregnancy beyond 20 weeks of gestation; (4) women aiming for normal vaginal delivery. All women were seen between July 2007 and March 2014, first antenatally at a mean gestation of 36 weeks and again 3–6 months postpartum. At both time points, they underwent a standardized clinical interview, International Continence Society (ICS) Pelvic Organ Prolapse Quantification (POP Q) assessment and a 4D translabial ultrasound (TLUS). They received standard obstetric care throughout the antenatal, intrapartum and postpartum periods. Delivery data were collected from hospital databases and/or participants' medical records.

TLUS was performed in the supine position, after voiding, using GE Voluson 730 Expert and E8 systems (GE Medical Systems, Zipf, Austria), with an 8-4-MHz curved array volume transducer, at an acquisition angle set to the system maximum of 85°, as previously described [15]. Volumes were acquired at rest, on pelvic floor muscle contraction (PFMC) and on Valsalva maneuvers. Post-processing of US volume data sets for the assessment of LAM and EAS integrity and LAM microtrauma was performed at a later date, using the proprietary software 4D View version 9.0 (GE Medical Systems) on a desktop PC, blinded to all other data.

Assessment of LAM integrity was undertaken utilizing tomographic ultrasound imaging (TUI) at 2.5-mm inter-slice intervals, from 5 mm caudal to 12.5 mm cranial to the plane of minimal hiatal dimensions, incorporating the entire puborectalis muscle, on volumes acquired on PFMC. The plane of minimal hiatal dimensions was identified in the midsagittal orthogonal plane, where the distance between the hyperechogenic posterior aspect of the symphysis pubis and hyperechogenic anterior border of the LAM is minimal. LAM avulsion was diagnosed in the presence of an abnormal LAM insertion observed in at least the three central TUI slices, i.e., slices 3–5 in Fig. 1a and b (reference slice and the slices 2.5 to 5 mm cranial), as previously described and validated [16].

EAS integrity was evaluated on TUI in eight slices on volumes acquired on PFMC at an inter-slice interval tailored to the individual's EAS length, encompassing the entire EAS from the level of the puborectalis muscle to the subcutaneous part of EAS. A 'significant EAS defect' was defined as a gap of ≥ 30° in its circumference, in at least four out of six central slices (slice 2 to 7 in Fig. 1c and d), as previously described [17].

Hiatal area for the diagnosis of levator overdistension or 'microtrauma' was measured in a rendered volume of 1–2 cm thickness incorporating the plane of minimal hiatal dimensions [18] using the volume showing the greatest degree of pelvic organ descent on maximal Valsalva maneuver. Levator microtrauma was defined as a peripartum increase in hiatal area on Valsalva of > 20% [3], resulting in a hiatal area of at least 25 cm^2 [19] in the absence of LAM avulsion; see Fig. 2.

'Any perineal tear' is defined as any first, second, third or fourth degree tears, with third and fourth degree tears considered as 'major perineal tear.' 'Composite trauma' is defined as the presence of LAM avulsion and/or a significant residual defect of the EAS diagnosed sonographically.

Statistical analyses were undertaken using SPSS 20 (SPSS, Chicago, IL). Normality of data was assessed using the Kolmogorov-Smirnov method. Normally and non-normally distributed continuous data were analyzed using the Student t-test and Mann-Whitney U test, respectively. Categorical variables were analyzed using the chi-squared test. $P < 0.05$ was regarded as statistically significant. Multivariate binary logistic regression modeling was performed to control for potential confounders between the association of maternal birth trauma and hospitals, with the former being the dependent variable. Delivery hospital was fitted into the model as independent variable with maternal age, body mass index (BMI), length of second stage and forceps delivery being the covariates.

