intravenous fluids were given sparingly, to minimize fluid shifts and airway edema.

Since this delivery, our patient has required fewer interventions for excision of papilloma, four in 2015 and three in 2016. During her most recent operation she experienced severe intraoperative bronchospasm, hypoxia, and ventricular bigeminy. Unfortunately she has now developed tracheal stenosis and may soon require a tracheostomy.

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Transthoracic echocardiography and electrical cardiometry elucidate the hemodynamics of autotransfusion during labor under epidural analgesia

Electrical cardiometry (EC), a type of impedance cardiography, is a promising technique for continuous, hands-free trending of stroke volume (SV) and cardiac output (CO) with no known risk. The manufacturer (ICON device, Osypka Medical, Inc. La Jolla, CA, USA) states that EC measures the maximum rate of decrease of thoracic electrical impedance during systole (the square root of which is termed ICON), and that ICON relates to mean systolic blood flow velocity. Patients in active labor have periodic changes in hemodynamic parameters due to autotransfusion from uterine contractions.

After written informed consent, a healthy patient in active induced labor under epidural analgesia and with an intrauterine pressure catheter in place was studied with transthoracic echocardiography (TTE) and EC during eight consecutive uterine contractions. The patient was pain free and resting comfortably in the supine position with a 45° tilt to the left. During uterine contractions both TTE and EC showed increases in CO, SV and certain blood velocity parameters. Fig. 1 shows CO as measured by TTE and EC in relation to intrauterine pressure during the eight uterine contractions over approximately 21 minutes. Pearson correlation coefficients (r) between CO, SV and heart rate (HR) by TTE and EC were: CO_EC vs. CO_TTE, r=0.733, sig.=0.000; SV_EC vs. SV_TTE, r=0.551, sig.=0.000 and HR_EC vs. HR_TTE, r=0.963, sig.=0.000.

The three blood velocity parameters measured by TTE were velocity time integral (VTI) and mean and maximum blood velocity (Vmean and Vmax, respectively), whereas the blood velocity parameter measured by EC was ICON. Fig. 2 shows ICON and VTI in relation to intrauterine pressure. Pearson correlation coefficients between ICON and VTI, Vmean and Vmax were: ICON vs. VTI, r=0.67, sig.=0.000; ICON vs. Vmean, r=0.51, sig.=0.000; ICON vs. Vmax, r=0.53, sig.=0.000.

Regarding estimates of the duration of systole by the two techniques, mean left ventricular ejection time (LVET) by EC was 264 msec (range 230–294, SD=11.5) and mean envelope time (ET) by TTE was 247 msec (range 214–285, SD=10.9). The Pearson correlation coefficient between LVET and ET was 0.548, sig.=0.000.

The trending agreement between EC and TTE might have been better if not for the fact that EC measurements, as obtained in this study, were averages of the preceding 10 heartbeats, whereas TTE reflects the hemodynamics of one single heartbeat. Hence, hemodynamic changes measured by EC tend to lag and to be damped when compared to TTE changes. Electrical cardiometry might track TTE even more closely under rapidly changing hemodynamic circumstances if it were used in its beat-to-beat mode. Nevertheless, EC does seem to detect the same trends as are seen with TTE in this patient.

Increases in CO and SV due to uterine contraction and autotransfusion during labor are often discussed but have been little studied. The parturient's hemodynamic response to uterine contraction and autotransfusion may be worthy of formal study for two reasons: first, the absence of an increase in CO during a uterine

