OBSTETRICS

Contraction of the levator ani muscle during Valsalva maneuver (coactivation) is associated with a longer active second stage of labor in nulliparous women undergoing induction of labor

Check for updates

Rasha Kamel, MD, PhD; Elisa Montaguti, MD; Kypros H. Nicolaides, MD; Mahmoud Soliman, MD, PhD; Maria Gaia Dodaro, MD; Sherif Negm, MD, PhD; Gianluigi Pilu, MD, PhD; Mohamed Momtaz, MD, PhD; Aly Youssef, MD, PhD

BACKGROUND: The Valsalva maneuver is normally accompanied by relaxation of the levator ani muscle, which stretches around the presenting part, but in some women the maneuver is accompanied by levator ani muscle contraction, which is referred to as levator ani muscle coactivation. The effect of such coactivation on labor outcome in women undergoing induction of labor has not been previously assessed.

OBJECTIVE: The aim of the study was to assess the effect of levator ani muscle coactivation on labor outcome, in particular on the duration of the second and active second stage of labor, in nulliparous women undergoing induction of labor.

STUDY DESIGN: Transperineal ultrasound was used to measure the anteroposterior diameter of the levator hiatus, both at rest and at maximum Valsalva maneuver, in a group of nulliparous women undergoing induction of labor in 2 tertiary-level university hospitals. The correlation between anteroposterior diameter of the levator hiatus values and levator ani muscle coactivation with the mode of delivery and various labor durations was assessed.

RESULTS: In total, 138 women were included in the analysis. Larger anteroposterior diameter of the levator hiatus at Valsalva was associated with a shorter second stage ($r = -0.230$, $P = .021$) and active second stage ($r = -0.338$, $P = .001$) of labor. Women with levator ani muscle coactivation had a significantly longer active second stage duration (60 ± 56 vs 28 ± 16 minutes, $P < .001$). Cox regression analysis, adjusted for maternal age and epidural analgesia, demonstrated an independent significant correlation between levator ani muscle coactivation and a longer active second stage of labor (hazard ratio, 2.085; 95% confidence interval, 1.158–3.752; $P = .014$). There was no significant difference between women who underwent operative delivery ($n = 46$) when compared with the spontaneous vaginal delivery group ($n = 92$) as regards anteroposterior diameter of the levator hiatus at rest and at Valsalva maneuver, nor in the prevalence of levator ani muscle coactivation (10/46 vs 15/92; $P = .49$).

CONCLUSION: Levator ani coactivation is associated with a longer active second stage of labor.

Key words: coactivation, induction of labor, levator ani muscle, levator hiatus, operative vaginal delivery, pelvic floor, perineal ultrasound, transperineal ultrasound

Introduction

The second stage of labor is the defined as the duration from full cervical dilatation to delivery.[1] Prolonged second stage of labor is associated with an increased risk of maternal and neonatal complications.[2] The length of the second stage of labor can be influenced by many factors. These may include fetal head dimensions, fetal weight, the use of epidural analgesia, and fetal head engagement.[3–5] However, accurate prediction of the second stage duration, and the definition and management of a prolonged second stage of labor remain challenging.[6]

EDITORS' CHOICE

Valsalva maneuver, whereby the mother is asked to take a deep breath, hold the breath, and push downward when uterine contraction starts, is widely used in the management of the active second stage of labor. However, there is contradictory evidence concerning the benefit and harm in the use of this maneuver.[7–9] The Valsalva maneuver is normally accompanied by relaxation of the levator ani muscle, which stretches around the presenting part, but in some women the maneuver is accompanied by levator ani muscle contraction, which is referred to as levator ani muscle coactivation.[10]

Vaginal delivery is one of the most important risk factors for pelvic floor dysfunction.[11–15] Transperineal ultrasound has been used extensively for assessment of the levator hiatus and levator ani muscle integrity[16–28] and several studies have increased the understanding of the relationship between failure of vaginal delivery and pelvic floor dysfunction.[24,26,28–30] Indeed, it has been suggested that the viscoelastic properties of the intact distal birth canal in healthy nulliparous women may predict the duration of the second stage of labor.[31] However, the effect of levator ani muscle coactivation on labor outcome in women undergoing induction of labor has not been previously assessed.

The aim of this study was to assess the effect of levator ani muscle coactivation on the outcome of labor, in particular on the duration of the second and active second stage of labor in nulliparous women undergoing induction of labor.

Cite this article as: Kamel R, Montaguti E, Nicolaides KH, et al. Contraction of the levator ani muscle during Valsalva maneuver (coactivation) is associated with a longer active second stage of labor in nulliparous women undergoing induction of labor. Am J Obstet Gynecol 2019;220:189.e1-8.

0002-9378/free

https://doi.org/10.1016/j.ajog.2018.10.013

Click Supplemental Materials and Video under article title in Contents at ajog.org

AJOG at a Glance

Why was this study conducted?

Levator ani muscle contraction during Valsalva maneuver (coactivation) may represent an obstacle to spontaneous vaginal delivery. The effect of this phenomenon on labor outcome has not been studied previously.

Key findings

Levator ani muscle contraction during Valsalva maneuver (coactivation) is associated with a significantly longer active second stage of labor. Larger diameters of the levator hiatus under Valsalva maneuver, but not at rest, are associated with shorter second and active second stage of labor.

What does this add to what is known?

The effect of a new mechanism (namely levator ani muscle contraction during Valsalva; also known as coactivation) on the duration of the active second stage of labor.

