Ultrasound Obstet Gynecol 2011; **38**: 52–56
Published online in Wiley Online Library (wileyonlinelibrary.com). **DOI:** 10.1002/uog.9021

Elastography of the uterine cervix: implications for success of induction of labor

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KEYWORDS: consistency; elastography; labor induction; post-term pregnancy; preterm delivery; uterine cervix

ABSTRACT

Objectives *To perform a preliminary investigation into the use of elastography for cervical assessment, in order to determine the effectiveness of this method for the evaluation of cervical consistency.*

Methods *Elastography of the uterine cervix was performed in 29 patients before induction of labor, with tissue surrounding the internal os described using a numeric scale called the elastography index (EI). A color map from purple to red was produced with the hardest tissues displayed as purple and assigned a score of 0 points and progressively softer tissues displayed as blue (1 point), green (2 points), yellow (3 points) and red (4 points). The EI of tissue around the internal os, in the middle part of the cervical canal and around the external os were analyzed in relation to the success of induction of labor using the* t*-test.*

Results *The mean EI of the internal os in the group of patients with successful induction of labor was 1.23, while in the group with failed induction of labor it was 0.39 (Student's* t*-test,* $P = 0.024$*). No difference was found for the EI of the middle part of the cervical canal or for the EI of the external os in relation to the success of induction of labor (*$P > 0.05$*).*

Conclusion *Elastography of the uterine cervix may be an objective method for assessment of softening of tissue in the region of the internal os before induction of labor. Standardization of the cervical properties observed on elastography during pregnancy may help to guide the use of prostaglandins or oxytocin for induction of labor.*

INTRODUCTION

During pregnancy the uterine cervix changes throughout the entire period of gestation and the changes at the end of pregnancy lead to delivery. Preterm delivery can be caused by certain of these changes beginning too early, while if they do not start at term a post-term pregnancy will result. Understanding the underlying mechanisms of cervical shortening and ripening and dilatation of the internal os helps to plan treatment. However, the accurate diagnosis of abnormal cervical status is difficult to achieve. Obtaining an obstetric history, palpation of the cervix and ultrasonographic assessment of the internal os and length of the cervical canal are the most reliable methods for predicting preterm delivery and the result of induction of labor[1,2]. Asakura *et al.*[3] presented a report about assessment of the glandular zone of the cervix and suggested that it should disappear after 31 weeks' gestation. Finding this phenomenon earlier may be a factor in predicting preterm delivery.

The cervix can be assessed by digital examination using the Bishop score[4,5]. Many attempts to develop methods of objectively assessing the length of the cervix have been made, but all those developed so far depend on the examiner's skill and experience. One such attempt led to the creation of the CerviLenz (CerviLenz, Chagrin Falls, OH, USA), which was devised to measure the length of the vaginal portion of the cervix[6]. Ultrasound examination enables objective measurement of the length of the internal os and cervical canal. The use of ultrasonography in the assessment of cervical stiffness has also been studied using gray-scale histograms (with a variable representing cervical consistency calculated by measuring the difference between the anterior and posterior cervical walls), computer-based texture analysis systems and the analysis of three-dimensional images. However, these methods are neither simple nor reliable and have thus far not been widely used[6–9].

Elastography measures the distance of tissue movement after application of pressure using ultrasound imaging equipment and specialized software. Soft tissue deforms more easily than does hard tissue; this difference is

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Accepted: 29 March 2011

observed as a difference in ultrasound signals, and is represented by use of a color map.

The objective of this study was to assess whether elastographic images of the tissue surrounding the internal os of the uterine cervix can be used to represent ripening of the cervix before delivery and to predict the result of oxytocin infusion for induction of labor.

METHODS

The study group comprised 29 women with a singleton pregnancy who were being prepared for induction of labor. Indications for induction were: post-term pregnancy in eight cases (27.6%), non-reassuring non-stress test in eight cases (27.6%), gestational diabetes in five cases (17.2%), pregnancy-induced hypertension in four cases (13.8%), fetal malformation in two cases (6.9%), premature rupture of membranes in one case (3.4%) and in one case (3.4%) intrauterine fetal death at 39 weeks' gestation during a previous pregnancy. Two of the women were examined twice because, owing to ineffective induction of labor, they were prepared for a second induction, resulting in 31 examinations.

