DOI: 10.1111/j.1471-0528.2011.03152.x
www.bjog.org

Impact of mode of delivery on levator morphology: a prospective observational study with three-dimensional ultrasound early in the postpartum period

SB Albrich,[a] RM Laterza,[a] C Skala,[a] S Salvatore,[b] H Koelbl,[a] G Naumann[a]

[a] Department of Obstetrics and Gynaecology, Johannes Gutenberg University, Mainz, Germany [b] Department of Obstetrics and Gynaecology, Insubria University, Varese, Italy
Correspondence: RM Laterza, Department of Obstetrics and Gynaecology, Johannes Gutenberg University, Langenbeckstrasse 1, Mainz, Germany. Email rmslaterza@libero.it

Accepted 23 June 2011. Published Online 10 October 2011.

Objective To evaluate morphology and integrity of the levator ani muscle (LAM) with three-dimensional ultrasound early in the postpartum period.

Design Prospective cross-sectional observational study.

Setting University hospital in Germany.

Population Women after vaginal delivery and caesarean section with no previous vaginal delivery.

Methods Three-dimensional perineal ultrasound was performed between 48 and 72 hours postpartum. The axial plane at the level of minimal hiatal dimension and tomographic ultrasound imaging were used to determine LAM biometry and defect.

Main outcome measures Primary outcome was to compare hiatal dimensions and levator defect following vaginal delivery or caesarean section. For secondary outcomes, we evaluated the role of caesarean section in protecting levator integrity, and the possible involvement of the first stage of labour in LAM changes.

Results In all, 157 women participated: 81 (51.6%) following vaginal delivery (70 spontaneous and 11 operative deliveries) and 76 (48.4%) following caesarean section (55 elective and 21 emergency caesarean sections). All biometric indices of the levator were higher after vaginal delivery ($P < 0.001$), except for LAM thickness. LAM defects were found to be significantly associated with vaginal delivery, with relative risk 7.5 ($P < 0.001$). Following vaginal delivery, 32 (39.5%) levator defects were found: 27 (38.5%) after spontaneous delivery and five (45.4%) after operative delivery. Four (5.2%) women had a levator defect following emergency caesarean section.

Conclusion Vaginal delivery modifies and damages the LAM: the risk of levator defect after vaginal delivery is more than seven times higher than after caesarean section. Despite this, emergency caesarean section seems to have no complete preventive effect on LAM trauma.

Keywords Caesarean section, levator ani defect, three-dimensional ultrasound, vaginal delivery.

Please cite this paper as: Albrich S, Laterza R, Skala C, Salvatore S, Koelbl H, Naumann G. Impact of mode of delivery on levator morphology: a prospective observational study with three-dimensional ultrasound early in the postpartum period. BJOG 2011;118: DOI: 10.1111/j.1471-0528.2011.03152.x.

Introduction

The anatomical and functional integrity of the levator ani muscle (LAM) plays a fundamental role in pelvic organ support. Throughout the whole female lifespan, the LAM closes the pelvic floor. It is only during vaginal delivery that it undergoes an enormous stretching, to allow the passage of the newborn through it.

The involvement of the LAM on morbidity of the pelvic floor has been widely investigated. The finding that enlarged hiatus is associated with genital prolapse has suggested that LAM trauma or an enlargement of the urogenital hiatus, influences pelvic support.[1,2] Dietz and Simpson[3] have demonstrated, through the use of ultrasound, that women with levator defects may be around twice as likely to develop pelvic organ prolapse later in life. The association of LAM avulsion with prolapse of the anterior and central compartment has also been confirmed by magnetic resonance imaging (MRI).[2,4] On the other hand, the aetiological role of LAM integrity in bladder dysfunction is still not clear. A weak significant association between levator avulsion and worsening or *de novo* urinary incontinence has been reported 3 months postpartum, through the use of ultrasound.[5] Recent evidence questions this link, reporting that women with a major levator defect diagnosed by MRI are less likely to experience stress urinary incontinence,[6] and that puborectalis trauma evaluated by ultrasound is not associated with an increased risk of stress urinary incontinence or urodynamic stress incontinence.[7] As regards anorectal function, Heilbrun et al.[8] have shown a weak trend towards more fecal incontinence in women with LAM avulsion and anal sphincter tears, but the interpretation of these results must take into account that this is a rather select group, with a special set of risk factors.

Whether and how vaginal delivery is responsible for pelvic floor morbidity is a controversial debate that is still wide open. If it is true that all women undergo pelvic floor stretching during delivery, not all of them suffer injury. The latency of symptoms and the multifactorial aetiology of prolapse and of urinary and faecal incontinence, do not facilitate an understanding of the true role of vaginal birth. There is no doubt that delivery is the most stressful and dangerous event that the pelvic diaphragm is submitted to during a woman's life. The area of the levator hiatus, which varies widely in size from 6 to 35 cm^2 during the Valsalva manoeuvre,[9] needs a distension of between 25% and 245% to allow the passage of the fetal head (for an average cross-sectional area of 68 cm^2, based on Caucasian biometric data).[10]

Several studies have considered the mechanism of vaginal delivery and its effect on LAM. With an MRI-based computer model, DeLancey's group[11] demonstrated that the medial part of the pubococcygeal muscle is submitted to a stretch equal to a factor of 3.2 during crowning of the fetal head. Allen et al.[12] concluded that the first vaginal delivery is responsible for injuries to the pudendal nerve and so for partial denervation of the pelvic diaphragm. The risk of LAM trauma after vaginal delivery evaluated by ultrasound is reported in the literature at between 18% and 36% in nulliparous women.[5,13,14]

If the damage to the LAM depends only on the passage of the fetus through the birth canal, then caesarean section, both elective and emergency, should assure absolute protection of the pelvic floor. This hypothesis has so far been supported by several thousand MRI and ultrasound assessments quoted in the literature, which have not reported any LAM avulsion in primiparae after caesarean section. The aim of this study was to evaluate the morphology and biometry of the LAM muscle in women in the early postpartum period, specifically looking at:

- the possible differences in hiatal dimensions and levator integrity after vaginal delivery and caesarean section,
- the role of caesarean section in protecting LAM integrity by avoiding fetal passage through the birth canal, and
- the possible effects of the first stage of labour on LAM morphology changes, in terms of women who have undergone emergency caesarean section.