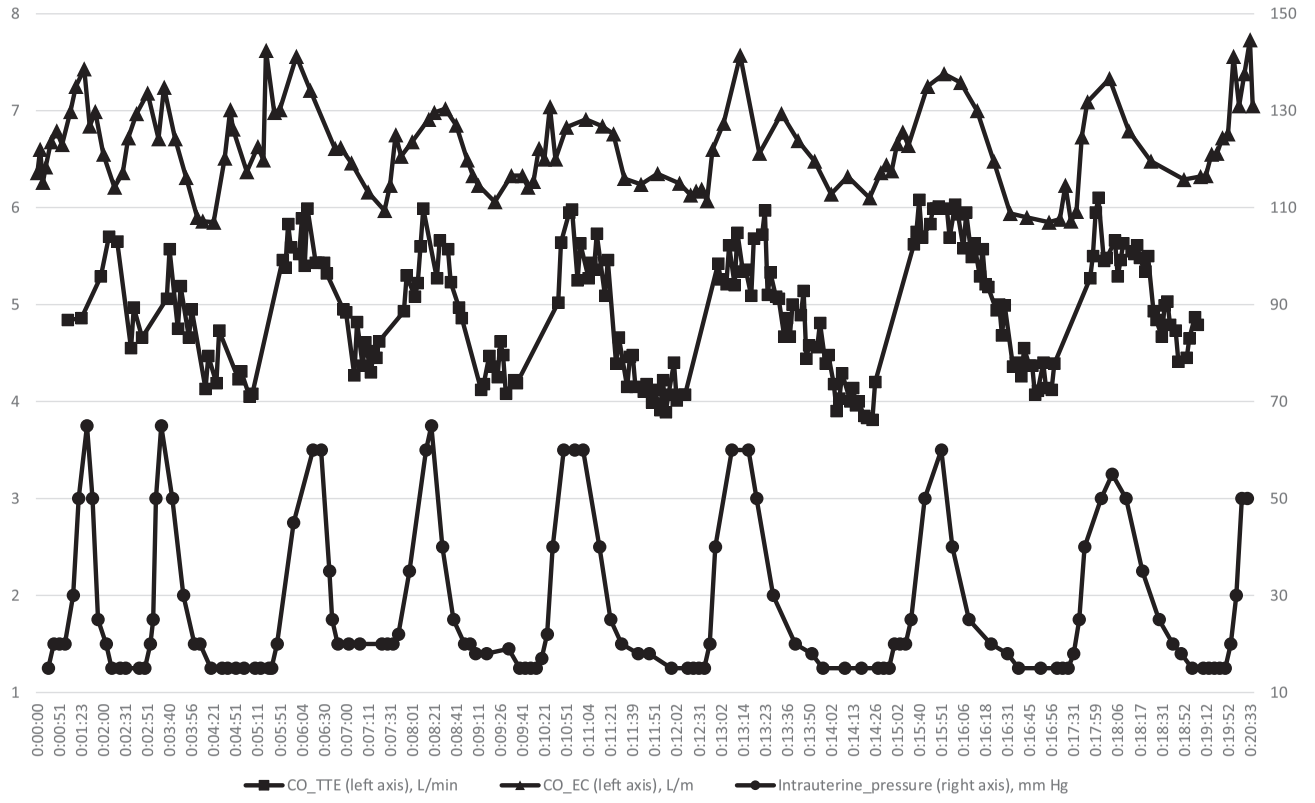


Fig. 1 Intrauterine pressure versus cardiac output (CO) by transthoracic echocardiography (TTE) and electrical cardiometry (EC) during eight uterine contractions