All the patients were first examined vaginally and the cervix was assessed by means of the Bishop score. Written informed consent to the use of elastography was obtained. A transvaginal probe was introduced and the cervical canal length and width of the internal os were measured. Elastography was performed with images of the cervix saved to the hard disk of the ultrasound system. An Accuvix V10 ultrasound machine with transvaginal probe and ElastoScan™ elastography software (Medison, Seoul, Korea) was used. During the examination no additional pressure was applied to the cervix; the operator did not move the probe after visualization of the cervix in B-mode, and the patient was asked to breathe normally. Elastographic images of the cervix were achieved due to movement generated by the patient's breathing and arterial pulsation, and were not operator-dependent. If the probe was being pressed against the cervix, or if the patient was moving or coughing, then an image could not be obtained because all parts of the cervix were moving too much and were visualized as being 'soft'.

A color map from purple to red was produced and points were assigned according to the following scheme: purple (hardest tissue), 0 points; blue, 1 point; green, 2 points; yellow, 3 points; and red (softest tissue), 4 points[10–12]. A five-step scale – the elastography index (EI) – was thereby created and the various parts of the cervix were described using this system. If one part of the cervix had two colors the highest possible was assigned to it. For example, if the internal os was represented by both yellow and red, it was described as having an EI of 4 (i.e. red). Images in which the amniotic fluid was coded as red and in which the fetal skull (if visible) was coded as purple were selected for analysis, with the best available image used in each case. EI values of tissue around the internal os, at the middle part of the cervical canal and around the external os were recorded in a database.

In all patients, induction of labor was performed using standard oxytocin infusion. Induction of labor was regarded as successful if uterine contractions and labor progress were noted during oxytocin infusion. Otherwise, the infusion was routinely stopped after 9 hours. If during 9 hours of oxytocin infusion no progress was noted then induction of labor was described as having failed. No prostaglandins were used in the study group.

Normality of variables was tested using the Kolmogorov–Smirnov test and means were compared using Student's *t*-test. Pearson's correlation coefficient was used to assess the relationship between the EI of different parts of the cervix and the Bishop score and cervical canal length measurement before induction of labor.

Microsoft Excel 2010 (Microsoft Corp., Redmond, WA, USA) and Statistica 7.0 (StatSoft®, Krakow, Poland) software was used, and $P \leq 0.05$ was considered to be statistically significant.

RESULTS

The average age of the patients in the study group was 27 (range, 18–39) years and the median gestational age at examination was 39 weeks. Sixteen examinations (51.6%) were performed before 40 weeks' gestation and 15 (48.4%) at 40 weeks or more. The average Bishop score was 2.38. The Bishop score was higher in the group of subjects with successful induction of labor (mean, 3.0) than in the group of subjects with poor reaction to oxytocin (mean, 1.9) (Student's *t*-test, $P = 0.041$). Table 1 presents characteristics of the study group.

Visualization of the cervix using elastography and calculation of the EI of the internal os was possible in all patients. Figure 1 shows a case in which the cervical canal was much softer than the anterior and posterior walls of the cervix, with an EI of the internal os of 4 (i.e. red). Figure 2 shows a cervix with the same stiffness for all its parts, the EI of the internal os being 0 (i.e. purple).

Eighteen of the 31 inductions of labor (including the two that were attempted twice) failed in 16 patients (55.2% of the women) and 13 (44.8%) were successful. In

Table 1 Characteristics of the study group

	Induction of labor		
Parameter	*Failure*	*Success*	P
Number of patients	16 (55.2)	13 (44.8)	NA
Maternal age (years)	26.2 ± 6.0	28.3 ± 4.6	0.16
Parity	0 (0–1)	0 (0–3)	0.01*
GA at examination (weeks)	40 (33–42)	38 (36–41)	0.13
Bishop score	1.9 ± 1.3	3.0 ± 1.8	0.04*
Cervical canal length (mm)	26.9 ± 6.4	23.8 ± 7.6	0.12
Elastography index			
Internal os	0.39 ± 0.70	1.23 ± 1.54	0.024*
Cervical canal	1.17 ± 1.29	1.13 ± 1.25	0.764
External os	1.11 ± 1.53	1.00 ± 1.4	0.838

Data are shown as *n* (%), mean ± SD or median (range).
*Significant difference. GA, gestational age; NA, not applicable.