Methods

A single-institution prospective cross-sectional observational study was designed to compare the levator ani biometry following vaginal delivery and caesarean section, using perineal three-dimensional (3D) ultrasound. For the purpose of this study, we prospectively considered all women who delivered at the Department of Obstetrics and Gynaecology at the Johannes Gutenberg University in Mainz, between January 2009 and June 2009, to be eligible for inclusion. The Institutional Review Board approved the study protocol. After a vaginal delivery or caesarean section, women were then consecutively offered the opportunity to participate in this trial. Each woman was carefully informed about the aim and design of the trial. Instructions regarding the perineal 3D ultrasound were given and an information sheet about the study was handed out. Written informed consent was obtained before any investigation took place.

The following exclusion criteria were considered: refused consent, previous vaginal delivery, severe mental illness, severe physical handicap or difficulties in communication because of insufficient knowledge of German or English.

All 3D static volume acquisitions were performed by the same experienced investigator, highly trained in pelvic 3D ultrasound. It was not possible to blind the assessors to the delivery mode because of the evidence of a caesarean section scar in women after surgical delivery and of perineal trauma following vaginal delivery.

Consenting women underwent a perineal ultrasound scan in bed, between 48 and 72 hours after delivery. The examination was performed in dorsal lithotomy position (the woman lying on her back with bent knees positioned above the hips and spread apart, without the use of stirrups) after voiding, using a GE Voluson-e® System (GE Medical System Kretztechnik GmbH & Co OHG, Zipf, Austria) with a RAB 4-8-RS 4–8.5 MHz volume transducer and convex volume probe.

The 3D ultrasound assessment and imaging were obtained with the woman in a resting position. The probe was positioned longitudinally, parting the vulvar labia in the area of the fourchette and perineal body, with minimal pressure being applied. Before beginning the examination, women were asked to cough to part the labia, to expel air bubbles and to ensure good contact between the transducer and tissue.

The transducer axis was oriented in the mid-sagittal plane to visualise, from right to left, the symphysis pubis, the urethra (distinguishable by the hypoechogenic mucosa and submucosa layers), the bladder, the vaginal walls, the distal part of the rectum with anorectal junction, the proximal part of the anal canal and, posterior to the latter structure, a hyperechogenic spot representing the puborectalis sling.

The method of obtaining hiatal dimensions used in our trial was performed according to the study published by Dietz et al.[9] and found to be reproducible by others.[15,16] The plane of minimal hiatal dimensions was identified in the mid-sagittal plane, evident as the minimal distance between the hyperechogenic posterior aspect of the pubic symphysis and the hyperechogenic anterior border of the levator ani muscle, just posterior to the anorectum. When a satisfactory two-dimensional ultrasound image was achieved, the 3D volume was obtained automatically by the 3D function of the system, which maximises the quality of the acquisition and is saved in the system memory.

Post-processing and assessment of the volume ultrasound acquisition were performed by two investigators (S.A. and R.L.), both highly trained in urogynaecological 3D ultrasound. Each examiner was blind to the other's results but not to the obstetric features of the study participants. A test–retest series of 40 examinations was performed by the same investigators and the results were analysed with the κ statistic.

The axial plane at the level of minimal hiatal dimensions between the pubic bone and the dorsal aspect of the puborectalis sling, was used to determine mid-sagittal (hAP) and coronal (hLL) diameters of the levator hiatus, hiatal area (hA) and hiatal circumference (hC). The maximal thickness of the pubococcygeus-puborectalis muscle was measured by cranially moving the plane of minimal hiatal dimension until it was possible to visualise the maximal thickness of the muscle and take a measurement on each side, close to the rectum.[9]

To assess levator ani integrity, we used tomographic multislice ultrasound imaging with 2.5-mm slice intervals, from 5 mm below to 12.5 mm above the plane of minimal hiatal dimensions. This produced eight slices for each woman (see Figure S1). Despite the fact that we obtained the volumes with the woman in a resting position, we decided to consider slices at and above the plane of minimal hiatal dimensions only, as proposed by Dietz and Shek[17] for the volumes obtained on pelvic floor contraction. We documented each discontinuity (a break in the normal texture of the pubocoggygeal-puborectalis muscle, evident as an ultrasound hypo/anechogenic lesion interrupting the hyperechogenic course of muscle fibres) involving the pubococcygeus-puborectalis muscle, recognisable in the coronal C-plane slice (unilateral if the defect involves one side, bilateral if both sides are damaged). To standardise the diagnosis of a puborectalis sling injury and to differentiate true lesions from artefacts, we decided to diagnose an abnormality (meant as ultrasound discontinuity) evident in at least three consecutive slices above the plane of minimal hiatal dimension, as a LAM defect (see Figure S2).

Some difficult and unclear cases were evaluated a second time by both investigators (each blind to the other's evaluation), analysing single slices with the help of rendered volume and volume contrast imaging in C-plane and using the measurement of the levator urethra gap, with a measurement >2.5 cm being regarded as abnormal.[18]

All characteristic data on women were collected from a specific database program available in our clinic (KIM-PDM Program, version 5.7.0.0; Nexus AG, Villingen-Schwenningen, Germany), and analysed using the Excel program (Microsoft Office Excel 2007).

Statistical analysis was performed using GraphPad Prism, version 4.03 for Windows (GraphPad Software, San Diego, CA, USA). Normality testing (D'Agostino and Pearson omnibus normality test) was performed to determine whether data were sampled form a Gaussian distribution. The Student's *t* test and the Mann–Whitney *U* test were performed to compare continuous parametric and non-parametric variables respectively. The proportion of categorical variables was analysed for statistical significance by using Fisher's exact test. Statistical significance was considered to have been reached when the *P*-value was <0.05.

Results

During the study period, a total of 157 primiparae were considered eligible for participation in the study and gave their consent for ultrasound examination.