Results

Of 660 women recruited, 504 (76.4%) returned for postpartum review at a mean interval of 5.1 (SD 2.4, range 2.3–22.4) months. Two women were excluded because of

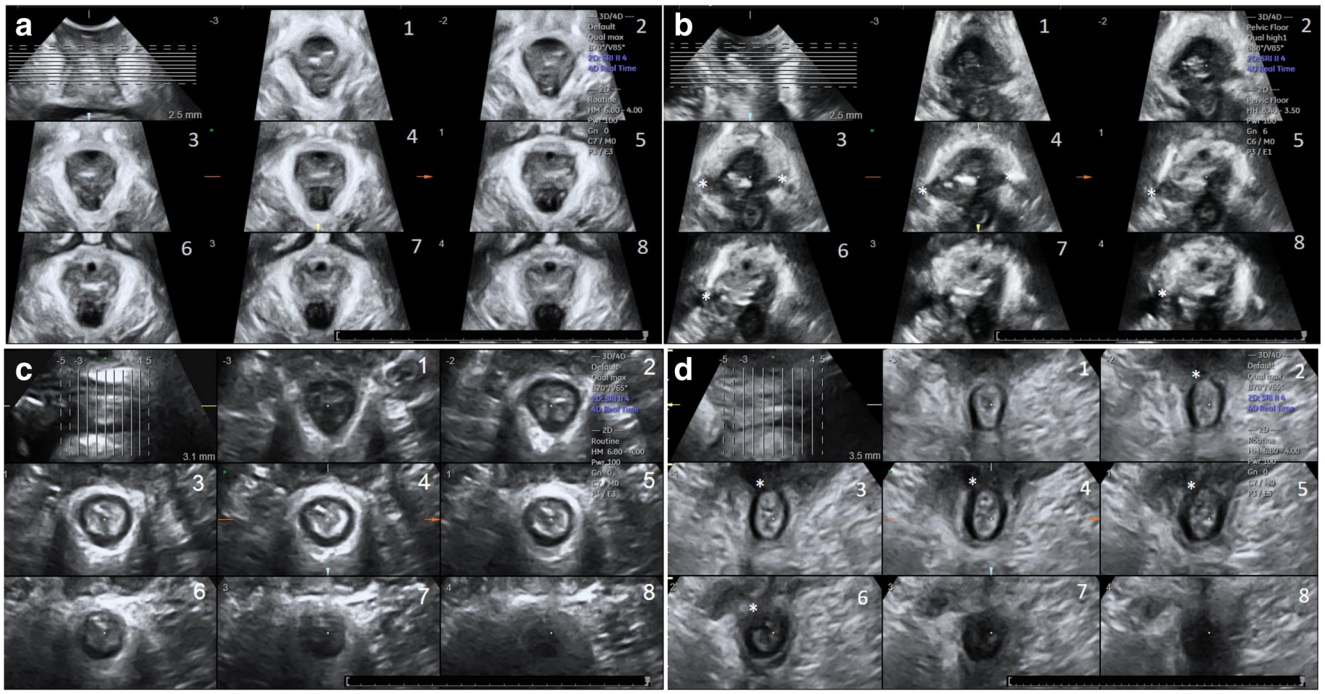

Fig. 1 Transperineal tomographic ultrasound imaging (TUI) of (**a**) a normal pelvic floor and (**b**) a complete right-sided levator avulsion (marked with *, in slices 3–8) and a partial avulsion on the left (marked with * in slices 3-4). **c** Transperineal tomographic ultrasound imaging (TUI) of an intact/normal EAS and (**d**) a significant residual defect of the EAS involving five out of six slices, i.e., slices 2–6. Asterisks (*) demonstrate defect location