Materials and Methods

This was a prospective observational study conducted from November 2017 through May 2018 in 2 tertiary-level university hospitals (Sant'Orsola Malpighi University Hospital, University of Bologna and Kasr Al-Ainy University Hospital, Cairo University). The study population constituted a nonconsecutive series of nulliparous women with singleton pregnancies, fetuses in cephalic presentation, and no history of uterine surgery, undergoing induction of labor at 37—42 weeks of gestation for any indication. Pregnancies resulting in operative delivery for suspected fetal distress due to an abnormal fetal heart rate pattern in labor were excluded from the study, as it is unlikely that pelvic floor function may influence fetal condition. Women were recruited when one of the physicians involved in the study and experienced in transperineal ultrasound was present in the inpatient ward exclusively for the aim of the study.

Following recruitment, an operator with >3 years of experience in transperineal ultrasound, blinded to clinical examination results, performed a transperineal ultrasound scan with a convex transducer covered by a sterile glove (Voluson 730 Expert or E10, GE Medical Systems, Zipf, Austria). In the midsagittal view the following structures were visualized: pubic symphysis, fetal head, rectum, and puborectalis muscle (Figure 1). The anteroposterior diameter of the levator hiatus, running from the inferior border of the symphysis pubis to the anterior border of the puborectalis muscle, which is the main portion of the levator ani muscle, was measured under resting condition and under maximum Valsalva maneuver (Figure 2). Levator ani muscle coactivation was diagnosed when the anteroposterior diameter of the levator hiatus under Valsalva maneuver was less than that in the resting state.[10] Figures 3 and 4 and Videoclip 1 illustrate the phenomenon of levator ani muscle coactivation.

Birth attendants were unaware of the results of transperineal ultrasound assessment. The second stage of labor was defined as the duration from full cervical dilatation to delivery, while the active second stage was calculated from the beginning of active maternal effort following confirmation of full dilatation of the cervix to delivery.[1]

Since there is insufficient evidence to justify routine use of any specific timing of pushing in the second stage, in both centers immediate and delayed pushing approaches were chosen according to women's preference and comfort, and to the preference and experience of the birth attendant.[32] In the 2 participating centers there is no policy to limit the time of second or active second stage of labor and the pushing technique, coached vs spontaneous, is left to the preference of the birth attendant.

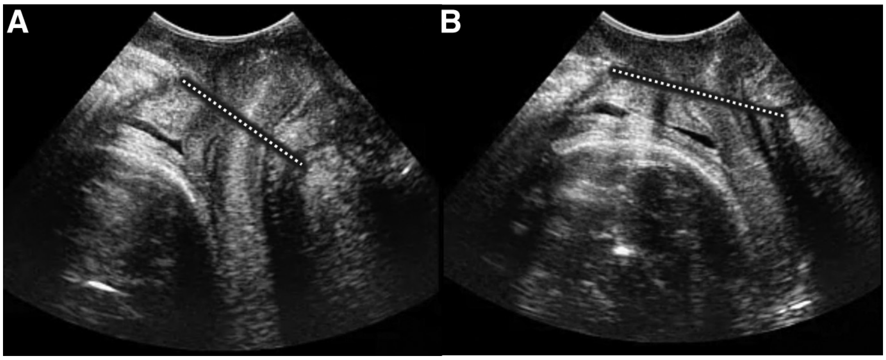
Following delivery, the medical records of the women were examined and the following data were extracted: maternal

FIGURE 1
Technique of transperineal ultrasound showing structures on the midsagittal plane

Technique of transperineal ultrasound. **A**, Placement of convex transducer in midsagittal plane. **B**, Ultrasound image. **C**, Structures visualized, including pubic symphysis (PS), urinary bladder (UB), fetal head, vagina (VAG), rectum (R), anus (A), and puborectalis muscle (P.R.).

Kamel et al. Levator ani contraction and active second stage. Am J Obstet Gynecol 2019.

FIGURE 2
Anteroposterior diameter of levator hiatus at rest and Valsalva maneuver



Transperineal ultrasound images illustrating measurement of anteroposterior diameter of levator hiatus under **A**, resting condition and **B**, maximum Valsalva maneuver.