No women complained of pain or discomfort during the scan or refused to finish the ultrasound evaluation, as a result all women completed the examination and were included for data analysis. Women who delivered vaginally were considered as group A and women who had a caesarean section were classed as group B. Within group A, the women were also subdivided in relation to the mode of delivery as follows: spontaneous delivery, vacuum extraction and forceps extraction, whereas in group B distinction was made between elective and emergency caesarean section.

Eighty-one (51.6%) women delivered in group A (70 spontaneous deliveries, ten vacuum extractions, one forceps extraction) and 76 (48.4%) in group B (55 elective and 21 emergency caesarean sections). There was no statistical difference between the two groups for patient characteristics (age and body mass index [BMI]) except for gestational age (Table 1).

All biometrical indices of levator ani hiatus were higher after vaginal delivery compared with post-caesarean section values ($P < 0.001$). The thickness of the LAM both on the

Table 1. Demographic characteristics of group A and group B

Characteristics	Group A (n = 81)	Group B (n = 76)	P-value
Age (years)	30.76 (±5.5)	32.3 (±4.9)	0.074*
BMI (kg/m^2)	23 (17–36)	23 (16–47)	0.581**
Gestational age (days)	278 (238–301)	269 (183–292)	<0.001**

Data are expressed as mean ± SD, median (range).
Group A, vaginal deliveries; group B, caesarean sections.
*Student's *t* test; **Mann–Whitney *U* test.

Table 2 Biometric indices of LAM of group A and group B

Biometrical indices	Group A (n = 81)	Group B (n = 76)	P-value
hAP (cm)	6.0 (±0.8)	4.9 (±0.8)	<0.001*,***
hLL (cm)	4.0 (3.0–5.5)	3.6 (2.6–5.7)	<0.001*,***
hA (cm^2)	14.35 (8.6–22.4)	10.57 (5.8–31.37)	<0.001**
hC (cm)	15.89 (11.28–18.93)	13.16 (9.5–20.08)	<0.001*,***
Right levator thickness (cm)	0.7 (0.4–1.32)	0.66 (0.33–1.24)	0.126**,***
Left levator thickness (cm)	0.69 (0.34–1.85)	0.65 (0.31–1.02)	0.114**,***

Data are expressed as median (range) or mean ± SD.
Group A, vaginal deliveries; group B, caesarean sections; hAP, mid-sagittal (antero-posterior, AP) diameter of the hiatus (h) delimited by levator ani muscle; hLL, coronal (latero-lateral, LL) diameter of the hiatus (h) delimited by levator ani muscle; hA, area (A) of the hiatus (h) delimited by levator ani muscle; hC, circumference (C) of the hiatus delimited by levator ani muscle.
*Student's *t* test; **Mann–Whitney *U* test; ***explorative *P*-value.

left and on the right side did not significantly vary between the two groups (Table 2). Similar findings were observed when comparing a subgroup of group A (spontaneous vaginal delivery) with a subgroup of group B (elective caesarean section) (see Table S1), and these two groups were also comparable in age ($P = 0.06$) and BMI ($P = 0.64$), though not in gestational age ($P < 0.001$).

The presence of levator ani defects was significantly higher in group A (32/81, 39.5%) in comparison to group B (4/76, 5.2%) (Figures 1–4, and see Figures S3–S6) ($P < 0.001$), with a strong positive association between vaginal delivery and levator trauma (relative risk 7.5; 95% CI 2.78–20.23). Twenty-two (27.1%) and two (2.6%) unilateral defects, and ten (12.4%) and two (2.6%) bilateral defects were found in group A and group B, respectively. In group A, unilateral defects were found to be significantly more frequent than bilateral ($P = 0.009$).

Overall, 32 levator defects were found in group A: 27 (38.5%) after spontaneous delivery, four (40%) after vacuum extraction and one after the only forceps extraction in the study. In group B, four levator defects were observed, all of them after emergency caesarean section with complete cervix dilatation. These caesarean sections were performed on three women because of intrauterine asphyxia before the active pushing phase of the second stage of labour had begun (Figures 1–3 and see Figures S3–S5), and in one woman because of the arrest of fetal head descent during the late second stage of labour (Figure 4 and see Figure S6). In no woman was it documented that the head had descended below the level of the ischial spines before caesarean delivery. None of these four women had previously given birth, and none had attempted vaginal delivery in the index pregnancy before caesarean delivery. Consequently there was no potential for them to have had application of vacuum or forceps before caesarean delivery.

Comparing levator ani biometry after elective and emergency caesarean section, no significant difference on any level was found, as is shown in Table S2 (see Supporting information). These groups were comparable in terms of age ($P = 0.07$) and BMI ($P = 0.87$), but not in terms of gestational age ($P < 0.006$). Our data show that the presence of levator ani defects was significantly higher after emergency caesarean section (4/21, 19%), than after elective caesarean section (0/55) ($P = 0.004$), and that elective caesarean section protects from LAM defect with a relative risk of 0.03 (95% CI 0.001–0.683) in comparison with emergency caesarean section. The κ-statistic for agreement between examiners was performed on a subgroup of 40 women and gave $\kappa = 0.899$ ($P < 0.005$).

Discussion

The findings of our study suggest that after vaginal delivery a woman is seven times more likely to develop LAM defects than after a caesarean section. Despite this, we also found LAM abnormalities following emergency caesarean section. In our caesarean section group, four women were found to have a levator defect, three of them after a caesarean section performed before the active pushing phase of the second stage of labour had begun and before fetal head engagement.

The finding of a levator tear after caesarean section was absolutely unexpected in terms of the data published in the current literature. Furthermore, it is difficult to understand how tearing of the levator could occur before crowning of the fetal head because the distension of the puborectalis muscle does not appear to be necessary before crowning.[19] Nevertheless, we considered it to be important to describe and discuss our data, considering the limitations and the possible bias of this cohort trial.