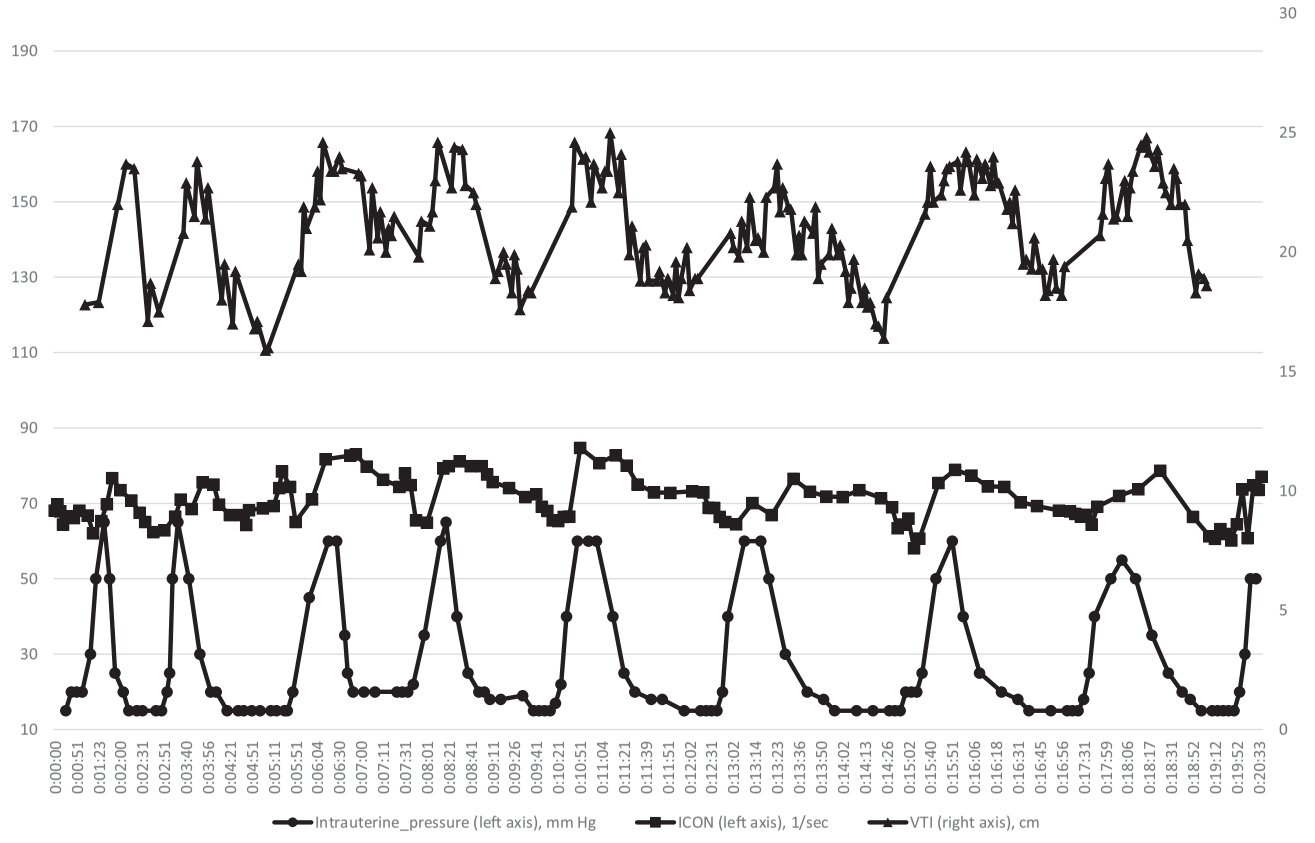


Fig. 2 Intrauterine pressure versus velocity time integral (VTI) and ICON during eight uterine contractions

contraction may indicate the presence of vena caval obstruction,[1] and second, the parturient's cardiovascular response to autotransfusion in the presence of an unobstructed vena cava may give useful information about the patient's volume status or other aspects of maternal cardiac function.

Transthoracic echocardiography is labor intensive and requires a highly skilled operator for every measurement, whereas EC is an easy-to-use and hands-free technique with no known risk. Electrical cardiography may prove a useful technique for detecting the hemodynamic response to uterine contraction. Specifically, the use of EC during labor may be able to answer the following two questions: (1) is the vena cava obstructed at any given time and in any given position? and, (2) how does the maternal cardiovascular system respond to periodically increased venous return?

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A simulation study of epidural catheter threading using a cardboard model of the ligamentum flavum

Threading an epidural catheter into the epidural space is difficult in 4–5% of lumbar epidural catheter placements.[1] Several theories exist as to the etiology of this phenomenon, including the possibility that contents of the epidural space may obstruct passage of the catheter. We sought to demonstrate that this phenomenon might be due to incomplete passage of the bevel of the epidural needle through the ligamentum flavum. We created a cardboard model of the ligamentum flavum and used high-definition imaging to measure the distance the bevel of the needle must traverse the ligamentum flavum in order to allow successful passage of the catheter into the epidural space. Our hypothesis was that a normal loss of resistance to saline could be obtained even when the bevel of the needle has not completely traversed the ligamentum flavum.

We used a $24'' \times 2'' \times 0.5''$ strip of conventional packing cardboard to simulate the ligamentum flavum (Fig. 1A–C). We advanced a 17-gauge Weiss needle perpendicular to the cardboard, through the model, performing a standard loss-of-resistance to saline technique. Once we obtained loss-of-resistance, we attempted to thread two different types of epidural catheters: a 19-gauge Arrow® FlexTip Plus® catheter, and a 20-gauge Portex® firm-tip catheter. Two inches below, we repeated another loss-of-resistance technique but this time with the needle at a 10–15 degree upward angle. Using a Canon® Rebel T3i digital SLR camera with macro lens, we photographed each needle insertion and catheter passage attempt in detail (Fig. 1A–D).

In our experiments, we were able to demonstrate that loss-of-resistance to saline may occur when the bevel of the needle barely traverses the ligamentum flavum (Fig. 1A). At this point, passage of both the 19-gauge Arrow® FlexTip Plus® catheter and the 20-gauge Portex® firm-tip catheter were impossible (Fig. 1B). The catheters could only pass when the point at which the width of the epidural needle orifice, equaling the diameter of the catheter (1 mm), had traversed the ligamentum flavum (Fig. 1C). Using Adobe Photoshop®, we were able to determine that the point at which the 17-gauge epidural needle orifice measures 1 mm in width occurs 1.3 mm from the tip (Fig. 1D).

Our model suggests that a potential cause of inability to thread the epidural catheter through the epidural needle is inadequate passage of the bevel of the epidural needle through the ligamentum flavum. Although advancing the epidural needle may facilitate the bevel of the needle completely traversing the ligamentum flavum, there may be an increased risk of accidental dural puncture.[1] Some clinicians rotate the needle believing that it may be inserted lateral to the midline, but again this may increase the risk of an accidental dural puncture.[2] According to Sviggum et al, the most successful strategy when faced with inability to thread an epidural catheter is to re-attempt the epidural placement.

Another common maneuver to overcome difficult catheter passage is injection of saline, local anesthetic, or air, presumably to expand the epidural space. However, this technique has never been shown to make catheter insertion easier; one study comparing saline and no saline found no difference in the ease of catheter threading.[3] Given our findings, flushing saline through the epidural needle would not be expected to improve catheter threading as saline can be easily injected, even if the majority of the needle orifice remains within the ligamentum flavum.