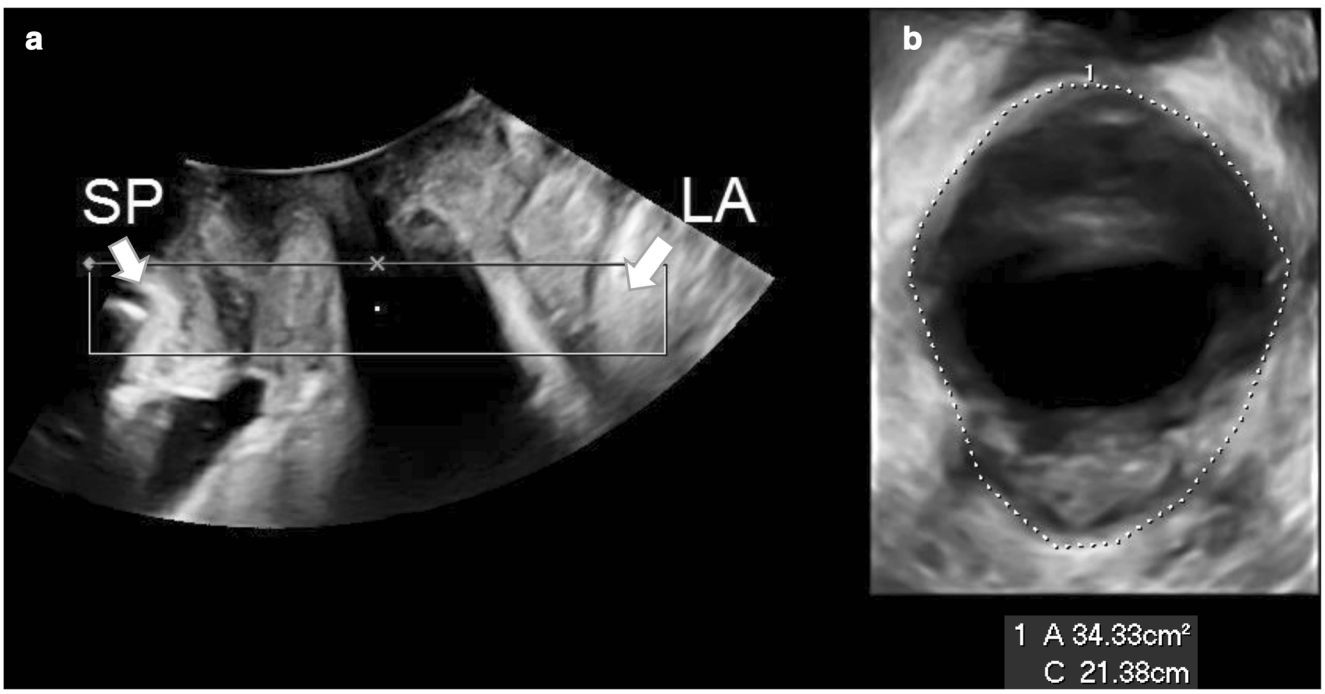

Fig. 2 Midsagittal view (**a**) of the pelvic floor on TLUS at maximal Valsalva, demonstrating the plane of minimal hiatal dimension, i.e., the shortest distance between the inferoposterior margin of the symphysis pubis (SP) and anterior border of the levator ani muscle (LA) within the rendering box or 'region of interest.' **b** Measurement of the levator hiatal area on Valsalva in the axial plane (hiatal area = 34.33 cm^2, i.e., moderate hiatal ballooning)

missing postpartum US volume in one and an intercurrent birth in another, leaving 502 to whom these results pertain, unless otherwise stated. The trial intervention (antenatal Epi-No birth trainer use) proved to have no effects on outcome measures [20]; hence, women in both the control and treatment arms were included in this analysis. Assessment of LAM avulsion was possible in all women. Sixty-eight were excluded from evaluation of microtrauma (66 had LAM avulsion, 1 had missing antepartum US volume, and 1 was pregnant at follow-up), leaving 434. In 14 women, the imaging was of insufficient quality for the assessment of EAS integrity, leaving 488. Mean age at antepartum assessment was 30.9 (SD 5.2, range 18–45) years with a mean BMI of 28.5 (SD 4.9, range 14–47) kg/m^2. Of the 502 women, 116 (23.1%) were delivered by cesarean section and 386 (76.9%) delivered vaginally. They were normal vaginal deliveries in 280 (55.8%), vacuum deliveries in 70 (13.9%) and forceps in 36 (7.2%). Of 116 women who had a cesarean section, 9 (7.8%) delivered by second stage CS. Of these nine, two had a CS after a failed attempt at vacuum delivery. Two hundred twenty-seven (45.2%) and 275 (54.8%) delivered in tertiary Hospital A and B, respectively. Demographic and delivery characteristics of the study population between these two hospitals are presented in Table 1.

LAM avulsion and significant EAS defects were diagnosed in 13.1% (66/502) and 17.6% (86/488) of the study population, i.e., 17.1% and 22.6% of those who delivered vaginally; see Table 2. No LAM avulsion was found in those who delivered by CS. One woman who delivered by CS was found to have significant EAS defects.