First, the prevalence of LAM defects in our study is the highest reported in literature to date: 39.5% in comparison

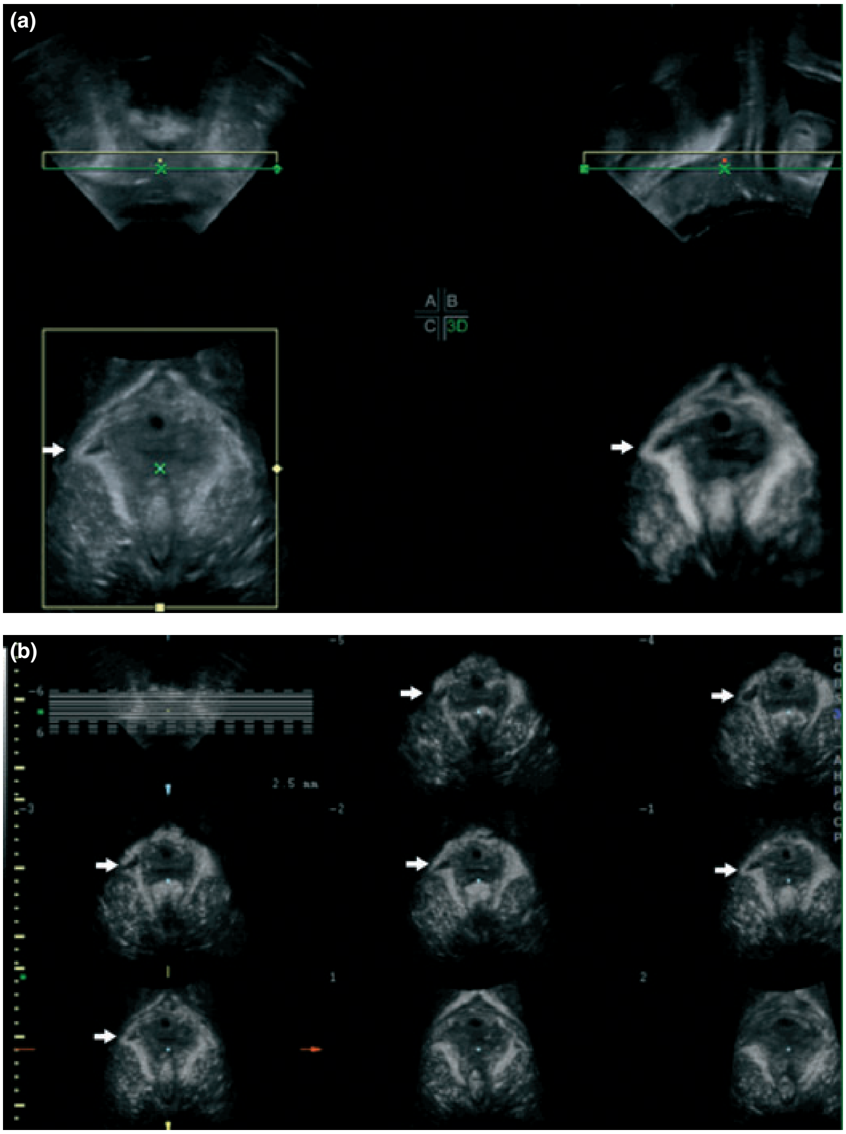

Figure 1. Levator assessment after an emergency caesarean section because of intrauterine asphyxia during late first stage of labour (acquisition screen GE Voluson-e® System). (A) Acquisition screen shows the orthogonal plane (lower left) and the rendered volume (lower right): a hypoechogenic spot interrupting course of fibres of LAM is evident on the right side of the LAM (arrow). (B) In the same woman the tomographic multislice ultrasound imaging slices above the plane of minimal hiatal dimension confirm the presence of a defect of the LAM (arrow): the absence of retraction of the damaged muscle could be because the levator plate has not come under load, so shortly after surgical delivery.

with 18.8% reported by Valsky et al.,[14] during the same postpartum period and using the 3D perineal ultrasound assessment. Over-diagnosis could be a possible explanation, when you consider that every test produces false-positive results, especially one that is so operator-dependent.

The decision to include all recognisable LAM abnormalities could also explain the difference in our results. Indeed, we have defined 'defect' and not avulsion as the assessed LAM abnormality, assuming that 'avulsion' is considered to be the complete detachment of the muscle from the bone.

The ultrasound assessment of complete and incomplete trauma is sometimes difficult, because of the complex and 3D nature of the levator hiatus occupying a warped (non-Euclidean) plane.[20] Recently, Dietz et al.[21] proposed a method to define partial and complete trauma of the LAM: they considered a complete avulsion to be if all three central slices (slice at plane of minimal hiatal dimension plus the two above) were abnormal, and partial avulsion was diagnosed when any three to eight slices were abnormal. Considering these criteria for diagnosis of avulsion, we have included complete and partial avulsion in our results.

The ultrasound differential diagnosis between a muscular tear and the presence of a fluid collection, e.g. a haematoma, is also sometimes unclear.

