Dreaming of fetal ICU

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One morning, I dreamt of an intensive care unit (ICU) for the fetus. The heart rate, blood pressure, cardiac output, and blood volume of the fetus were monitored. We also had access to the fetal blood. I just thought this should be the true picture of fetal ICU. Suddenly, I woke up and realized the time had not yet come.

Fetal cardiac function is recognized as a marker of disease severity and prognosis in different fetal conditions. Although several postnatal imaging methods for measuring cardiac function, such as magnetic resonance imaging (MRI) or multi-detector computed tomography (CT), are now available in many tertiary care centers, non-invasive fetal ultrasound imaging is still the only way to evaluate fetal cardiac function. However, there remain several technical difficulties with fetal ultrasound. In utero, the fetus is surrounded by amniotic fluid and maternal skin, which increases the distance from the probe to the fetal heart. Additionally, the normal fetal heart rate is around 140 bpm, and the heart is only a few centimeters in diameter, much smaller than the adult heart. Moreover, MRI and CT require large equipment and cannot be used at the bedside. Precise ultrasonographic evaluation of fetal cardiac function is thus needed in the field of maternal fetal medicine.

The most obvious method of determining the hemodynamic function of the heart is by measuring the cardiac output (CO), which is the blood volume expelled by the ventricle over a given unit of time. The CO is obtained by multiplying the heart rate by the ventricular stroke volume (SV). The latter can be measured using Doppler, M-mode,

and two- or three-dimensional ultrasound images. Doppler-based estimation of SV relies on measurement of the out-flow valve diameter combined with the blood flow velocity over the aortic or pulmonary valve and is routinely used in adult cardiology. However, various factors, such as Doppler insonation angle or valve diameter measurement, limit its feasibility, especially in the fetus. The valve diameter is small, usually only a few mm, and the free fetal position does not allow us to use a fixed insonation angle.

To overcome the limitations of Doppler techniques, direct estimations of ventricular volume have recently been proposed. The concept of physical deformation of an object is used extensively in materials science and engineering. When an object or physical body moves with identical displacement of all its constituent particles it is known as rigid displacement. All the particles in this instance will have the same velocity of movement. However, if the particles differ in their velocity of movement and are differentially displaced, the body will undergo deformation or strain. The deformation is elastic when it is temporary so that the constituent particles of the physical body do not show any relative displacement once the stress is removed. Ultrasound speckles are the manifestation of amplitude variations in backscattered ultrasound signals from randomly distributed scatterers. Myocardial deformation parameters can be measured by tracking the frame-to-frame displacement of the speckles. Such measurements are angle-independent, allowing multidirectional assessment of the deformation. Two-dimensional speckle fetal echocardiography-derived values are replicable, and measurements have been validated in animals and patients. Fetal speckle tracking echocardiography, such as velocity vector imaging (VVI), is not based on Doppler technology and therefore does not suffer from the latter's limitations. Although reports are still preliminary, they show not only

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the feasibility of using these approaches in the fetus but also their potential use for evaluating fetal cardiac performance in high-risk pregnancies.

I really hope that my dream of having true fetal ICU comes true. In the near future, I hope, novel technical

innovations in ultrasound medicine will emerge and provide new opportunities for extending the field of maternal fetal medicine.