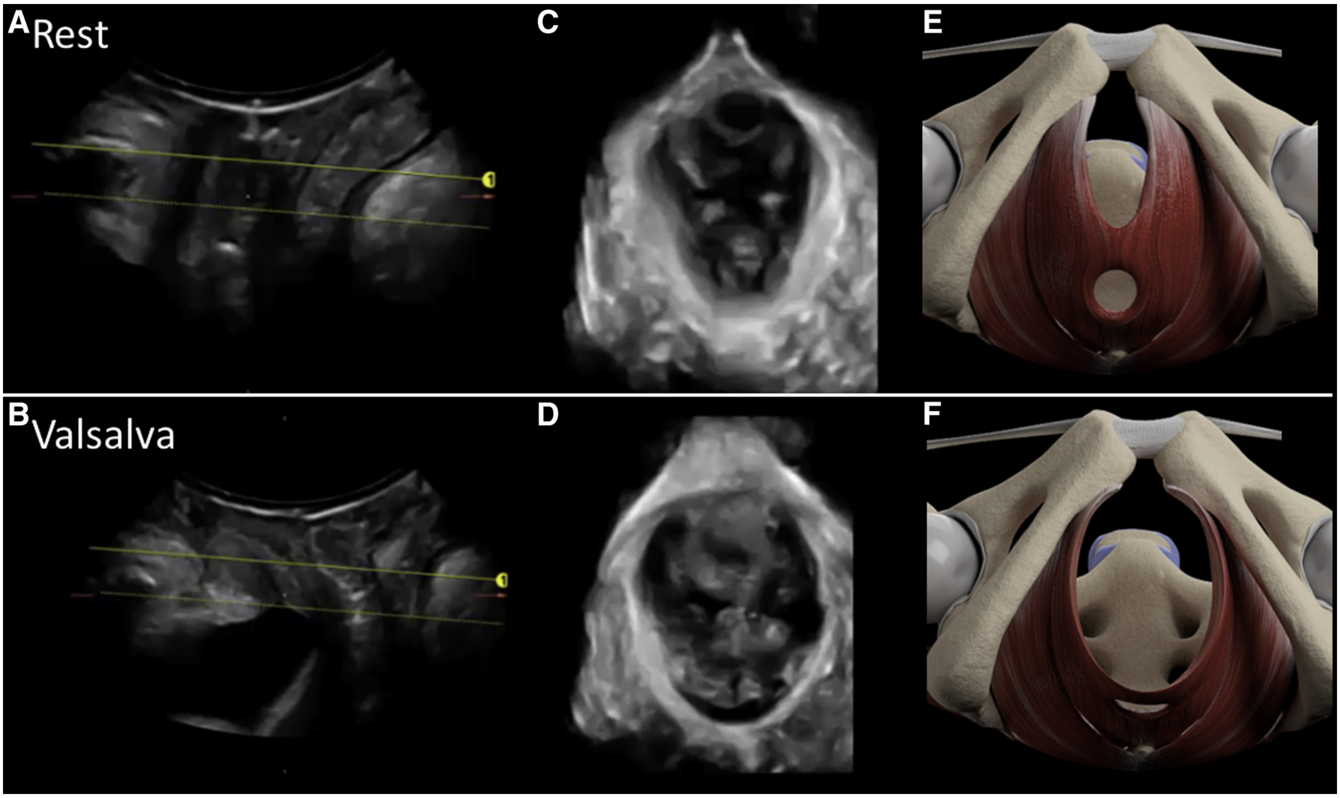
Kamel et al. Levator ani contraction and active second stage. Am J Obstet Gynecol 2019.

age and body mass index (BMI), gestational age, indication and method of induction of labor, use of epidural analgesia, mode of delivery, birthweight, interval between ultrasound assessment and delivery, and duration of second and active second stages of labor. The primary outcome of the present study was the duration of the second stage.

Statistical analysis

Differences between women with spontaneous vaginal delivery and the operative delivery group, and between women with and without coactivation, were assessed by unpaired 2-tailed Student *t* test and Fisher exact test. Pearson correlation was used to assess the significance of association between the anteroposterior diameter of the levator hiatus and various labor durations. The durations of induction of labor to delivery, and of second and active second stage were evaluated in relation to levator ani muscle coactivation using Cox regression analysis adjusted for identified significant confounders, and with Kaplan-Meier survival analysis.

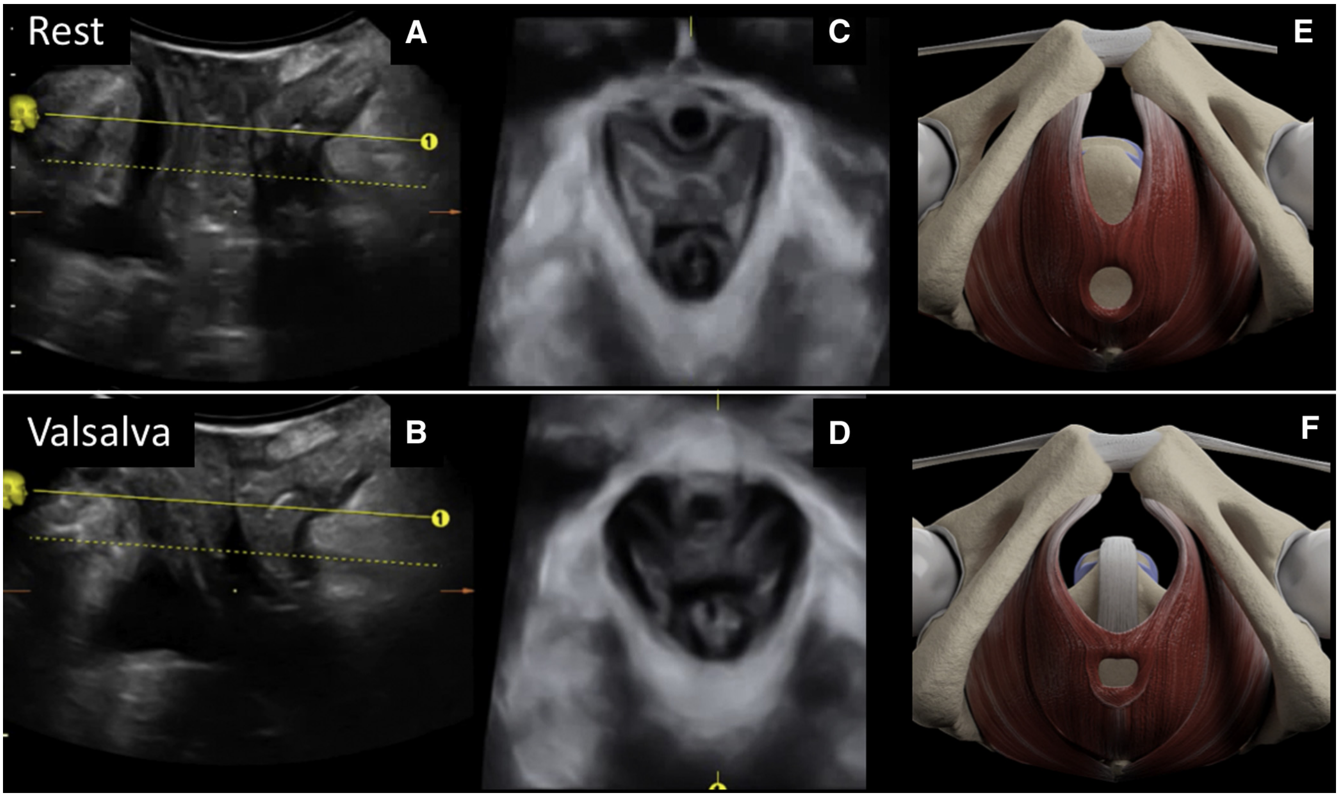
FIGURE 3
Valsalva maneuver associated with appropriate relaxation of the pelvic floor



