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Journal:	*Ultrasound in Obstetrics and Gynecology*
Manuscript ID	UOG-2018-0164.R2
Wiley - Manuscript type:	Original Article
Date Submitted by the Author:	n/a

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Manuscript Categories:	Urogynecology
Keywords:	Levator ani muscle, intrapartum ultrasound, labour, transperineal ultrasound, intrapartum

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Running headline: GAP intrapartum and LAM avulsion

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Word Count of Abstract: 245

Word Count of Main Text: 1674

Keywords: Levator ani muscle, intrapartum ultrasound, labour, transperineal ultrasound. intrapartum

SUCCESIVE INTRA- AND POST-PARTUM MEASUREMENTS OF LEVATOR-URETHRA GAP TO ESTABLISH THE TIMING OF LEVATOR AVULSION

Abstract:

Introduction: Levator trauma during childbirth highly increases the risk for future pelvic organ prolapse and thus it is important to understand the changes levator ani muscle suffers during labor. The aim of our study was to describe the levator urethra gap (LUG) measurements during the descent of the fetal head throughout labor, delivery and postpartum.

Material and methods: Prospective observational study including 27 primigravid patients, recruited during the first phase of labor, with fetus in cephalic presentation and without severe maternofetal pathology. An intrapartum transperineal 3D ultrasound study was performed at the following moments: vertex at -3 to -4 station, vertex at -2 to +2 station, vertex at +3 to +4 station, immediate postpartum and six months after the delivery. The ultrasound was carried out including the plane of minimal dimensions and the two slices 2.5mm and 5mm cranial to this plane, in which the LUG was measured.

Results: Eleven patients completed the study; 3 patients had instrumented deliveries, and 8 patients had spontaneous vaginal deliveries. Postpartum and 6 month's LUGs were slightly higher than those presented at the different stages of the delivery (right and left LUG in millimeters at vertex at +3 to +4 station: 18.8 and 18.8 versus 20.1 and 19.8 immediate postpartum, and 21.1 and 19.7 at 6 months postpartum, respectively); p not statistically significant. In cases of avulsion, the difference in LUG was visible after delivery (right and left LUG in millimeters at vertex at +3 to +4 station: 17.2 and 17.0, 25.7 and 33.0 immediate postpartum, and 35.0 and 34.9 at 6 months postpartum, respectively).

Conclusions: In patients diagnosed with levator avulsion, LUG measurements remain stable during the descent of the fetal head and increase after the delivery.

Keywords: Levator ani muscle, intrapartum ultrasound, labour, transperineal ultrasound. intrapartum

Key message: LAM avulsion occurs at the moment preceding the exit of the fetal head from the maternal perineum.

Main test

Introduction:

Vaginal delivery is one of the most important risk factors for the future appearance of pelvic floor dysfunctions. Muscle and ligament injuries that occur during vaginal deliveries favor the development of pelvic organ prolapse[1].

Avulsion of the levator ani muscle (LAM), defined as the discontinuity of the muscle fibers of the LAM in its pubic insertion[2], is present in 10-35% of women after a vaginal delivery[3]. Avulsion has been associated with several risk factors, such as prolonged second stage of labor[4], fetal head circumference[5], increased maternal age at first delivery[6], sphinter tear[7], low BMI[8], and forceps delivery[9]. LAM avulsion has an important role in the development of pelvic organ prolapse[1] and its recurrence after surgical repair[10].

Although modifiable risk factors for LAM avulsion have been identified[11], the mechanism by which it is produced has not been described. Different authors have hypothesized that the lesion of the LAM could be due to the bulging of the head of the fetus on the maternal perineum[2,12,13]. Recently, a study carried out using intrapartum transperineal 3D ultrasound has described that the maximum distension of the levator hiatus area occurs when the head is in the 4th plane of Hodge (vertex at +3 or +4 station)[14], moment at which the muscle seems to be most susceptible to trauma.

LAM avulsion diagnosis has been established using ultrasound and its multislice mode[15], identifying the muscle's abnormal insertion in different slices[15].

The measurement of the levator-urethra gap (LUG), defined as the distance between the center of the urethral lumen and the insertion of the levator in the inferior pubic ramus, is a reproducible method associated/well-realted with avulsion diagnosed by vaginal palpation[16]. In addition, multislice evaluation and LUG measurements show a good agreement for the diagnosis of avulsion, especially in doubtful cases[17], offering an objective mode for the diagnosis of these lesions.

