Spatiotemporal electromyography during human labor to monitor propagation of the uterine contraction wave and diagnose dystocia

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Understanding the evolution and progress of uterine contractility during pregnancy is a major goal in biology.[1] Despite decades of effort by reproductive biologists, the "puzzle" of what activates and sustains the powerful myometrial contractile machinery during human parturition still remains unresolved. In 1871, during his state of the art lecture, Sir James Y. Simpson Bar described natural labor simplistically as the physiologic process of expelling the fetus from the uterus in 3 stages: preparation and dilatation, expulsion of the child, separation and expulsion of the placenta.[2] Thus, it was held for centuries that forceful myometrial contractions lead to the gradual opening of the os uteri followed by the slow descent of the fetal head into the pelvis.[2] Unfortunately, expulsion of the fetus was not always accomplished via natural ways, and in the absence of compelling scientific evidence many labor concepts, including labor "dystocia," remained intuitive rather than evidence based.[3]

For thousands of years women sensed their readiness for labor by judging the frequency of their "womb" contractions and the degree of pain they engendered. Unbeknownst to us, sometime in history the accoucheur's hand began to describe the character, intensity and strength of the labor pain. Yet, the origin of our understanding regarding uterine contractility most probably rests within the classical work of Braxton Hicks.[4] His observation in 1872 that the uterus possesses the habit of contracting spontaneously from very early pregnancy is still valid. On this base, Schatz, Rubsamen, and others attempted first to record the force of uterine contractions by using an internal or an external monitor, respectively.[5,6] Since intuitively, the descent of the fetus through the cervix and bony pelvis would not be possible unless the expulsive force of uterine contraction is not directed toward the internal cervical os, a considerable amount of research has focused on the origin, propagation, and directionality of the uterine contraction wave.[7,8] By using internal pressure catheters or external multiple channels tocographs, Reynolds and Caldeyro-Barcia demonstrated that the normal mechanical contractile wave of labor originates at the uterine fundus and spreads downwards.[7,8]

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Conversely, uterine contractions originating at sites other than uterine fundus were correlated with "stagnant labor" and an increased rate of operative delivery. Based on their results the concept of "fundal dominance" was established. This paradigm was largely based on the belief that myometrial growth during pregnancy is asymmetric and greatest at the uterine fundus.[3] Recently, this notion was disproved through ultrasonographic studies, which demonstrated that at term myometrial thickness did not differ among sites.[9] It can thus be inferred that the directionality of the expulsive force is not a function of asymmetric myometrial growth but rather the result of a highly coordinated 3-dimensional propagation of the uterine electrical activity.

Action potentials generated and propagated by muscle cells are responsible for initiation of uterine contractions.[10] The first attempts to record uterine activity with action potentials were made at the beginning of the 20th century, and the reader is referred to a number of excellent reviews on this specific area of research.[11-14] Unfortunately, electrohysterography had limited clinical and research use until Robert E. Garfield demonstrated in 1977 that, similar to the heart, myometrial activation in labor requires an increase in connexin-43 protein to facilitate the propagation of electrical activity.[15] This determination allowed him to propose that myometrial gap junctions transform the uterus during labor into an electrical functional syncitium. The concept of electromechanical coupling elicited increased interest and consequently visionary investigators reevaluated and reconsidered the value of electrohysterography in predicting normal and abnormal labor.[16-20]

Dr Tammy Euliano and her colleagues report in this issue of the *American Journal of Obstetrics and Gynecology* (AJOG) a study that makes evident the value of electrohysterography in identifying patients with labor dystocia. The investigative team performed a spatiotemporal mapping of the uterine electrical activity in women with eutocic and dystocic labors. To interpret their results, the authors applied the principles of continuous probability distribution (Gaussian modeling). The center of uterine activity was defined based on the evolution of the electrical energy of the myometrial system during uterine contractions. The direction of propagation of the center of uterine activity movement was calculated based on changes in the electrical potential recorded from the abdominal surface during the onset and resolution of mechanical activity. Based on analysis of the temporal and spatial movement of the center of uterine activity, contraction patterns were classified as moving downward (toward the lower uterine segment) or upward (toward the uterine fundus). Interestingly, the study reports that women who underwent cesarean delivery for labor arrest had a predominant lower uterine segment direction of the center of uterine activity. This suggests that the uterine fundus begins to relax earlier than the lower uterine segment. In contrast, the center of uterine activity had a predominant fundal direction in women who delivered successfully. This implies that the lower uterine segment begins to relax earlier than the upper portion of the uterus in women who deliver vaginally.