Valsalva maneuver associated with appropriate relaxation of pelvic floor. This can be demonstrated by increasing anteroposterior diameter of levator hiatus on 2-dimensional ultrasound images from **A**, rest to **B**, Valsalva, increasing hiatal area on 3-dimensional ultrasound using Omniview-VCI[21,22] reconstruction from **C**, rest to **D**, Valsalva and **E** and **F**, on graphic illustration.

Kamel et al. Levator ani contraction and active second stage. Am J Obstet Gynecol 2019.

FIGURE 4
Valsalva maneuver associated with contraction of the pelvic floor (coactivation)



Valsalva maneuver associated with levator ani muscle coactivation. This can be demonstrated by reduction of anteroposterior diameter of levator hiatus on 2- and 3-dimensional ultrasound images using Omniview-VCI[21,22] (GE Healthcare, Zipf, Austria) reconstruction from **A** and **C**, rest to **B** and **D**, Valsalva and **E** and **F**, on graphic illustration.

Kamel et al. Levator ani contraction and active second stage. Am J Obstet Gynecol 2019.

Considering the duration of the second stage as the primary outcome, an incidence of coactivation of 20%,[10] and based on recent unpublished data from a study on nulliparous women at term in Bologna University Hospital showing an average second stage duration of 60 ± 30 minutes, we calculated that a sample size of 135 women would be needed to exclude the null hypothesis that coactivation increases the second stage duration by 30%, considering an α of 0.05% and 80% power.

The statistical analyses were performed using software (21.0 SPSS, Version; IBM Corp, Armonk, NY), and 2-tailed P values <.05 were considered statistically significant.

The protocol of the study was approved by the local ethical committee of each participating hospital (reference number 139/2016/U/Oss in Bologna University Hospital and O18001 in Cairo University Hospital) and a consent form was signed by each eligible patient at the onset of labor. The study protocol coheres with the ethical guidelines of the World Medical Association Declaration of Helsinki—Ethical Principles for Medical Research Involving Human Subjects adopted by the 18th WMA General Assembly, Helsinki, Finland, June 1964 and amended by the 59th World Medical Association General Assembly, Seoul, South Korea, October 2008.

Results

In total, 161 women were recruited to the study, but 23 were excluded because of operative delivery for fetal distress. Demographic characteristics and data on labor and delivery for the 138 women (96 from Cairo University Hospital and 42 from Bologna University Hospital) included in the study are summarized in Table 1.

Delivery was spontaneous vaginal in 92 (66.7%), by vacuum in 6 (4.4%), and cesarean in 40 (28.9%) women. Women in the operative delivery group, in comparison with the spontaneous vaginal delivery group, were older, had a higher BMI, and had a higher birthweight, but there were no significant differences between the 2 groups in the anteroposterior diameter of the levator hiatus at rest and at maximum Valsalva, nor in the prevalence of levator ani muscle coactivation.

In 25 (18.1%) women there was levator ani muscle coactivation and in this group, compared to those without coactivation, there was no significant difference in median gestational age at induction of labor, maternal age, BMI,

TABLE 1

Demographic characteristics and data on labor and delivery for 138 women included in study and comparison of findings in women who underwent operative vs spontaneous vaginal delivery

Population characteristics	Total population n = 138	Operative delivery n = 46	Spontaneous delivery n = 92	*P* value[a]
Gestational age, wk	39.1 ± 1.5	39.2 ± 1.6	39.1 ± 1.4	.90
Maternal age, y	27.7 ± 6.6	29.7 ± 6.5	26.6 ± 6.4	.009
Body mass index, kg/m^2	29.8 ± 5.3	32.2 ± 5.8	28.5 ± 4.7	<.001
Indication for induction of labor				
Postdates	61 (44.2)	16 (34.8)	45 (48.9)	.15
Prelabor rupture of membranes	32 (23.2)	12 (26.0)	20 (21.7)	.67
Diabetes mellitus	17 (12.3)	9 (19.6)	8 (8.7)	.10
Oligohydramnios and/or SGA fetus	17 (12.3)	5 (10.9)	12 (13.0)	.79
Hypertensive disease in pregnancy	7 (5.1)	3 (6.5)	4 (4.3)	.69
Other	4 (2.9)	1 (2.2)	3 (3.3)	1.0
Method of induction of labor				
Prostaglandins	130 (94.2)	43 (93.5)	87 (94.6)	1.0
Oxytocin	8 (5.8)	3 (6.5)	5 (5.4)	1.0
Bishop score	3.9 ± 1.7	3.1 ± 1.6	4.3 ± 1.7	<.001
Epidural analgesia	29 (21.0)	11 (23.9)	18 (19.5)	.35
Induction to delivery interval, min	1510 ± 720	1754 ± 860	1387 ± 608	.004
Duration of second stage, min[b]	76 ± 60	141 ± 88	70 ± 57	.001
Duration of active second stage, min[b]	34 ± 30	94 ± 71	28 ± 13	<.001
Birthweight, g	3251 ± 387	3368 ± 375	3193 ± 381	.012
Anteroposterior diameter of levator hiatus, mm				
At rest	54.6 ± 8.5	56.1 ± 9.1	53.8 ± 8.1	.13
At Valsalva	59.9 ± 10.4	60.2 ± 10.9	59.8 ± 10.3	.80
Levator ani muscle coactivation	25 (18.1)	10 (21.7)	15 (16.3)	.49

Data are given as mean ± SD or n (%) unless otherwise noted.