This study aims to determine, the modifications in the LUG measurements during the descent of the fetal head and in the postpartum.

Material and Method

This prospective observational study was conducted between October 1, 2016 and January 31, 2017, with patients recruited from the Valme University Hospital Maternity Unit in Seville (Spain). The study (registration number: PI-232013) was approved by Andalucia's Board of Biomedicine Ethics Committee.

Twenty-seven primiparous patients, recruited during the first stage of delivery, were invited to participate. They all had a fetus in cephalic presentation and no severe maternofetal pathology. Written informed consent was obtained before the enrolment of all patients in the study. We analyzed maternal age, gestational age, epidural presence, epidural time, duration of first and second stages of labor, type of delivery, presence of episiotomy, perineal tears and weight of the newborn.

The deliveries were performed by personnel belonging to Valme's University Hospital Maternity Unit in Seville (Spain), with a minimum experience of 3 years in obstetric practice.

The ultrasound study was performed using 3D transperineal ultrasound, which was performed as previously described[18]. The sonographic volumes were captured at the following moments (identified by digital palpation): (1) vertex at -3 to -4 station (first plane of Hodge); (2) vertex at -2 to +2 station (second or third plane of Hodge); (3) vertex at +3 to +4 station (fourth plane of Hodge); (4) immediately postpartum (in the delivery room); (5) six months after delivery. These captures were performed by the same sonographer and stored for offline analysis. The sonographer who performed the ultrasound scan and carried out the offline analysis was blinded to clinical data regarding the delivery.

Sonographic evaluation was performed by a single sonographer with previous knowledge in 3-4D ultrasound of the pelvic floor (more than 500 previous studies), using a Toshiba Aplio 500® ultrasound system (Toshiba Medical Systems Corp., Tokyo, Japan) and an abdominal 3D probe PVT-675MV. The multislice ultrasound study was focused on the analysis of the plane of minimal dimensions (PMD)[18], (figure 1) obtained from the mid sagittal plane. From this plane, slices at 2.5 mm and 5 mm above the PMD were obtained. The LUG was measured by placing the calipers in the center of the hypoechogenic structure to indicate the urethral mucosa and smooth muscle as well as on the most medial border of the muscle insertion on the inferior pubic ramus[16]. The diagnosis of avulsion was established by ultrasound, using the criteria described by previous authors[15] at 6 months postpartum.

Quantitative variables were reported as means and standard deviations, and qualitative variables were reported as percentages. To perform mean comparisons of quantitative variables between the groups defined by type of delivery, Student's t-test for independent samples was applied in the case of normally distributed data, and the nonparametric Mann-Whitney U test was applied in the case of non-normal distributions (Shapiro-Wilk test). To analyze the relationships between qualitative variables, contingency tables were made, and the chi-square test or the non-asymptotic methods of Monte Carlo and the exact test were used. Statistical analysis was performed with SPSS Statistics version 23.

Results

Twenty-seven patients were recruited during their admission to the Maternity Unit. Sixteen did not complete the study, 4 due to the need for intrapartum caesarean section (1 due to failure to induce labor, 1 due to risk of loss of fetal well-being and 2 due to failure to progress), 10 due to not being able to capture all the ultrasound volumes during the stages previously planned and 2 for not attending the 6 month postpartum evaluation. Thus, 11 patients completed the study, of whom 3 had instrumented deliveries (2 vacuum and 1 forceps) to shorten the second stage of labor. General data of the study population is shown in Table 1. Two cases of LAM avulsion were detected, one of them bilateral and the other unilateral (both of the patients had had a spontaneous vaginal delivery).

Table 2 shows LUG measurements (right and left) in the different ultrasound sections analyzed and at the different moments of the delivery studied. The immediate postpartum and 6-month postpartum LUG measurements were higher than those presented at the different stages of delivery (although this was not statistically significant). The patients were classified according to the existence or absence of LAM avulsion (right and left), and the LUG measurements (right and left) were grouped by stages (table 2). In cases of LAM avulsion, a LUG increase was identified both at the immediate postpartum evaluation and 6 months postpartum assessment, not statistically significant (figure 2).

