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New techniques in evaluation of the cervix

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ABSTRACT

The process of parturition is poorly understood, but the cervix clearly plays a key role. Because of this, recent research efforts have been directed at objective quantification of cervical remodeling. Investigation has focused on two basic areas: (1) quantification of tissue deformability and (2) presence, orientation, and/or concentration of microstructural components (e.g. collagen). Methods to quantify tissue deformability include strain elastography and shear wave elasticity imaging (SWEI). Methods to describe tissue microstructure include attenuation and backscatter. A single parameter is unlikely to describe the complexities of cervical remodeling, but combining related parameters should improve accuracy of cervical evaluation. This chapter reviews options for cervical tissue characterization.

Introduction

The three clinical parameters used to evaluate the uterine cervix in today's obstetrical practice are its length, softness, and dilatation. These parameters are usually assessed by similar methods that were used during the time of Hippocrates, namely, via digital examination, and they provide about as much information about timing of delivery as they did 2000 years ago.[1] The major problem with these three parameters are measurement, imprecision, and subjectivity. For instance, although practitioners consider cervical softness a critical parameter,[2] they use their face as a frame of reference to assess cervical softness: a *soft* cervix feels like a cheek, a *medium* cervix like a nose, and a *firm* cervix like a forehead. Dilatation seems less subjective because it is measured in centimeters, but in a study using soft simulation training models (to replicate the *in vivo* situation), only 19% of experienced clinicians' measurements of cervical diameter were correct.[3] Another study employing a position-tracking system to verify the practitioner's measurement of cervical dilatation in nearly 200 women during labor showed a mean error of 10.2 ± 8.4 mm,[4] an error that seems alarmingly large considering that a 1 cm difference informs clinical decision-making about interventions such as cesarean section. Cervical length is the only objectively quantifiable parameter in clinical use for cervical evaluation, but even the gold standard transvaginal cervical length measurement has significant limitations with respect to predicting timing of delivery.[1] Fortunately, at present there is effort by many groups to objectively quantify cervical parameters to improve understanding of cervical remodeling in pregnancy.

Quantifying cervical remodeling

The cervix is not a simple structure. It is comprised of cells (e.g., smooth muscle cells, fibroblasts, glandular cells, vascular cells, and immune cells) embedded in an extracellular matrix (ECM). The ECM contains proteins (mostly

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collagen) and proteoglycans that are arranged in a scaffold, or matrix, that define cervical mechanical properties. The ECM actively changes throughout gestation, allowing the cervix to transform from a stiff, long, and closed structure to one that is soft, short, and dilated to allow delivery. Understanding the process of cervical remodeling is crucial to understanding both normal and abnormal pregnancy, and therefore is a subject of active research. Current attempts to quantify cervical remodeling can be separated into two general categories: those that address tissue deformability and those that address the presence, organization and/or concentration of extracellular matrix components.

Quantifying tissue deformability

Softer tissue is more compressible than stiffer tissue; in other words, it deforms more under compression. This is the principle behind techniques that evaluate tissue stiffness/softness via measuring tissue response to a stimulation, such as stretching or compressing (pushing).

Aspiration

The aspiration technique focuses on stretching, as opposed to compressing, cervical tissue to measure distensibility. The aspiration device consists of a thin tube (into which cervical tissue is sucked), a minicamera to observe cervical distensibility, a light, and a pressure sensor and a vacuum. Figure 1 shows an image of the aspiration device. With the vacuum running, the tube is placed against the distal end of the anterior cervix (at 12:00) and cervical tissue is sucked into the cylinder a preset amount (4 mm), after which the pressure is reversed, and the tube automatically detaches from the cervix when atmospheric pressure is reached.[5] More tension is required to reach 4 mm of deformation in stiffer tissues as compared to softer tissues, and therefore the closing pressure value (p_{cl}, millibar) can directly measures stiffness. In a longitudinal study of 42 pregnant women, the aspiration technique showed a statistically significant difference between the 1st and 2nd, but not the 2nd and 3rd, trimesters, with postpartum values returning to nonpregnant stiffness values.[5]