SGA, small for gestational age.

[a] Student *t* test for continuous data and Fisher exact test for categorical data; [b] 101 Women.

Kamel et al. Levator ani contraction and active second stage. Am J Obstet Gynecol 2019.

anteroposterior diameter of the levator hiatus at rest, induction to delivery interval, duration of the second stage, or incidence of epidural anesthesia (Table 2). However, in the levator ani muscle coactivation group the anteroposterior diameter of the levator hiatus at Valsalva was shorter and the duration of the active second stage was longer. There was a significant negative association between the anteroposterior diameter of the levator hiatus at Valsalva and duration of the second stage (r = −0.230; *P* = .021) and duration of the active second stage (r = −0.338; *P* = .001). There was no significant association between gestational age at induction of labor, BMI, birthweight, or the anteroposterior diameter of the levator hiatus at rest with either the duration of the second stage or duration of the active second stage. Cox regression analysis, adjusted for potential significant confounders (maternal age and epidural analgesia), demonstrated that levator ani muscle coactivation was the only significant and independent predictor of the duration of the active second stage (hazard ratio, 2.085; 95% confidence interval, 1.158−3.752; *P* = .014) (Figure 5). Kaplan-Meier survival analysis, with censoring of women who underwent operative delivery in the second stage, confirmed a significantly increased duration of the active second stage in women with coactivation in comparison with women who did not have coactivation (*P* = .007, log rank test).

Comment

Principal findings

This study has demonstrated that: (1) in nulliparous women undergoing induction of labor at term, levator ani muscle coactivation is associated with a longer

TABLE 2
Comparison of demographic characteristics and data on labor and delivery between women with and without levator ani muscle coactivation

Variable	Coactivation n = 25	No coactivation n = 113	*P* value[a]
Gestational age at induction, wk	39.0 ± 1.5	39.2 ± 1.5	.52
Maternal age, y	30.0 ± 7.0	27.2 ± 6.4	.06
Body mass index, kg/m^2	29.9 ± 6.5	29.7 ± 5.1	.90
Epidural analgesia	8 (32.0)	21 (18.6)	.17
Anteroposterior diameter of levator hiatus, mm			
At rest	54.5 ± 8.5	54.7 ± 8.6	.93
At Valsalva	50.1 ± 8.0	62.1 ± 9.7	<.001
Induction to delivery interval, min	1368 ± 456	1540 ± 764	.28
Duration of second stage, min[b]	101 ± 59	71 ± 76	.07
Duration of active second stage, min[b]	60 ± 56	28 ± 16	<.001

Data are given as mean ± SD or n (%) unless otherwise noted.

[a] Student *t* test for continuous data and Fisher exact test for categorical data; [b] 101 Women.

Kamel et al. Levator ani contraction and active second stage. Am J Obstet Gynecol 2019.

active second stage; and (2) larger diameters of the levator hiatus under Valsalva maneuver, but not at rest, are associated with shorter second and active second stage of labor.

Comparison with results of previous studies

Viscoelastic properties of the distal birth canal have been suggested as a strong contributor to the time a mother needs to push in the second stage to deliver the fetal head.[31] Previous studies used transperineal ultrasound to investigate the relation between antenatally assessed pelvic organ mobility on Valsalva and levator ani hiatal dimensions in the prediction of outcome of labor and reported that reduced mobility and smaller levator ani hiatal dimensions are associated with increased risk of operative delivery.[33−35] However, other authors did not find any association between pelvic floor dimensions and the mode of delivery.[36] None of these studies evaluated the association between levator ani coactivation and labor outcome. In the present study, we have demonstrated that pelvic hiatal diameter at rest and under Valsalva was not associated with the mode of delivery. However, we have found that pelvic floor relaxation, as represented by larger levator hiatal diameter under Valsalva, was associated with a shorter duration of the second and active second stage of labor.

Clinical implications

Many studies have found an association between a prolonged second stage and various adverse labor outcomes. These include increased maternal morbidity, operative delivery rates, complicated cesarean deliveries, chorioamnionitis, severe perineal lacerations, pelvic floor damage, and neonatal complications such as sepsis and asphyxia.[2,37,38] Our study allows the identification of a group of nulliparous women at risk of a longer second stage of labor prior to induction of labor. Despite the importance of this finding, in the absence of a valid corrective intervention for these women with levator ani muscle coactivation, the clinical applicability of this information remains limited.

Research implications

In the present study, we identified a new mechanism involved in the duration of the active second stage of labor, namely levator ani muscle contraction during Valsalva (coactivation) in nulliparous women undergoing induction of labor.