Discussion

Modifications suffered by the LAM during labor can lead to pelvic floor muscle injuries. In fact, excessive stretching during the second stage of labor can lead to LAM[12,20]. A 3D geometric model of the pelvic floor has been described in which the iliococcygeus, pubococcygeus and puborectal muscles were stretched during the descent of the fetal head through the birth canal[20]. The fascicle that suffers a greater stretching ratio is the pubococcygeus muscle[20]. Therefore, the pubococcygeus is the pelvic floor muscle with the highest risk of injury during the second stage of labor. However, this model presented two important limitations: it did not take into consideration the different tensions to which the different tissues were subjected, and it simplified the geometry of the fetal head. In a later study, it was the medial portion of the pubovisceral muscle the muscular region the one that presented the greatest stretching during a vaginal delivery[21], acquiring a higher probability of injury[22]. Similar findings were described by our group, using intrapartum 3D transperineal ultrasound. We observed that the moment at which the levator's hiatus was greater was when the fetal head reached the 4th plane of Hodge[23] (vertex at +3 to +4 station). In addition, it was suggested that the moment at which the avulsion occurs is immediately before the exit of the fetal head[23]. However, in that work, intra-partum ultrasound analysis of the LAM was performed in a single slice (PMD), which is why the diagnosis of intrapartum avulsion could be questioned. Therefore, in the present study, in order to assess the LAM, multislice mode was applied during all phases of labor. We observed that in the cases that had avulsion of the LAM, the diagnosis could only be achieved after the exit of the fetal head and not before.

It can be thought that the tissue distortion the fetal head could cause during labor and immediate postpartum period, could be a limitation for the diagnosis of avulsion. However, in none of the intrapartum images studied have we observed such striking artifacts that could lead us to identifying incorrectly an injury when it really did not exist, 6 months after the delivery. The study of LUG measurements has been established as a reproducible method for the diagnosis of LAM avulsion[16]. In fact, the qualitative analysis of multislice mode and the LUG measurement have proved to have a good correlation for the diagnosis of avulsion[17], when a cut-off point for the LUG measurements of 25 mm was used for the diagnosis of avulsion[16]. In our study, this cut-off point was exceeded exclusively in postpartum evaluations in patients with LAM avulsion (figure 2). Thus, the measurements of LUG in the immediate postpartum and 6 months after delivery were higher than the intrapartum LUG measurements, as shown in table 2. In our study, the diagnosis of avulsion was achieved only in the postpartum, with no intrapartum diagnoses.

This work presents a series of limitations, such as the great loss of patients suffered throughout the study. This fact is justified by the strict inclusion criteria that we have established, as if all the images for all the predefined stages of the delivery were not obtained, the cases were excluded.

Being this one the first study that analyzes LAM, by means of the multislice mode during the passage of the fetal head throughout the different stages of labor, we believe we were able to obtain a suitable number of patients. However, we do consider sample size should be increased for future studies.

Another remarkable aspect of our study is the fact that the defects of LAM identified during the immediate postpartum period persisted 6 months after delivery, as previously described24. However, this fact must be contrasted with studies that include a larger number of patients and a standardized methodology for the diagnosis of LAM avulsion.

We have not observed an increase in intrapartum LUG measurements, nor in those cases in which LAM avulsion was diagnosed. Therefore, we conclude that the LUG measurements remain stable during the descent of the fetal head and increase once the delivery has occurred.

Acknowledgements and funding

We acknowledge the support of the Spanish Ministry of Health by a grant of the "Fondo de Investigaciones Sanitarias-Instituto de Investigación Carlos III" (FIS Grant PI16/01387)

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Table 1 General characteristics of study population **(n=11)**.

	Mean (± SD) - %	**95% CI**
Mean maternal age (years)	27.6 (±6.2)	23.3 - 32.0
Gestational age (weeks)	39.2 (±1.3)	38.3 - 40.1
BMI	26.2 (± 0.4)	25.4-27.1
Epidural analgesia	100% (11/11)	
Epidural period (minutes)	360.4 (±101.2)	292.4 - 428.5
Lenght of first stage of labor (minutes)	333.6 (±131.8)	245.1 – 422.2
Lenght of second stage of labor (minutes)	106.4 (±27.0)	88.2 – 124.5
Episiotomy	54.5 % (6/11)	25.1 – 83.9
Perineal tears	45,5 % (5 /11)	16.1 – 74.9
High grade perineal tears	40.0 % (2/5)	0 – 82.9
Weight at birth (gr)	3170.9 (±387.5)	2910.6 – 3431.2

Table 2. Levator-urethra gap (LUG) measurements taken from plane of minimal dimensions (PMD).