In the group of 386 women who delivered vaginally, we found a significant difference in the incidence of LAM avulsion (19/165 or 11.5% vs. 47/221 or 21.3%, $P = 0.01$) between the two delivery centers (Table 3A). Due to the higher CS rate in Hospital A, this effect was even stronger when the entire cohort was considered, resulting in a levator avulsion rate of 8.3% ($n = 19/227$) at Hospital A and

Table 1 Demographic and delivery characteristics of the study population ($N = 502$) at the two hospitals

	Hospital		*P* value
	A ($n = 227$)	B ($n = 275$)	
Maternal age at delivery (years)*	28.1 ± 4.9	33.2 ± 4.1	< 0.001
BMI (kg/m^2)*	29.8 ± 5.4	27.5 ± 4.2	< 0.001
Gestation at delivery (weeks)*	39.9 ± 1.2	40.1 ± 1.3	0.08
Ethnicity†			
Caucasian	188 (83.2%)	211 (76.6%)	0.07
Non-Caucasian	38 (16.8%)	64 (23.4%)	
• Asian	7 (3.1%)	29 (10.6%)	
• Polynesian	7 (3.1%)	0 (0%)	
• Arab	4 (1.8%)	6 (2.2%)	
• Other	20 (9.3%)	27 (9.9%)	
Mode of delivery†			0.002
Cesarean section	62 (27.3%)	54 (19.6%)	0.04
Normal vaginal delivery	120 (52.9%)	160 (58.2%)	0.23
Ventouse assisted (VD)	39 (17.2%)	31 (11.3%)	0.06
Forceps assisted (FD)	6 (2.6%)	30(10.9%)	< 0.001
Intrapartum epidural†	100 (44.4%)	120 (43.6%)	0.86
Intrapartum syntocinon†	102 (45.1%)	138 (51.3%)	0.17
Length of second stage (minutes)‡	46 (IQR 23.0–82.5)	73 (IQR 34.0–132.0)	< 0.001*
Head circumference (cm)*	34.5 ± 1.4	34.6 ± 1.3	0.45
Neonatal birth weight (g)*	3431.7 ± 385.0	3454.3 ± 437.3	0.54
#Episiotomy†	51/165 (30.9%)	50/221 (22.6%)	0.07
#Any perineal tear†	71/165 (43.0%)	128/221 (58.0%)	0.002
#Major perineal tear†	11/165 (6.7%)	14/221 (6.3%)	0.93

Data are presented as * mean ± standard deviation, † *n* (%) or ‡ median (interquartile range). # Vaginal delivery only ($n = 386$, i.e., 165 and 221 in Hospital A and B, respectively). Analyzed using * Student t- test, † chi-square test and ‡ Mann-Whitney test. 'Any perineal tear' = any 1st–4th degree tear;'major perineal tear' = 3rd and 4th degree perineal tear, i.e., OASIs

Table 2 Incidence of LAM avulsion, microtrauma and EAS defects sonographically diagnosed in women who delivered vaginally ($n = 386$ for LAM avulsion, *$n = 376$ for EAS defects, $n = 318$ for LAM microtrauma)

Mode vaginal delivery	LAM avulsion		P value	*EAS defects		P value	**LAM microtrauma		P value
	Yes ($N = 66$)	No ($N = 320$)		Yes ($N = 85$)	No ($N = 291$)		Yes ($N = 53$)	No ($N = 265$)	
NVD	36/280 (12.9%)	244/280 (87.1%)	< 0.001	46/273 (16.8%)	227/273 (83.2%)	< 0.001	39/242 (16.1%)	203/242 (83.9%)	0.003
VD	12/70 (17.1%)	58/70 (82.6%)		20/69 (29%)	49/69 (71%)		6/58 (10.3%)	52/58 (89.7%)	
FD	18/36 (50%)	18/36 (50%)		19/34 (55.9%)	15/34 (44.1%)		8/18 (44.4%)	10//18 (55.6%)	