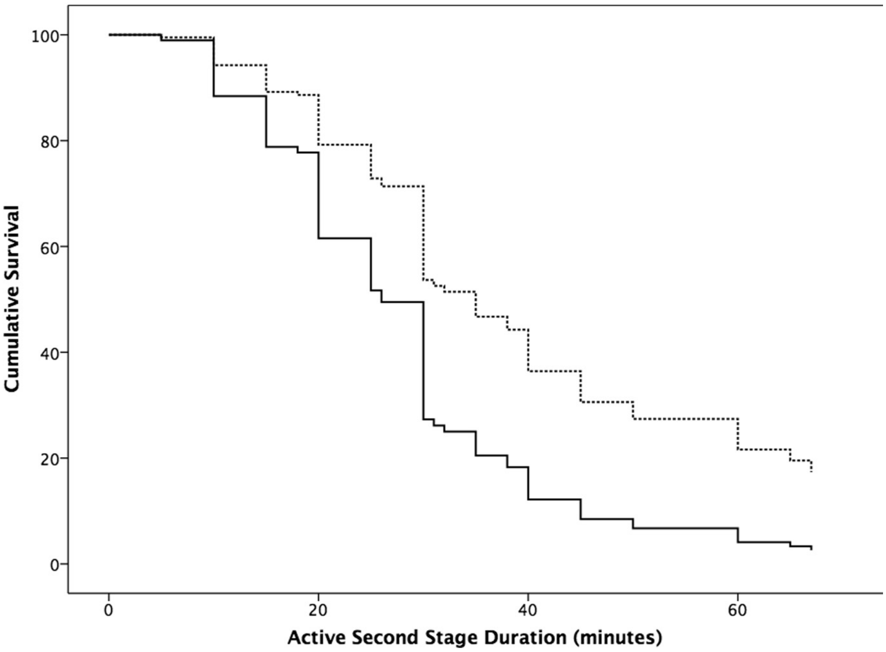
Conflicting results have been reported on the efficacy of prenatal training of the pelvic floor in improving delivery outcome. A randomized controlled trial in 100 nulliparous women found that antenatal education utilizing observation of the perineum and vaginal examination did not result in altered obstetric outcomes.[39] In contrast, another trial in 301 nulliparous women reported that structured pelvic floor training was associated with a lower rate of prolonged second stage labor.[40] However, both of these studies included an unselected group of nulliparous women and, as shown in our study, >80% of nulliparous women are able to appropriately relax their levator ani muscle during Valsalva. Consequently, future intervention studies should focus in women with levator ani muscle coactivation, who are at increased risk of prolonged active second stage, rather than unselected nulliparous women. Such interventions may include ultrasound coaching by visual feedback which has been reported to be beneficial when used in the labor ward.[41,42]

Strengths and weaknesses

This is the first study to investigate levator ani muscle coactivation during Valsalva maneuver and the duration of the active second stage of labor in women undergoing induction of labor. Induction of labor is one of the most common obstetrical procedures.[43−45] Many predictors of the outcome of induction of labor have been assessed.[45−50] However, the production of a reliable and validated predictive model remains challenging.[51−57]

A limitation of the study is that it was restricted to the measurement of the anteroposterior diameter of the levator hiatus. Although other measurements like the levator hiatal area and the transverse diameter may have been interesting to assess, these need 3-dimensional ultrasound machines and skills, which are less readily available and require more operator skills. Another limitation is the inclusion of a heterogeneous group of indications for induction of labor. Since the absolute number of each indication was relatively small,

FIGURE 5
Cumulative incidence of delivery from beginning of active second stage of labor



Plot of cumulative incidence of delivery from beginning of active second stage of labor, with respect to levator ani coactivation (dashed line) vs no coactivation (solid line) adjusted for epidural analgesia and maternal age.

Kamel et al. Levator ani contraction and active second stage. Am J Obstet Gynecol 2019.

it was not possible in the present study to stratify the results by indication. This can be the subject of a future larger study.

Conclusion

In summary, inadequate pelvic floor muscle relaxation as documented by levator ani muscle coactivation in nulliparous women undergoing induction of labor is associated with a longer active second stage of labor. Further studies are needed to investigate the efficacy of antenatal and intrapartum interventions to correct this phenomenon and to assess their potential benefit on labor outcomes. ■

References

1. National Institute for Health and Care Excellence. Intrapartum care for healthy women and babies, 2014. Clinical guideline [CG190]. Available at: https://www.nice.org.uk/guidance/cg190. Accessed September 20, 2018.

2. Laughon SK, Berghella V, Reddy UM, Sundaram R, Lu Z, Hoffman MK. Neonatal and maternal outcomes with prolonged second stage of labor. Obstet Gynecol 2014;124:57–67.

3. Kamel R, Youssef A. How reliable is fetal occiput and spine position assessment prior to induction of labor? Ultrasound Obstet Gynecol 2018.

4. Lipschuetz M, Cohen SM, Israel A, et al. Sonographic large fetal head circumference and risk of cesarean delivery. Am J Obstet Gynecol 2018;218:339.e1–7.

5. Ghi T, Maroni E, Youssef A, et al. Sonographic pattern of fetal head descent: relationship with duration of active second stage of labor and occiput position at delivery. Ultrasound Obstet Gynecol 2014;44:82–9.

6. Gimovsky AC, Berghella V. Randomized controlled trial of prolonged second stage: extending the time limit vs usual guidelines. Am J Obstet Gynecol 2016;214:361.e1–6.

7. Yildirim G, Beji NK. Effects of pushing techniques in birth on mother and fetus: a randomized study. Birth 2008;35:25–30.

8. de Tayrac R, Letouzey V. Methods of pushing during vaginal delivery and pelvic floor and perineal outcomes: a review. Curr Opin Obstet Gynecol 2016;28:470–6.