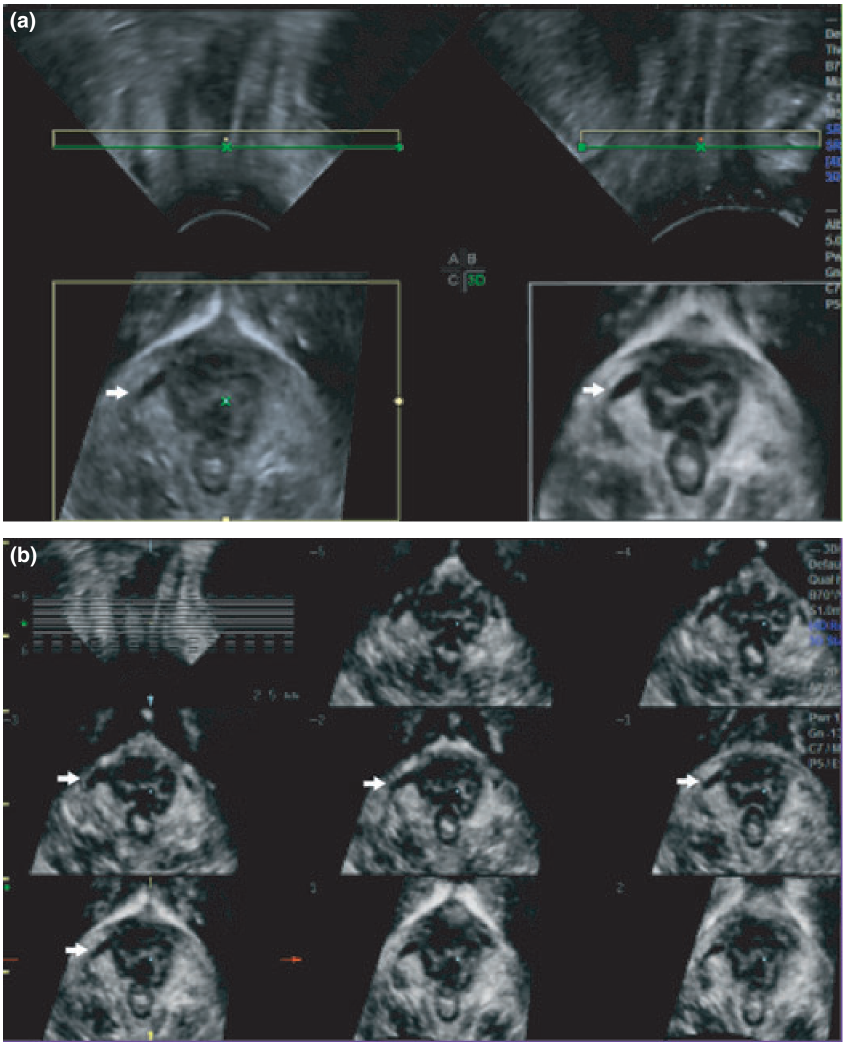

Figure 2. Levator assessment after an emergency caesarean section for intrauterine asphyxia during late first stage of labour (acquisition screen GE Voluson-e® System). (A) Acquisition screen shows the orthogonal plane (lower left) and the rendered volume (lower right): in the right side the course of muscular fibres appears interrupted (arrows). (B) In the same woman the tomographic multislice ultrasound imaging slices (*slice is the reference plane, the plane of minimal hiatal dimension; slices –1, –2, –3, –4, –5 correspond respectively to slice at 2.5, 5, 7.5, 10 and 12.5 mm above the reference plane): in at least three slices at and above the plane of minimal hiatal dimension a discontinuity can be seen on the right part of the muscle.

The avulsion rates following first vaginal delivery reported by Dietz's group, 19%[13] and 36%,[5] are not comparable with our own because of the different assessment time (3–4 and 2–6 months postpartum, respectively). From our data it also seems that bilateral avulsion (more than 30% of all defects in both groups), is not as rare as previously described.[5,14] This can be considered acceptable in light of the inclusion of complete and partial avulsion.

We cannot exclude the possibility that those women who underwent an emergency caesarean section may have begun inadequate voluntary pushing for some time before complete dilatation, considering that it appears to be more plausible for maternal expulsion forces to generate an injury rather than uterine contractions. This could create a bias when it comes to interpreting the data.

The lack of antepartum scans also includes the possibility of the presence of asymmetric levators as a normal anatomic variant in nulliparous women.

We considered women who had previously undergone a caesarean section to be eligible for inclusion in our study, assuming that those women had an intact levator ani. This is based on the demonstration by the literature to date that women who have undergone a caesarean section have an intact levator ani. From our database it was not possible to extract information on the unsuccessful trial of forceps in the delivery index. However, none of the women with

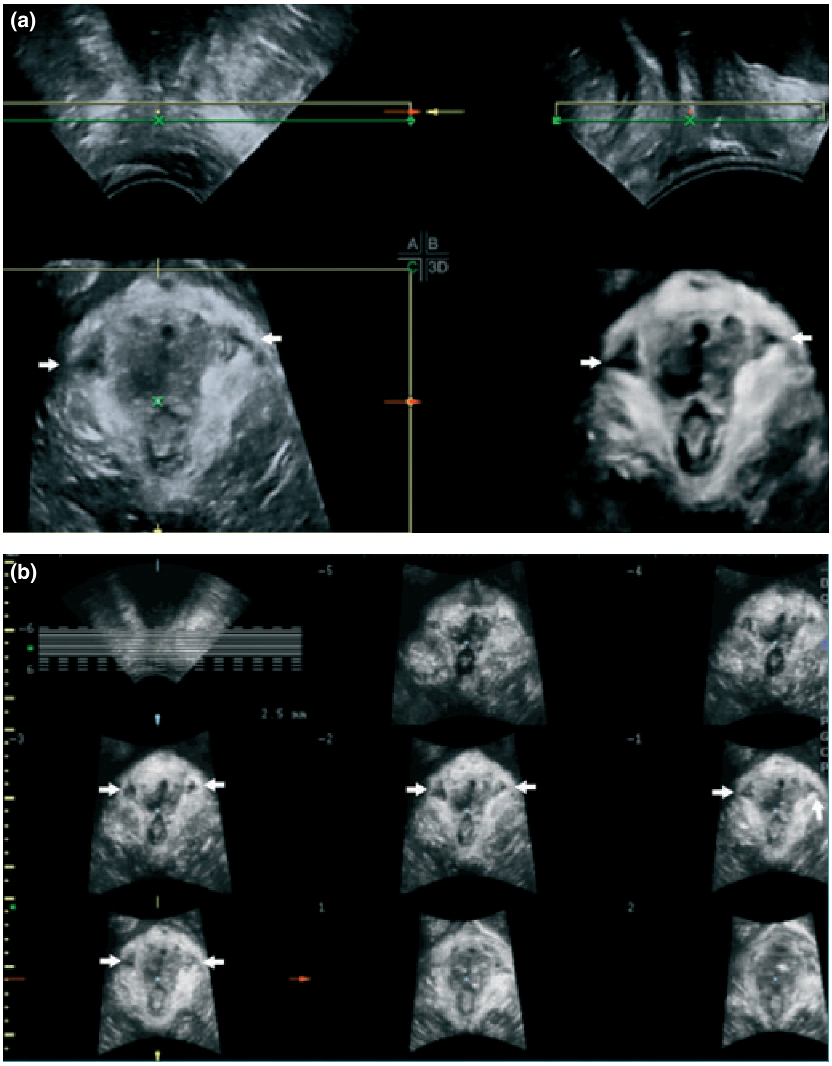

Figure 3. Levator assessment after an emergency caesarean section for intrauterine asphyxia during late first stage of labour (acquisition screen E Voluson-e® System). (A) Acquisition screen shows the orthogonal plane (lower left) and the rendered volume (lower right): the course of muscular fibres appears bilaterally interrupted (arrows). (B) In the same woman the tomographic multislice ultrasound imaging slices (*slice is the reference plane, the plane of minimal hiatal dimension; slices –1, –2, –3, –4, –5 correspond respectively to slices at 2.5, 5, 7.5, 10 and 12.5 mm above the reference plane): in at least three slices at and above the plane of minimal hiatal dimension is recognisable a bilateral discontinuity of LAM course.