	Mean (± SD)					p					
	Vertex at -3 to -4 station	Vertex at -2 to +2 station	Vertex at +3 to +4 station	Postpartum	Six months after delivery	p 1.A	p 2.A	p.3A	p 1.B	p 2.B	p 3.B
Right LUG (Reference slice) (mm)											
All	18.2 (±3.2)	19.9 (±2.9)	18.8 (±2.3)	20.1(±4.5)	21.1 (±7.1)	0.529	0.894	0.462	0.433	0.520	0.355
Without avulsion	19.5 (±2.9)	19.1 (±2.2)	19.1 (±2.3)	18.8 (±2.2)	17.9 (±1.7)	0.596	0.772	0.820	0.330	0.233	0.087
With avulsion	15.9 (±3.5)	23.1 (±4.3)	17.2 (±0.4)	25.7 (±9.3)	35.0 (±0.7)	0.476	0.833	0.438	0.063	0.134	0.007
Left LUG (Reference slice) (mm)											
All	19.1 (±2.8)	19.7 (±2.1)	18.8 (±2.4)	19.8 (±4.8)	19.7 (±5.4)	0.706	0.957	0.579	0.793	0.996	0.628
Without avulsion	19.42 (±2.6)	19.8 (±2.1)	18.9 (±2.3)	18.5 (±2.0)	18.7 (±2.0)	0.175	0.158	0.445	0.361	0.135	0.180
With avulsion	16.2 (±0)	19.1 (±0)	17.0 (±0)	33.0 (±0)	34.9 (±0)	-	-	-	-	-	-
Right LUG (2,5 mm cranial) (mm)											
All	18.6 (±2.8)	19.2 (±2.8)	19.2 (±2.3)	20.2 (±4.8)	21.1 (±7.0)	0.420	0.550	0.572	0.362	0.431	0.425
Without avulsion	19.0 (±2.8)	19.4 (±2.5)	19.4 (±2.4)	18.5 (±2.1)	18.0 (±1.9)	0.626	0.472	0.401	0.523	0.136	0.142
With avulsion	16.8 (±2.4)	17.7 (±4.3)	17.8 (±0.6)	27.4 (±8.4)	34.9 (±0.3)	0.400	0.185	0.374	0.070	0.103	0.026
Left LUG (2,5 mm cranial) (mm)											
All	18.2 (±2.5)	19.9 (±2.6)	19.4 (±2.3)	20.3 (±5.0)	19.4 (±5.0)	0.268	0.809	0.601	0.537	0.824	0.962
Without avulsion	18.58 (±2.2)	19.9 (±2.6)	19.46 (±2.2)	18.9 (±2.1)	18.0 (±1.9)	0.208	0.136	0.316	0.602	0.111	0.067
With avulsion	14.6 (±0)	19.2 (±0)	18.3 (±0)	34.1 (±0)	33.4 (±0)	-	-	-	-	-	-
Right LUG (5 mm cranial) (mm)											
All	18.2 (±1.7)	18.7 (±2.9)	19.0 (±2.5)	20.3 (±4.7)	20.8 (±6.5)	0.214	0.320	0.476	0.253	0.393	0.444
Without avulsion	18.3 (±1.7)	18.9 (±2.7)	19.3 (±2.7)	18.7 (±2.0)	17.8 (±1.2)	0.541	0.805	0.558	0.611	0.277	0.084
With avulsion	17.6 (±1.8)	17.3 (±4.5)	17.6 (±0.9)	27.2 (±8.2)	33.7 (±1.7)	0.406	0.164	0.380	0.002	0.170	0.022

Left LUG (5 mm cranial) (mm)											
All	18.5 (±2.1)	19.6 (±2.6)	19.3 (±2.2)	20.3 (±5.2)	19.3 (±4.9)	0.289	0.681	0.571	0.636	0.863	0.996
Without avulsion	18.7 (±2.0)	19.6 (±2.6)	19.4 (±2.2)	18.9 (±2.1)	17.9 (±1.9)	0.777	0.245	0.395	0.582	0.180	0.133
With avulsion	16.1 (±0)	19.5 (±0)	18.2 (±0)	34.5 (±0)	32.9 (±0)	-	-	-	-	-	-