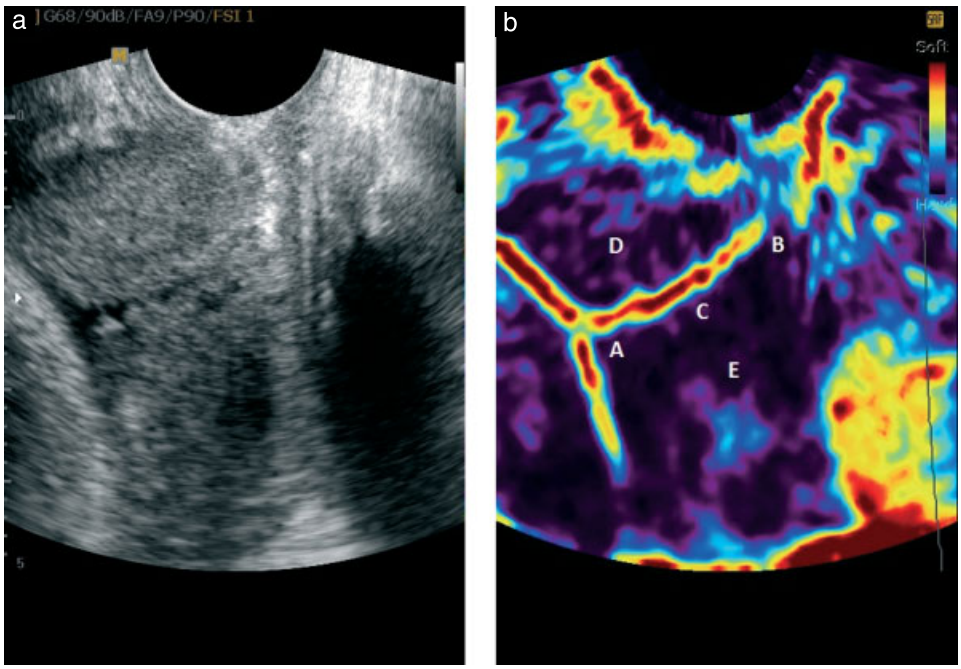

Figure 1 Elastography of the uterine cervix with soft cervical canal and orifices. (a) Gray-scale ultrasound image of the uterine cervix. (b) Elastogram showing differences in the stiffness of uterine parts visualized as different colors. A, internal os; B, external os; C, cervical canal; D, anterior wall of the cervix; E, posterior wall of the cervix.

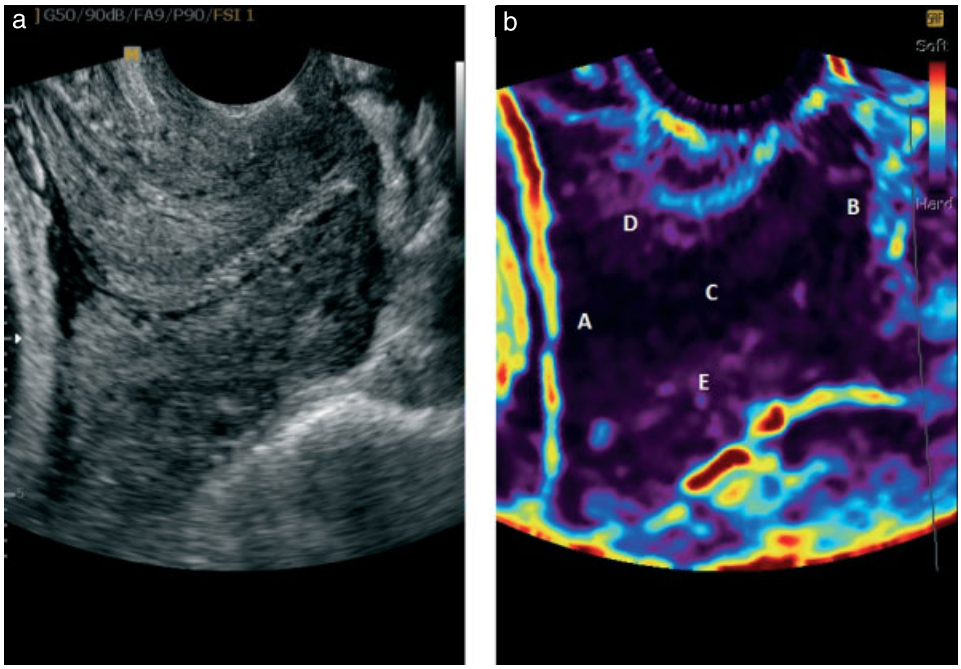

Figure 2 Elastography of the uterine cervix with hard cervical canal and orifices. (a) Gray-scale ultrasound image of the uterine cervix. (b) Elastogram showing that the entire cervix is the same color, representing the same stiffness. A, internal os; B, external os; C, cervical canal; D, anterior wall of the cervix; E, posterior wall of the cervix.

the group of successful inductions, nine women (69.2%) delivered vaginally while four (30.8%) underwent Cesarean section. Indications for Cesarean section were fetal asphyxia in three cases and threat of uterine rupture in one patient after a previous Cesarean section.