levator defect after emergency caesarean section had had a previous birth, or an attempt at vaginal delivery during the index pregnancy, so we can exclude that these findings are the result of a previous unsuccessful attempt at operative vaginal delivery. The only study demonstrating the presence of levator abnormalities after caesarean section was published by Novellas et al.[22] They assessed primiparous women with MRI shortly after a caesarean section had been performed and they reported abnormalities (defined as hypersignal of the muscle, thinning or thickening, or rupture of the muscular insertion) in the pubococcygeus-puborectalis muscle of those women. They demonstrated that women experiencing active labour during a caesarean section had 2.7 times more abnormalities than women undergoing a caesarean without being in labour (including the emergency group of women with an average cervical dilatation of 6.2 cm [range 3–10 cm] and an average duration of labour of 5.65 hours [range 2–10 hours]).

A methodological aspect of our study was to investigate the structure of the LAM just after delivery. This is in contrast to most of the published studies, whereby its biometry was evaluated at least 6 weeks postpartum.[5,13,23–25] The minimal discomfort of 3D perineal sonography allowed us to evaluate the LAM even in the delicate and sensitive period of the early postpartum days. The fact that no woman complained of pain or discomfort during the assessment and that all completed the examination, confirms the broad feasibility and acceptance of this assessment procedure.

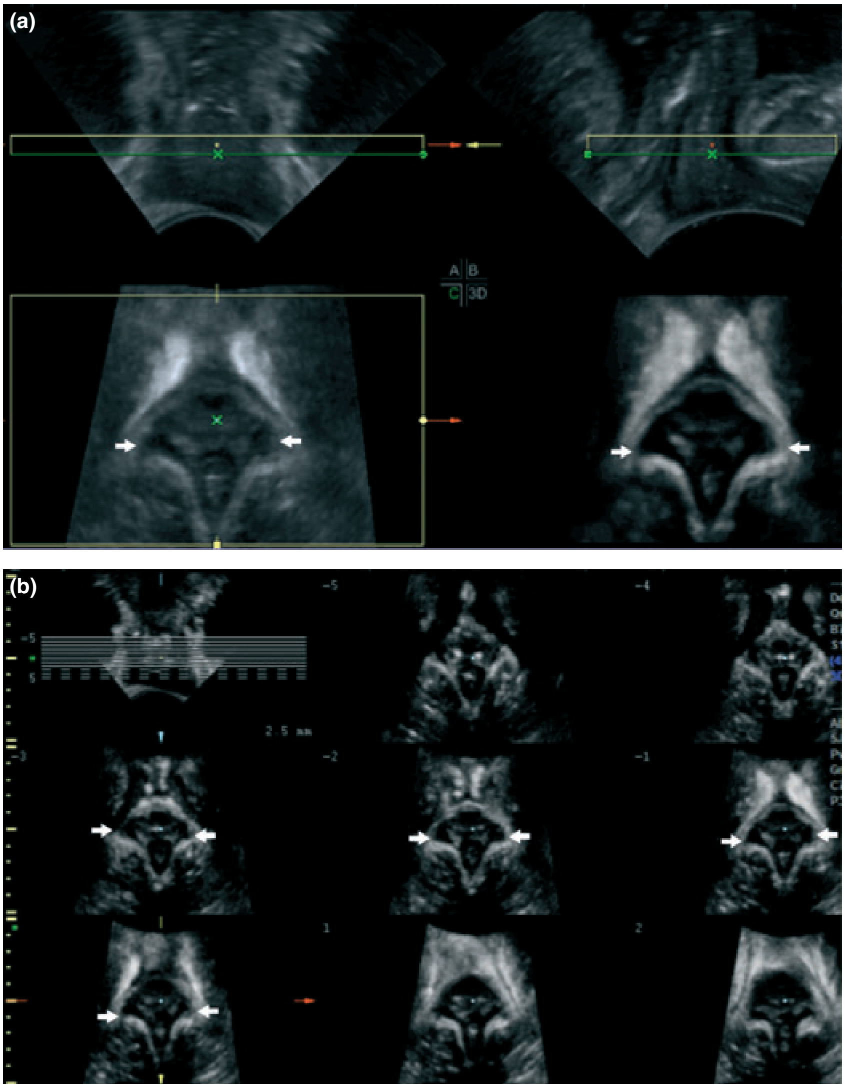

Figure 4. Levator assessment after an emergency caesarean section for arrest of fetal head descent during the late second stage of labour (acquisition screen GE Voluson-e® System). (A) Acquisition screen shows the orthogonal plane (lower left) and the rendered volume (lower right): in both sides the course of muscular fibres appear abnormal (arrows). (B) In the same woman the tomographic multislice ultrasound imaging slices (*slice is the reference plane, the plane of minimal hiatal dimension; slices –1, –2, –3, –4, –5 correspond respectively to slice at 2.5, 5, 7.5, 10 and 12.5 mm above the reference plane)in at least three slices at and above the plane of minimal hiatal dimension the course of pubococcygeus-puborectalis muscle seems bilaterally abnormal.

In addition, to scan the women at this time was favourable in terms of logistics because they were still in hospital. Such early ultrasound assessment allows us to evaluate the soft pelvic tissue immediately after the acute trauma, before tissue transformations and the remodelling process have occurred in the postpartum period.