9. Prins M, Boxem J, Lucas C, Hutton E. Effect of spontaneous pushing versus Valsalva pushing in the second stage of labor on mother and fetus: a systematic review of randomized trials. BJOG 2011;118:662–70.

10. Orno AK, Dietz HP. Levator co-activation is a significant confounder of pelvic organ descent on Valsalva maneuver. Ultrasound Obstet Gynecol 2007;30:346–50.

11. Jelovsek JE, Chagin K, Gyhagen M, et al. Predicting risk of pelvic floor disorders 12 and 20 years after delivery. Am J Obstet Gynecol 2018;218:222.e1–19.

12. Oliphant S, Canavan T, Palcsey S, Meyn L, Moalli P. Pregnancy and parturition negatively impact vaginal angle and alter expression of vaginal MMP-9. Am J Obstet Gynecol 2018;218:242.e1–7.

13. Handa VL, Blomquist JL, Roem J, Munoz A. Longitudinal study of quantitative changes in pelvic organ support among parous women. Am J Obstet Gynecol 2018;218:320.e1–7.

14. Bohlin KS, Ankardal M, Lindkvist H, Milsom I. Factors influencing the incidence and remission of urinary incontinence after hysterectomy. Am J Obstet Gynecol 2017;216:53.e1–9.

15. Lindo FM, Carr ES, Reyes M, et al. Randomized trial of cesarean vs vaginal delivery for effects on the pelvic floor in squirrel monkeys. Am J Obstet Gynecol 2015;213:735.e1–8.

16. 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.

17. Kearney R, Miller JM, Delancey JO. Interrater reliability and physical examination of the pubovisceral portion of the levator ani muscle, validity comparisons using MR imaging. Neurourol Urodyn 2006;25:50–4.

18. Weinstein MM, Jung SA, Pretorius DH, Nager CW, den Boer DJ, Mittal RK. The reliability of puborectalis muscle measurements with 3-dimensional ultrasound imaging. Am J Obstet Gynecol 2007;197:68.e1–6.

19. Dietz HP, Shek KL. The quantification of levator muscle resting tone by digital assessment. Int Urogynecol J Pelvic Floor Dysfunct 2008;19:1489–93.

20. van Delft K, Shobeiri SA, Thakar R, Schwertner-Tiepelmann N, Sultan AH. Intra- and interobserver reliability of levator ani muscle biometry and avulsion using three-dimensional endovaginal ultrasonography. Ultrasound Obstet Gynecol 2014;43:202–9.

21. Youssef A, Montaguti E, Sanlorenzo O, et al. A new simple technique for 3-dimensional sonographic assessment of the pelvic floor muscles. J Ultrasound Med 2015;34:65–72.

22. Youssef A, Montaguti E, Sanlorenzo O, et al. Reliability of new three-dimensional ultrasound technique for pelvic hiatal area measurement. Ultrasound Obstet Gynecol 2016;47:629–35.

23. Cyr MP, Kruger J, Wong V, Dumoulin C, Girard I, Morin M. Pelvic floor morphometry and function in women with and without puborectalis avulsion in the early postpartum period. Am J Obstet Gynecol 2017;216:274.e1–8.

24. Abdool Z, Shek KL, Dietz HP. The effect of levator avulsion on hiatal dimension and function. Am J Obstet Gynecol 2009;201:89.e1–5.