P 1.A. Comparison between Vertex at -3 to -4 station and Postpartum
P 2.A. Comparison between Vertex at -2 to +2 station and Postpartum
P 3.A. Comparison between Vertex at +3 to +4 station and Postpartum
P 1.B. Comparison between Vertex at -3 to -4 station and Six months after delivery
P 2.B. Comparison between Vertex at -2 to +2 station and Six months after delivery
P 3.B. Comparison between Vertex at +3 to +4 station and Six months after delivery

Figure 1: Mid sagittal plane. P: Pubis, B: Bladder, V: Vagina, R: Rectum, L: Levator ani muscle, H: Fetal head with vertex at -3 to -4 station. The box represents the plane of minimal dimensions.

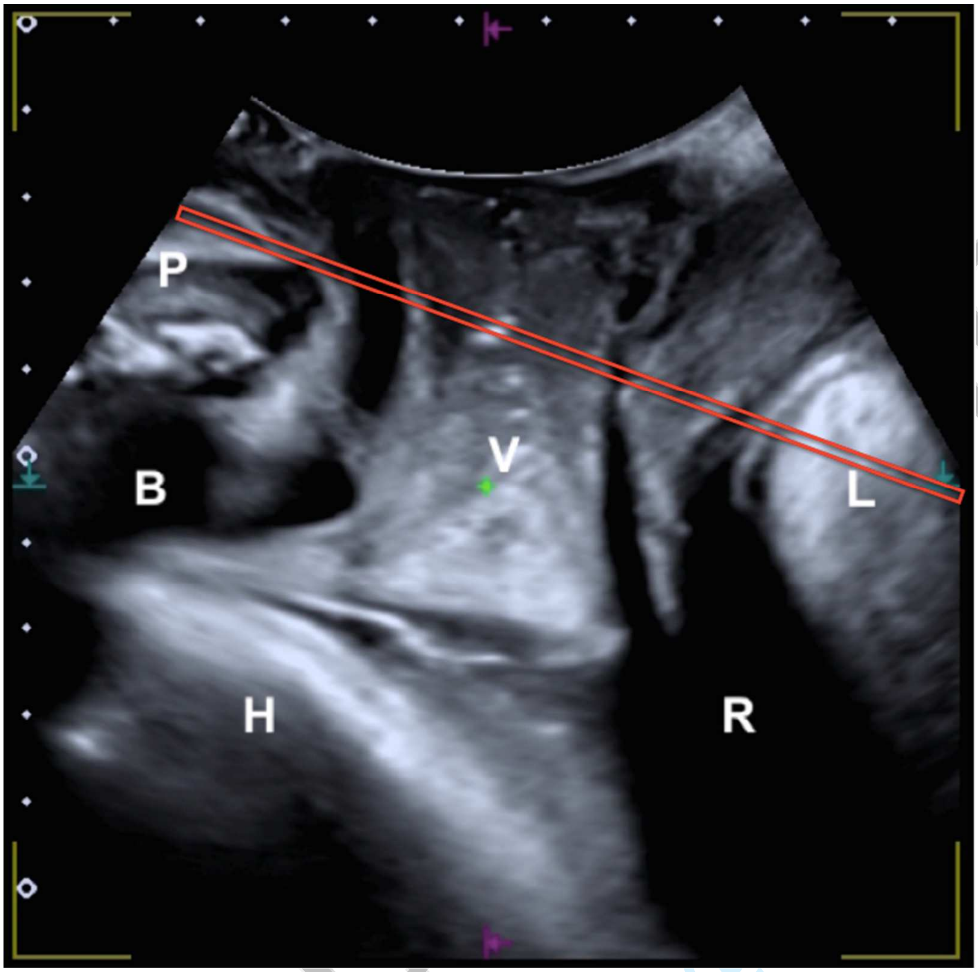

Figure 2: LUG measurements at the different moments of the delivery studied in a case with bilateral avulsion. A: LUG measurement with fetal head with vertex at -3 to -4 station. B: LUG measurement with the fetal head with vertex at -2 to +2 station and caput succedaneum reaching PMD. C: LUG measurement with the fetal head with vertex at +3 to +4 station; fetal head has reached PMD in an occipito-anterior position, allowing visualization of fetal skull and cranial sutures; at this level, compression of the urethra and anus by the fetal head can be appreciated. D: Significant alteration of LUG measurement postpartum. E: Significant alteration of LUG measurement six months after delivery.