Echocardiographic assessment of fetal arrhythmias

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Fetal arrhythmia assessment can at times be a challenging task. With the potential for evolution of fetal heart failure in both tachy- and bradyarrhythmias, and availability of successful strategies to treat and prevent progression, however, it is a critical aspect of fetal cardiology. Although fetal ECG has been described, low P wave amplitudes, difficult signal acquisition from 27 to 34 weeks, and use of signal averaging limit its clinical utility.¹ Fetal magnetocardiography, the magnetic analogue of fetal ECG is a promising modality,² but it is currently available in only a few centres. To date, the routine evaluation of fetal heart rate and rhythm has relied largely on the use of M-mode and Doppler techniques, which provide information about mechanical activity of the atria and ventricles used to reflect indirectly electrophysiological events.

M-MODE TECHNIQUE

One of the first echocardiographic modalities employed in fetal rhythm evaluation is that of M mode, in which the cursor is positioned simultaneously through the more trabeculated right atrium and a ventricle (fig 1).^{3–4} M mode requires adequate fetal positioning and sufficient image resolution to demonstrate details of the chamber walls or motion of atrioventricular (AV) valves. Although a rapid assessment of the relationship of atrial (A) and ventricular (V) contraction is usually possible, defining the exact timing of the onset of contraction for the AV and ventriculo-atrial interval measurement may be difficult owing to the small size of the fetal cardiac chambers, and frequent lack of sharp tracings with an oblique course of sampling.

PULSED DOPPLER TECHNIQUES

Pulsed Doppler techniques used in fetal rhythm assessment rely on the timing of blood flow to indicate mechanical activity. Simultaneous interrogation of left ventricular inflow (specifically the "A" wave in atrial systole) and outflow, one of the earliest methods used,⁵ requires the Doppler cursor be parallel or nearly parallel to the flow. Although the sharp Doppler signals have improved evaluation of the AV interval and the relationship between atrial and ventricular contractions, this technique is less effective when A and E waves are fused and when atrial systole is not associated with ventricular inflow. For instance, when atrial systole occurs coincidentally with ventricular systole in complete AV block or atrial flutter with AV block, the A wave cannot be detected.

Recently, Fouron introduced the technique of simultaneous pulsed Doppler interrogation of flow in the superior vena cava (SVC) and the ascending aorta (AO).⁶ For a short course these vessels are parallel and juxtaposed in the fetal chest (fig 2). The short A wave reversal in the SVC during atrial systole and the onset of forward flow in the ascending aorta indirectly define the mechanical relationship between the atria and ventricles. If the angle of insonation is not close to 0° or the filter is too high, the low-velocity SVC atrial systolic flow may not be demonstrable. Although this technique requires a considerable amount of practice and patience in order to achieve success, interpretation of the signals once acquired is not difficult. This technique has provided fetal cardiologists with a tool enabling better differentiation between long and short ventriculo-atrial tachyarrhythmias, which can assist in maternal–fetal treatment.⁶ Mechanism of onset and offset (gradual or abrupt and whether preceded by ectopic beats), and atrial and ventricular rates provide additional clues to the specific arrhythmia. As is true for the other techniques, though, it is very much limited by fetal position and image resolution.

Carvalho and colleagues⁷ provide an additional means of assessing the atrial and ventricular relationship, simultaneous Doppler interrogation of pulmonary artery (PA) and pulmonary vein (PV) flow (see article on page 1448). Given the orientation of the two PAs and their relation to the PVs, this technique may prove to be less limited by fetal position than the other techniques. However, unlike the retrograde atrial systolic flow in the SVC, atrial systolic flow in the PV is usually forward and of reduced velocity or absent altogether. With low left atrial pressure, timing of onset of atrial systole may be difficult to define, thus limiting the ability to interpret accurately the waveforms for the AV interval and arrhythmia assessment. This limitation may, at least in part, explain the wide variability observed in the AV interval measurements of Ciardelli and colleagues.⁸ With increasing left atrial pressure, flow in the PVs stops and eventually, at higher pressures there is flow reversal in atrial systole. When this occurs, the onset of atrial contraction may be more readily identified as observed in SVC–AO Doppler. Thus, in longer-standing tachyarrhythmias or in those more likely to be associated with an increased atrial pressure, interpretation of the flow signals may be facilitated. Although PA–PV signals permit definition of bradyarrhythmias if they are associated with more regular pulmonary vein to atrial

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Abbreviations: AO, ascending aorta; AV, atrioventricular; PA, pulmonary artery; PV, pulmonary vein; SVC, superior vena cava; TVI, tissue velocity imaging

Figure 1 (A) M-mode assessment with the cursor placed through the right atrium (RA) and left ventricle (LV) from an oblique four-chamber image. (B) Atrial (A) and ventricular (V) contraction.

flow, in complete AV block, where flow in the pulmonary veins may be more erratic as a consequence of occasional simultaneous atrial and ventricular systoles, interpretation of the arrhythmia is difficult. Finally, both SVC–AO and PA–PV

Figure 3 Tissue velocity imaging of the basal right ventricular free wall. The interval between the time of onset of atrial contraction (A) and isovolumic ventricular contraction (IVC) used to estimate the PR interval is represented by the bar at the bottom of the image. D, early diastole; V, ventricular systole.

techniques are limited in certain forms of structural heart disease with altered great artery position or flow. Despite these limitations, PA–PV Doppler adds to our armamentarium of simpler echo-based techniques for fetal rhythm assessment.

TISSUE VELOCITY IMAGING (TVI)

TVI, the newest echocardiographic modality to be employed in fetal rhythm assessment, has advantages over the M-mode and pulsed Doppler techniques described above.⁹ When the signals are stored as scan-line raw data, analysis of the activity of several regions of the heart can be acquired within the same

Figure 2 Pulsed Doppler techniques sampling the (A) left ventricular (LV) inflow and outflow and (C) the superior vena cava (SVC) and the ascending aorta (AO). The images demonstrate (A, C) the approach of the Doppler interrogation and (B, D) the corresponding Doppler signals. A, atrial contraction; AO, aortic outflow; LA, left atrium; LV, left ventricle; RV, right ventricle; V, ventricular outflow.

cardiac cycle. This modality, however, is not universally clinically available, and also requires sufficient acoustic windows. Nevertheless, TVI may be the most effective echocardiographic means of defining arrhythmias and AV intervals. For instance, the TVI interval between the onset of atrial contraction and isovolumic contraction (fig 3) more closely approximates the PR interval from fetal ECGs than do flow techniques.¹⁰ That flow-derived AV time intervals tend to be longer and more variable may be due to the influence of loading conditions, myocardial function, heart rate and speed of pulse-wave propagation.¹¹ In addition, the ventricular pre-ejection period (time delay from onset of the Q wave to ventricular ejection) tends to be longer than the atrial pre-ejection period (time delay from the P wave to atrial ejection), resulting in PR interval overestimation when based solely on flow.¹¹ Ciardelli *et al* found that AV measurements derived by PA–PV Doppler were longer than the other Doppler flow techniques and, unlike the other techniques and ECG-derived PR intervals, did not increase with gestation (unpublished data). Inherent limitations of AV interval assessment, different forces that influence the timing of flow and signals generated in the pulmonary arteries and veins that may change with gestation compared with the other Doppler techniques, and relatively small numbers of third trimester fetuses may have contributed to these observations.

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