25. DeLancey JO. The hidden epidemic of pelvic floor dysfunction: achievable goals for improved

prevention and treatment. Am J Obstet Gynecol 2005;192:1488–95.
26. Dietz HP. Pelvic floor ultrasound: a review. Am J Obstet Gynecol 2010;202:321–34.
27. Patel DA, Xu X, Thomason AD, Ransom SB, Ivy JS, DeLancey JO. Childbirth and pelvic floor dysfunction: an epidemiologic approach to the assessment of prevention opportunities at delivery. Am J Obstet Gynecol 2006;195:23–8.
28. Rahmanou P, Caudwell-Hall J, Kamisan Atan I, Dietz HP. The association between maternal age at first delivery and risk of obstetric trauma. Am J Obstet Gynecol 2016;215:451.e1–7.
29. van Delft K, Sultan AH, Thakar R, Schwertner-Tiepelmann N, Kluivers K. The relationship between postpartum levator ani muscle avulsion and signs and symptoms of pelvic floor dysfunction. BJOG 2014;121:1164–72.
30. Youssef A, Salsi G, Cataneo I, et al. Fundal pressure in second stage of labor (Kristeller maneuver) is associated with higher risk of levator ani muscle avulsion. Ultrasound Obstet Gynecol 2018.
31. Tracy PV, Wadhwani S, Triebwasser J, et al. On the variation in maternal birth canal in vivo viscoelastic properties and their effect on the predicted length of active second stage and levator ani tears. J Biomech 2018;74:64–71.
32. Lemos A, Amorim MM, Dornelas de Andrade A, de Souza AI, Cabral Filho JE, Correia JB. Pushing/bearing down methods for the second stage of labor. Cochrane Database Syst Rev 2017;3:CD009124.
33. Dietz HP, Moore KH, Steensma AB. Antenatal pelvic organ mobility is associated with delivery mode. Aust N Z J Obstet Gynaecol 2003;43:70–4.
34. Dietz HP, Lanzarone V, Simpson JM. Predicting operative delivery. Ultrasound Obstet Gynecol 2006;27:409–15.
35. Siafarikas F, Staer-Jensen J, Hilde G, Bo K, Ellstrom Engh M. Levator hiatus dimensions in late pregnancy and the process of labor: a 3- and 4-dimensional transperineal ultrasound study. Am J Obstet Gynecol 2014;210:484.e1–7.
36. Lanzarone V, Dietz HP. Three-dimensional ultrasound imaging of the levator hiatus in late pregnancy and associations with delivery outcomes. Aust N Z J Obstet Gynaecol 2007;47:176–80.
37. Sung JF, Daniels KI, Brodzinsky L, El-Sayed YY, Caughey AB, Lyell DJ. Cesarean delivery outcomes after a prolonged second stage of labor. Am J Obstet Gynecol 2007;197:306.e1–5.
38. Cheng YW, Hopkins LM, Caughey AB. How long is too long: does a prolonged second stage of labor in nulliparous women affect maternal and neonatal outcomes? Am J Obstet Gynecol 2004;191:933–8.
39. Phipps H, Charlton S, Dietz HP. Can antenatal education influence how women push in labor? Aust N Z J Obstet Gynaecol 2009;49:274–8.
40. Salvesen KA, Morkved S. Randomized controlled trial of pelvic floor muscle training during pregnancy. BMJ 2004;329:378–80.
41. Gilboa Y, Frenkel TI, Schlesinger Y, et al. Visual biofeedback using transperineal ultrasound in second stage of labor. Ultrasound Obstet Gynecol 2018;52:91–6.
42. Bellussi F, Alcamisi L, Guizzardi G, Parma D, Pilu G. Traditionally vs sonographically coached pushing in second stage of labor: a pilot randomized controlled trial. Ultrasound Obstet Gynecol 2018;52:87–90.
43. Martin JA, Hamilton BE, Osterman MJ, Curtin SC, Matthews TJ. Births: final data for 2013. Natl Vital Stat Rep 2015;64:1–65.
44. Grobman WA, Bailit J, Lai Y, et al. *Eunice Kennedy Shriver* National Institute of Child Health and Human Development Maternal-Fetal Medicine Units Network. Defining failed induction of labor. Am J Obstet Gynecol 2018;218:122.e1–8.
45. Kawakita T, Iqbal SN, Huang CC, Reddy UM. Nonmedically indicated induction in morbidly obese women is not associated with an increased risk of cesarean delivery. Am J Obstet Gynecol 2017;217:451.e1–8.
46. Levine LD, Downes KL, Parry S, Elovitz MA, Sammel MD, Srinivas SK. A validated calculator to estimate risk of cesarean after an induction of labor with an unfavorable cervix. Am J Obstet Gynecol 2018;218:254.e1–7.
47. Rouzi AA, Alsahly N, Alamoudi R, et al. Randomized clinical trial between hourly titrated and 2 hourly static oral misoprostol solution for induction of labor. Am J Obstet Gynecol 2017;216:405.e1–6.
48. Connolly KA, Kohari KS, Rekawek P, et al. A randomized trial of Foley balloon induction of labor trial in nulliparas (FIAT-N). Am J Obstet Gynecol 2016;215:392.e1–6.
49. Bauer AM, Lappen JR, Gecsi KS, Hackney DN. Cervical ripening balloon with and without oxytocin in multiparas: a randomized controlled trial. Am J Obstet Gynecol 2018;219:294.e1–6.
50. Sagi-Dain L, Sagi S. Vaginal delivery within 24 hours of labor induction as a primary outcome—what's the rush? Am J Obstet Gynecol 2018.
51. Reis FM, Gervasi MT, Florio P, et al. Prediction of successful induction of labor at term: role of clinical history, digital examination, ultrasound assessment of the cervix, and fetal fibronectin assay. Am J Obstet Gynecol 2003;189:1361–7.
52. Rane SM, Guirgis RR, Higgins B, Nicolaides KH. The value of ultrasound in the prediction of successful induction of labor. Ultrasound Obstet Gynecol 2004;24:538–49.
53. Hatfield AS, Sanchez-Ramos L, Kaunitz AM. Sonographic cervical assessment to predict the success of labor induction: a systematic review with metaanalysis. Am J Obstet Gynecol 2007;197:186–92.
54. Eggebo TM, Heien C, Okland I, Gjessing LK, Romundstad P, Salvesen KA. Ultrasound assessment of fetal head-perineum distance before induction of labor. Ultrasound Obstet Gynecol 2008;32:199–204.
55. Pereira S, Frick AP, Poon LC, Zamprakou A, Nicolaides KH. Successful induction of labor: prediction by preinduction cervical length, angle of progression and cervical elastography. Ultrasound Obstet Gynecol 2014;44:468–75.
56. Gillor M, Vaisbuch E, Zaks S, Barak O, Hagay Z, Levy R. Transperineal sonographic assessment of angle of progression as a predictor of successful vaginal delivery following induction of labor. Ultrasound Obstet Gynecol 2017;49:240–5.
57. Alavifard S, Meier K, D'Souza R. Prediction calculator for induction of labor: no Holy Grail yet! Am J Obstet Gynecol 2018;219:419–20.

Author and article information

From the Department of Obstetrics and Gynecology, Kasr Al-Ainy University Hospital, Cairo University, Cairo, Egypt (Drs Kamel, Soliman, Negm, and Momtaz); Department of Obstetrics and Gynecology, Sant'Orsola Malpighi University Hospital, University of Bologna, Bologna, Italy (Drs Montaguti, Dodaro, Pilu, and Youssef); and Harris Birthright Research Center for Fetal Medicine, King's College, London, United Kingdom (Dr Nicolaides).

Received Aug. 30, 2018; revised Oct. 2, 2018; accepted Oct. 7, 2018.

The authors report no conflict of interest.

Corresponding author: Aly Youssef, MD, PhD. aly.youssef78@gmail.com