NVD = normal vaginal delivery ($N = 280$), VD = ventouse-assisted delivery ($n = 70$), FD = forceps-assisted delivery ($n = 36$). *Assessment of integrity of EAS was possible in 376 women (NVD = 273, VD = 69, FD = 34), as sphincter imaging volumes were of insufficient quality for assessment in 10 women. **Assessment of LAM microtrauma was performed on 318 women (NVD 242, VD = 58, FD = 18), as 1 woman had missing antenatal ultrasound volumes, 1 was pregnant at follow-up (with the second child), and 66 had LAM avulsion. Data presented as *n* (% within delivery mode), analyzed using chi-squared test

17% ($n = 47/275$) at Hospital B (Table 3B). We found similar results when combining clinically diagnosed major perineal tears (3rd and 4th degree tears diagnosed in the labor ward) and sonographically diagnosed EAS defects in our analysis, i.e., OR 1.4 (0.8–2.2); $P = 0.22$ (cohort who had a vaginal delivery) and OR 1.5 (0.9–2.3); $P = 0.10$ (entire cohort including those who had a CS). The same was observed when clinically diagnosed major perineal tears were included as a component of composite trauma, i.e., OR 1.7 (1.1–2.6); $P = 0.02$ (cohort who had a vaginal delivery) and OR 1.8 (1.2–2.7); $P = 0.005$ (entire cohort including those who had a CS).

On multivariate binary logistic regression controlling for potential confounders, the association between delivery centers and LAM avulsion and composite trauma became non-significant ($P = 0.96$ and $P = 0.43$, respectively). BMI, length of second stage and forceps delivery remained significant predictors for LAM avulsion. Maternal age and forceps delivery were significant predictors for composite trauma. Forceps delivery was by far the strongest predictor ($P < 0.001$); see Table 4. Delivery by vacuum was not associated with an increased risk of any form of maternal trauma.

Discussion

Main findings

In this study, the significant difference in the incidence of maternal birth trauma between two tertiary hospitals was largely attributable to the variation in forceps rates, with an adjusted odds ratio of 5.1 and 8.7 for LAM avulsion and composite trauma, respectively. This is not surprising and consistent with previous studies, which have established forceps as the major risk factor for maternal birth trauma, conveying ORs (relative to normal vaginal delivery) of 3.4–32 for LAM avulsion [21] and 4.0–13.9 for anal sphincter injury [22, 23]. At Hospital A, the prevalence of forceps delivery remained largely static during the trial period, ranging from 1.3% –2.8% (1.4% at study completion), while at Hospital B forceps delivery rates have risen from 1.8% prior to study commencement to 7.9% at study

Table 3 (A) Incidence of maternal birth trauma among women delivered vaginally ($n = 386$) at two tertiary obstetric units. (B) Incidence of maternal birth trauma in study population including women delivered by CS at two tertiary obstetric units ($n = 502$)

	(A)			(B)		
	Hospital		OR (95% CI) P value	Hospital		OR (95% CI) *P* value
	A ($n = 165$)	B ($n = 221$)		A (n = 227)	B (n = 275)	
Levator avulsion	19/165 (11.5%)	47/221 (21.3%)	2.1 (1.2–3.7) 0.01	19/227 (8.4%)	47/275 (17.1%)	2.3 (1.3–4.0) 0.004
EAS defects	32/159 (20.1%)	53/217 (24.4%)	1.3 (0.8–2.1) 0.33	33/219 (15.1%)	53/269 (19.7%)	1.4 (0.9–2.2) 0.18
Composite trauma (LAM avulsion and/or EAS)	47/161 (29.2%)	87/219 (39.7%)	1.6 (1.0–2.5) 0.03	48/221 (21.7%)	87/271 (32.1%)	1.7 (1.1–2.6) 0.01
Levator microtrauma	20/144 (13.9%)	33/174 (19.0%)	1.5 (0.8–2.7) 0.23	27/206 (13.1%)	33/228 (14.5%)	1.1 (0.6–1.9) 0.68

Data presented as *n* (%) and analyzed using chi-squared test. (A) Data sets available for analysis of EAS defects were $n = 376$, of composite trauma $n = 380$ and of levator microtrauma $n = 318$. (B) Data sets available for analysis of EAS defects were $n = 488$, of composite trauma $n = 492$ and of levator microtrauma $n = 434$

Table 4 Binary logistic regression modeling of the association between potential predictors of (A) LAM avulsion and (B) composite trauma (LAM avulsion and/or EAS defects)