However, this timing of the assessment only permits us to evaluate the LAM morphology at rest: the movement of the pelvic floor (contraction or Valsalva manoeuvre) could not be performed correctly by all women immediately postpartum because of pain related to episiotomy, perineal lacerations, caesarean wound, uterine contractions or simply the discomfort related to recent delivery. Therefore the lack of dynamic volumes during pelvic floor muscle contraction could also be a possible explanation for our unexpected findings, considering that avulsions appear to be more defined during contraction of the muscle.[18]

Finally, the studied population is a consecutive cohort of women, including all eligible women in the order in which they are identified during the study period: the high percentage of elective caesarean sections is probably the result of a selection bias, considering that the percentage of elective caesarean sections in our department in 2009 was 40% of all caesarean sections.

Conclusion

From our results we can conclude that vaginal delivery is associated with a higher risk of enlarging the pelvic diaphragm hiatus, and with a greater risk of LAM trauma in comparison with caesarean section. Despite this, we cannot exclude that the act of labour itself may have a negative effect on pelvic floor musculature, independently of any mechanism of deformation caused by fetal passage during vaginal delivery. From our findings it seems that the beginning of labour itself may play a role in levator morphological changes. We are aware that there are a number of limitations in this study; our intention is to make use of these controversial data, which need to be confirmed or contradicted, to provoke further questions about when LAM trauma occurs: a better understanding of the timing of the occurrence of LAM trauma during delivery could be an important tool for primary prevention.

Disclosure of interests

This study was awarded the Eugen Rehfish Prize, Forum Urodynamicum, Mainz (Germany) 2010. The financial prize of € 3000 will be awarded after publication, donated by Pfizer GmbH. Pfizer was not involved in the design, planning or any other part of the execution, analysis or drafting of this study.

Contribution to authorship

SA and RL conceived the idea for this paper, wrote the first draft, collected the data and performed the data analysis. CS, SS and GN participated in critically reviewing drafts; HK reworked the manuscript for intellectual content before submission and gave final approval. All authors approved the final version of the manuscript.

Details of ethics approval

The procedures used during the study were in accordance with the guidelines of the Declaration of Helsinki on human experimentation and with the Good Clinical Practice guidelines, and were justified by their potential diagnostic value. The Institutional Review Board of the Department of Obstetrics and Gynaecology at the Johannes Gutenberg University in Mainz approved the study protocol on 7 January 2009. Women provided written informed consent before any assessment and gave specific permission for personal health information to be used for research purposes.

Funding

No funding sources supported the investigation and no financial support was provided by any pharmaceutical company for the execution of this research.

Acknowledgements

We would like to thank Dr Kathrin Kuhr from the Department of Statistics at the Johannes Gutenberg University in Mainz for assistance with statistical data analysis and Dr Daniel Boehm of the Department of Obstetrics and Gynaecology at the Johannes Gutenberg University in Mainz for assistance with illustrations.

Supporting information

The following supplementary material is available for this article:

Figure S1. The multiplanar mode (A) and the TUI slices (B) show an intact levator ani after elective cesarean section (acquisition screen GE Voluson-e® System).

Figure S2. Levator ani defect early postpartum in a patient had spontaneous vaginal delivery (acquisition screen GE Voluson-e® System).

Figure S3. Levator assessment after an emergency cesarean section due to intrauterine asphyxia during late first stage of labour (acquisition screen GE Voluson-e® System).

Figure S4. Levator assessment after an emergency cesarean section due to intrauterine asphyxia during late first stage of labour (acquisition screen GE Voluson-e® System).

Figure S5. Levator assessment after an emergency cesarean section due to intrauterine asphyxia during late first stage of labour (acquisition screen E Voluson-e® System).

Figure S6. Levator assessment after an emergency cesarean section due the arrest of fetal head descent during the late second stage of labour (acquisition screen GE Voluson-e® System).

Table S1. Biometrical indices of LAM after spontaneous deliveries versus elective cesarean section.

Table S2. Biometrical indices of LAM after elective cesarean section versus emergency cesarean section.

Additional Supporting Information may be found in the online version of this article:

Please note: Wiley-Blackwell are not responsible for the content or functionality of any supporting information supplied by the authors. Any queries (other than missing material) should be directed to the corresponding author. ■

References

1 DeLancey JOL, Hurd WW. Size of urogenital hiatus in the levator ani muscles in normal women and women with pelvic organ prolapse. *Obstet Gynecol* 1998;91:364–8.

2 DeLancey JO, Morgan DM, Fenner DE, Kearney R, Guire K, Miller JM, et al. Comparison of levator muscle defects and function in women with and without pelvic organ prolapse. *Obstet Gynecol* 2007;109:295–302.