The results of this study are novel as they support unequivocally the existence of a center of uterine activity. Although arguments have been made in favor of a uterine pacemaker, the evidence to support this claim has been elusive. The theory that myometrial cells can be alternatively pacemakers or pace followers has been proposed.[21] The current research neither proves nor disproves the presence of a fixed anatomic uterine pacemaker. Instead it demonstrates that computation of the uterine electrical activity allows for recognition of a dominant electrical area that has a vertical motion that varies with the onset (T1) or resolution (T2) of myometrial contraction.

Dr Euliano's observation that the center of uterine activity follows an upward or a downward propagation path dependent on labor's character is of clinical importance. In 1955, Friedman's graphycostatistical analysis of labor established that the process of normal labor follows a sigmoid shape curve.[22] This model has dominated obstetric practice of the past half century. However, evidence for a temporal trend toward an increase in the duration of normal labor, no active deceleration phase, and labors evolving for 1 to 2 hours without perceivable cervical changes is available.[3] Therefore, there are reasons to believe that the traditional labor curve does not necessarily fit in the context of modern obstetrics, and that the clinical definition of obstetrical dystocia requires further refinement.[23,24] Traditionally, dystocia is defined as abnormal labor that results from abnormalities in power (uterine contractions, maternal expulsive forces), passageway (pelvis), and passenger (fetus). The American College of Obstetricians and Gynecologists recommends that the diagnosis of dystocia should not be made before an adequate trial of labor has been accomplished.[25] Following assessment of the fetal status, position, and station as well as the size and shape of the maternal pelvis, evaluation of the uterine performance with intrauterine pressure catheters is a time-proven clinical and investigative method.[26,27]

Regrettably, even in the context of adequate uterine contractions, delivery of the fetus cannot always be successfully accomplished and the basis of this failure remains frequently unknown. In view of the previous published studies, contraction of the upper part of the uterus begins earlier, is stronger, and lasts longer than contraction in the lower uterine segment. As a result, the lower uterine segment is repeatedly distended during contraction allowing compression of the presenting part onto the cervix.[3] Evaluation of the uterine contractility with intrauterine pressure sensors provides the clinician with a global evaluation of the myometrial performance, but does not allow assessment of the directionally of the uterine contraction wave, which can be by itself a cause of dystocia. The findings of the study by Euliano et al set forth the proof of concept that propagation of the uterine contraction wave can be followed in a noninvasive fashion through computational analysis of the uterine electrohysterography. Development and implementation of this novel technologically advanced methodology may represent in the future a significant addition to the clinical practice by providing obstetricians with an additional powerful tool to follow the evolution and progress of uterine contractility during labor. Clinicians and scientists are encouraged to access and observe in real-time the propagation and directionality of the center of uterine activity during uterine contractions by accessing the AJOG video sharing service.

Publication of this work in the AJOG was recommended to encourage the investigators of this ambitious effort to expand their research in a larger sample size, and to determine if the observed changes in uterine electrical activity are the result or the consequence of myometrial (Bandl's ring) or mechanical pelvic dystocia.[25,28] A provocative question is whether the disruption in the propagation and directionality of the center of uterine activity can be detected early in the process of labor. An affirmative answer may suggest that the need for a cesarean delivery can be discovered at earlier stages of labor, thus reducing the risks of complications that can occur, such as infection, postpartum hemorrhage, and fetal distress. A critical issue relates to the role of labor augmentation in reversing the predominant lower uterine segment direction of the center of uterine activity in women diagnosed with dystocia. Based on these results, reappraisal of the clinical criteria necessary to define labor arrest may be needed. Dr Euliano's findings are broadening the field of research. We look forward to knowing if this technology may differentiate between true and false labor or provide the necessary breakthrough for early and accurate diagnosis of preterm birth. From large prospective studies, we know that measurement of the frequency of uterine contractions has not been useful for reducing the rate of preterm delivery.[29] Development of a telemetric uterine electrophysiologic monitoring system might be useful to determine the contribution of uterine contractions to cervical ripening and to predict preterm delivery. ■

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