Cervical consistency index

The cervical consistency index (CCI) is a ratio of the anteroposterior (AP) diameter of the cervix under maximal compression with the transducer compared to the AP diameter prior to compression.[6,7] Figure 2 shows a typical transvaginal cervical image on the left, and on the right is the same cervix under maximal compression from the transducer. For the CCI, the AP diameter is measured from images such as these. A ratio of 1 corresponds to a cervix that does not compress at all (stiff) and a ratio of 0.5 to a cervix in which the diameter is reduced by half (soft). A significant correlation was found between CCI and gestational age ($r^2 = 0.66$, $p < 0.001$) in a cross-sectional study of more than 1000 women undergoing ultrasound at 5–36 weeks of gestation; specifically, a lower CCI was seen in women in late, as compared to early, pregnancy.[6] The area under the receiver–operator curve (AUROC) for prediction of preterm birth (PTB) at <32 weeks, <34 weeks, and <37 weeks was 0.947, 0.943, and 0.907, respectively, although sensitivities were low (67%, 64%, and 45%, respectively). A recent prospective study evaluated low-risk women ($n = 532$) with both CCI and transvaginal cervical length (TVU CL) at 19 to 24 + 6 weeks of gestation. For the primary outcome of spontaneous PTB < 37 weeks, CCI outperformed TVU CL [AUROC = 0.84 (95% CI: 0.75–0.93) versus 0.68 (95% CI: 0.56–0.81)], and the authors have called for corroborative studies in other centers.[7]

Static (strain) elastography

Strain imaging (static elastography) is another method that can quantitate tissue deformability. A contact force (*stress*) is induced, and the displacement field between two points tracked to determine *strain*. The relationship between the contact force and strain value depends upon tissue deformability, with greater strain seen in softer tissues. Cervical strain elastography involves deforming the cervix extrinsically (manual compression with the transducer) or intrinsically (holding the transducer still while the cervix moves against it due to vascular pulsation). The *relative strain* is the rate of change in tissue displacement in a region of interest, computed from ultrasound signals acquired before and after the deformation. This is often depicted in a color map (*elastogram*). An important point is that an elastogram is

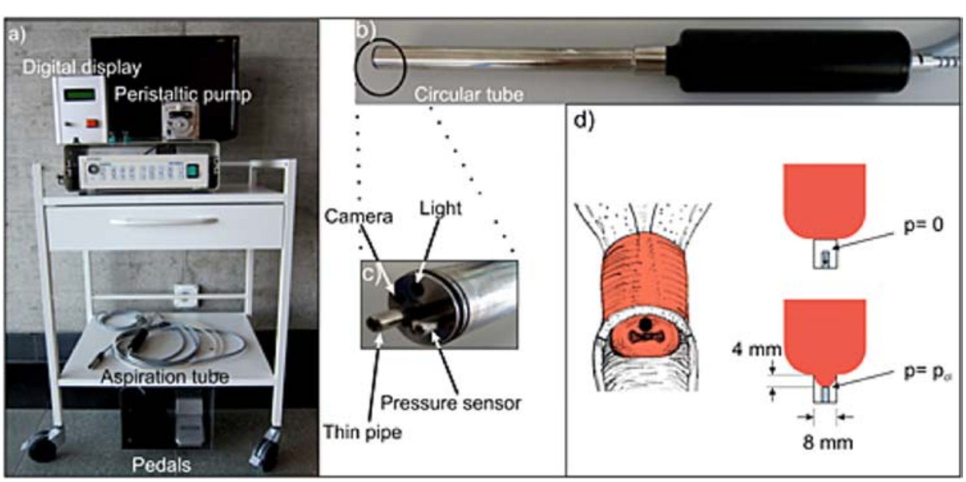

Fig. 1 – The aspiration device. (Reprinted with permission from Badir et al.[5])