3 Dietz HP, Simpson JM. Levator trauma is associated with pelvic organ prolapse. *BJOG* 2008;115:979–84.

4 Hoyte L, Schierlitz L, Zou K, Flesh G, Fielding JR. Two- and 3-dimensional MRI comparison of levator ani structure, volume, and integrity in women with stress incontinence and prolapse. *Am J Obstet Gynecol* 2001;185:11–9.
5 Dietz HP, Lanzarone V. Levator trauma after vaginal delivery. *Obstet Gynecol* 2005;106:707–12.
6 Morgan D, Cardoza P, Guire K, Fenner D, DeLancey JOL. Levator ani defect status and lower urinary tract symptoms in women with pelvic organ prolapse. *Int Urogynecol J* 2010;21:47–52.
7 Dietz HP, Kirby A, Shek KL, Bedwell PJ. Does avulsion of the puborectalis muscle affect bladder function? *Int Urogynecol J* 2009;20:967–72.
8 Heilbrun ME, Nygaard IE, Lockart ME, Richter HE, Brown MB, Kenton KS, et al. Correlation between levator ani muscle injuries on magnetic resonance and fecal incontinence, pelvic organ prolapse, and urinary incontinence in primiparous women. *Am J Obstet Gynecol*, 2010;202:488.e1–6.
9 Dietz HP, Shek C, Clarke B. Biometry of the pubovisceral muscle and levator hiatus by three-dimensional pelvic floor ultrasound. *Ultrasound Obstet Gynecol* 2005;25:580–5.
10 Svabík K, Shek KL, Dietz HP. How much does the levator hiatus have to stretch during childbirth? *BJOG* 2009;116:1657–62.
11 Lien K, Mooney B, DeLancey JOL, Ashton-Miller JA. Levator ani muscle stretch induced by simulated vaginal birth. *Obstet Gynecol* 2004;103:31–40.
12 Allen RE, Hosker GL, Smith AR, Warrel DW. Pelvic floor damage and childbirth: a neurophysiological study. *Br J Obstet Gynaecol* 1990;97:770–9.
13 Shek KL, Dietz HP. The effect of childbirth on hiatal dimension. *Obstet Gynecol* 2009;113:1272–8.
14 Valsky DV, Lipschuetz M, Bord A, Eldar I, Messing B, Hochner-Celnikier D, et al. Fetal head circumference and length of second stage of labour are risk factors for levator ani muscle injury, diagnosed by 3-dimensional transperineal ultrasound in primiparous women. *Am J Obstet Gynecol* 2009;201:91.e1–7.
15 Yang J, Yang S, Huang W. Biometry of the pubovisceral muscle and levator hiatus in nulliparous Chinese women. *Ultraosund Obstet Gynecol* 2006;28:710–6.
16 Hoff Braekken I, Majida M, Ellstrom Engh M, Dietz HP, Umek W, Bo K. Test–retest and intra-observer repeatability of two, three and four dimensional perineal ultrasound of pelvic floor muscle anatomy and function. *Int Urogynecol J* 2007;19:227–35.
17 Dietz HP, Shek KL. Tomographic ultrasound imaging of the pelvic floor: which levels matter most? *Ultrasound Obstet Gynecol* 2009;33:698–703.
18 Dietz H, Abbu A, Shek K. The levator urethral gap measurement: a more objective means of determining levator avulsion? *Ultrasound Obstet Gynecol* 2008;32:941–5.
19 Blasi I, Fuchs I, D'Amico R, Vinci V, La Sala GB, Mazza V, et al. Intrapartum translabial 3D ultrasound visualization of levator trauma. *Ultrasound Obstet Gynecol* 2011;37:88–92.
20 Kruger JA, Heap SW, Murphy BA, Dietz HP. How best to measure the levator hiatus: evidence for the non-Euclidean nature of the 'plane of minimal dimensions'. *Ultrasound Obstet Gynecol* 2010;36:755–8.
21 Dietz HP, Bernardo MJ, Kirby A, Shek KL. Minimal criteria for the diagnosis of avulsion of the puborectalis muscle by tomographic ultrasound. *Int Urogynecol J* 2011;22:699–704.
22 Novellas S, Chassang M, Verger S, Bafghi A, Bongain A, Chevallier P. MR features of the levator ani muscle in the immediate postpartum following caesarean delivery. *Int Urogynecol J*, 2010;21:563–8.
23 Toozs-Hobson P, Balmforth J, Cardozo L, Khullar V, Athanasoiu S. The effect of mode of delivery on pelvic floor functional anatomy. *Int Urogynecol J* 2008;19:407–16.
24 Kearney R, Miller JM, Ashton-Miller JA, DeLancey JOL. Obstetric factors associated with levator ani muscle injury after vaginal birth. *Obstet Gynecol* 2006;107:144–9.
25 Krofta L, Otccenasek M, Kasikova E, Feyereisl J. Pubococcygeus-puborectalis trauma after forceps delivery: evaluation of the levator ani muscle with 3D/4D ultrasound. *Int Urogynecol J* 2009;20:1175–81.

Commentary on 'Impact of mode of delivery on levator morphology: a prospective observational study with three-dimensional ultrasound early in the postpartum period'

This study makes an important contribution to our understanding of maternal birth trauma. The authors have used a tried methodology appropriately. Their figures, while using a different orientation to the original tomographic imaging papers, are of high quality. Their results are plausible and add to a growing body of evidence in this field.

One of the findings, however, apparently contradicts previously published evidence on this issue. Albrich et al. are the first to demonstrate abnormalities of the puborectalis muscle in women who have not delivered vaginally. As the authors state: 'is difficult to understand how tearing of the levator could occur before crowning of the fetal head because the distension of the puborectalis muscle does not appear to be necessary before crowning'. An avulsion of the puborectalis is such a drastic event that it would require substantial mechanical forces, and in the absence of vaginal childbirth (or a failed forceps) the probability of such forces coming to bear on that muscle–bone interface must be very small.

There are other potential explanations, some mentioned by the authors. It is likely that the timing of their assessment (48–72 hours postpartum) plays a role. Figures 1 and 2 are quite peculiar. Appearances may well be caused by a vascular structure, especially in Figure 2. There is no retraction of the muscle, arguing against avulsion. Figure 3 also presents some unusual features. It is possible that a haematoma is responsible for these appearances. If so, I would expect the women in Figures 1–3 to appear normal–or near normal–on imaging at 3 months.

Figure 4 poses a more substantial challenge. This woman has a highly abnormal puborectalis muscle. I think that either this is a congenital abnormality, or she has suffered an avulsion injury in the past. It is not possible to be sure as we have no antepartum data for comparison. Our group has found such appearances in only one out of 497 nulliparae (Adi Suroso et al. *Int Urogynecol J* 2011;22:S21–3) and speculated that the patient may have concealed a previous delivery.

We may never be entirely certain about the true aetiology of morphological appearances in every woman, but for clinical purposes that may not be necessary. Because of the substantial progress being made in imaging, I would encourage the follow-up of all women with levator abnormalities for longer time periods. In a minority of women the use of volumes obtained on pelvic floor muscle contraction improves tissue discrimination. In a minority of women appearances will change over time (Shek et al. *Int Urogynecol J* 2011;22:S12–13). In addition, I personally advocate vaginal digital palpation, because this helps with the interpretation of imaging findings. I congratulate the authors on their interesting work, and for their courage in confronting readers with counterintuitive data.

Disclosure of interests

HP Dietz has, in the past, acted as a consultant for AMS, CCS and Materna Inc., has received speaker's honoraria from GE and Astellas, and has received equipment loans from GE, Toshiba and B+K. ■

HP Dietz
University of Sydney, Nepean Clinical School, Sydney, NSW, Australia