	(A) Levator avulsion		(B) Composite trauma	
	Adjusted OR (95% CI)	P value	Adjusted OR (95% CI)	P value
Delivery hospital	0.98 (0.47–2.04)	0.96	0.80 (0.46–1.39)	0.43
Maternal age at delivery	1.05 (0.98–1.13)	0.16	1.06 (1.00–1.12)	0.04
BMI	0.90 (0.83–0.98)	0.02	0.95 (0.90–1.01)	0.09
Length of second stage (min)	1.01 (1.00–1.01)	0.02	1.004 (1.00–1.01)	0.06
Forceps-assisted delivery	5.24 (2.27–12.08)	<0.001	8.66 (3.31–22.66)	<0.001

completion [24]. Such changes are likely due to attempts to lower the CS rate, which is reflected in the drop in CS rates among primigravidae in Hospital B from 23.3% at study commencement to 22.0% at completion. In contrast, the prevalence of CS in Hospital A showed an increase from 28.9% to 33.3% during the same period [24]. This is also reflected in the significant difference in the intrapartum CS rate, being lower in Hospital B (27.3% vs. 19.6 in our study). In some countries, including Australia, pressure on clinicians to reduce CS rates has resulted in renewed interest in instrumental delivery [13, 14], including rotational Kielland's forceps [25, 26]. This is worrying in view of our findings and the large volume of data in the literature showing forceps delivery to be the strongest modifiable risk factor for maternal birth trauma.

Consistent with our previous study [2], a longer second stage of labor may also have contributed to the higher incidence of LAM avulsion in Hospital B. Tolerance of longer second stages may also be an inadvertent consequence of efforts to reduce CS rates [13, 14]. Previous studies have also demonstrated significant associations between longer second stages and a higher likelihood of levator microtrauma/overdistension, perineal and anal sphincter trauma at odds ratios of 1.01/min, 1.45 and 1.49–7.1, respectively [2, 23, 27, 28].

In this study, higher BMI seemed to be mildly protective against LAM avulsion. A possible explanation could be that women with higher BMI are more likely to be delivered by CS, as maternal obesity is associated with multiple adverse obstetric outcomes including gestational diabetes mellitus, hypertension and fetal macrosomia [29]. The alternative explanation is that nutritional status may have an effect on the biomechanical properties of connective tissue. This hypothesis, however, remains to be studied in future research.

Strengths and limitations

The strengths of this study include its large study population. Assessment for maternal trauma was performed blinded to all clinical data. Sonographic assessment for maternal trauma also included EAS trauma, which is often missed in the delivery suite [30], hence providing a more objective outcome measure than clinical diagnosis alone. In our study population, occult (clinically undiagnosed) sphincter trauma accounted for 84% ($n = 72/86$) of those with sonographic evidence of EAS tears, i.e., 14.8% ($n = 72/488$) of the entire cohort.

The post hoc nature of our analysis has to be acknowledged as a weakness of this study. Another is the fact that our study population was largely composed of Caucasians. Hence, our results may not be directly extrapolated to populations of other ethnic origin or to places with different obstetric practice. Finally, the obstetric information available to us precludes an analysis of the type of forceps used or the degree of difficulty encountered during vaginal operative delivery. Both are likely to influence the extent of maternal trauma and will have to be the object of future research.

Conclusions

In this study, we found a significant difference in the incidence of LAM avulsion and composite maternal birth trauma between two tertiary centers in Australia. This difference seems to be explained by variations in maternal age, BMI, length of second stage and rate of forceps delivery, with the latter being the strongest predictor by far. The significant differences in maternal birth trauma observed between these two tertiary hospitals were largely due to a variation in forceps rates. Clinicians and policymakers should be aware that changes in obstetric practice designed to reduce CS rates may have unintended deleterious consequences for patients because of increases in maternal birth trauma.

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Compliance with ethical standards

Conflicts of interest KL Shek and HP Dietz have received unrestricted educational grants from GE Medical. All other authors have no conflict of interest to declare.

Details of ethics approval The parent trial was approved by the Sydney West and Sydney South Area Health Service Human Research Ethics Committees (SWAHS HREC 07–022 and SSAHS HREC X09–0384) on 30 April 2007.

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