The mean EI of tissue around the internal os for patients with successful induction of labor was 1.23, while for those cases where induction failed it was 0.39, with a significant difference found using Student's *t*-test ($P = 0.024$). However, no significant difference was found for the EI of the middle part of the cervical canal or for the EI around the external os in relation to the success of induction of labor (Table 1).

There was no significant correlation between the EI of the internal os, middle part of the cervical canal or external os and the Bishop score, neither was there a

significant correlation between the EI of the internal os, middle part of the cervical canal or external os and the cervical canal length.

DISCUSSION

At present, the decision to use prostaglandins or oxytocin to induce labor after ultrasonographic assessment of the uterine cervix has to be complemented with vaginal examination and use of the Bishop score[1,2,4]. Efforts to avoid vaginal examination have so far been fruitless, as the consistency of the cervix is one of the most important features to be assessed, together with the length of the cervical canal and dilatation of the internal os. Some authors have tried to find methods of assessing the consistency of the cervix by ultrasound with the use of complex mathematical formulae, but they have not been adopted in everyday practice[7,8].

The walls of the cervix have also been the subject of studies on the use of ultrasonography in the quantitative assessment of cervical ripening[13–16]. Bigelow *et al.*[14] and McFarlin *et al.*[15] examined the uterine cervix in pregnant rats, Feltovich *et al.*[16] examined specimens of human uterus after hysterectomy and one study has been performed on pregnant women[13]. The use of radiofrequency imaging to visualize cervical ripening also seems very promising in predicting delivery, most importantly in detecting patients with a high risk of preterm delivery.

Elastography is an objective method of assessing the relative consistency of tissues. It allows visualization of stiffness by color-coding and enables comparison of different parts of tissues, e.g. soft cysts or hard tumors differ from the remaining healthy parts of prostate, breast, thyroid or salivary gland tissue[17–21]. It may also be used to find the hardest parts of tumors when performing needle biopsy, allowing the examiner to sample not just the middle of the mass, but rather the most changed region. There are reports about the use of elastography as an intraoperative tool in cases with difficult-to-palpate tumors located deep in tissues (such as non-palpable hepatic tumors)[22]. Some authors have tried to assess the stiffness of whole organs, such as cirrhotic liver, but it is more difficult to interpret such findings because elastography shows the relative stiffness of different parts of tissues rather than providing an objective measurement of stiffness[23]. Recently, research has been carried out on the preoperative evaluation of the mechanical and elastic properties of arteries and veins before the creation of arteriovenous fistulas for dialysis, but the results obtained are not clear[24]. Elastography is also being examined as a tool for imaging in gynecology for the visualization of fibroids in more detail than is possible using B-mode imaging[25].

Thomas *et al.*[26] investigated elastography of the uterine cervix in non-pregnant women and showed that there was no correlation between cervical stiffness and patient age, but they found that it was possible to diagnose malignant tumors of the cervix using this method. Despite the fact that these results seemed promising, no further work on this topic has been published.

We have shown that elastography can differentiate the cervix from other parts of the genitourinary tract, and that it is able to show differences in stiffness between parts of the cervix that relate to differences in the clinical outcome of pregnancy. The internal os and cervical canal are hard during pregnancy and it is this factor that prevents delivery until term in uncomplicated pregnancies[27]. Differences between the soft internal os and harder external parts of the cervix are good predictors of a favorable reaction to oxytocin during induction of labor.

Ripening of the internal os is not evaluated during routine vaginal examination during pregnancy; we can assess the stiffness of the external os and the walls of the vaginal portion of the cervix, but palpation of the internal os is not possible. Evaluation of dilatation of the internal os by ultrasound is helpful, but not ideal, and the additional evaluation of elastographic features seems a very promising option. A decrease in the consistency of the tissue around the internal os may be a symptom of approaching delivery and in cases of induction of labor, may help us to decide whether to use prostaglandins before oxytocin.

In conclusion, elastography of the uterine cervix may be used for the objective assessment of softening of tissue in the region of the internal os before labor. Standardization of the cervical properties seen on elastography during pregnancy may help to guide the use of prostaglandins or oxytocin in the induction of labor.

ACKNOWLEDGMENT

Elastography software (ElastoScan™ for Medison Accuvix V10) was provided by Mar-Med Sp. z o.o.

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