CONGENITAL HEART DISEASE

Assessment of fetal atrioventricular time intervals by tissue Doppler and pulse Doppler echocardiography: normal values and correlation with fetal electrocardiography

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Objective: To establish gestational age-specific reference values of normal fetal atrioventricular (AV) time interval by spectral tissue Doppler imaging (TDI) and pulse-wave Doppler (PD) methods, and to assess their correlation with signal-averaged fetal PR intervals (ECG).
Design: Cohort study.
Setting: Tertiary centre for fetal cardiology.
Patients and measures: 131 pregnant women between 14 and 42 weeks' gestation underwent 196 fetal echocardiograms and 158 fetal ECG studies. TDI-derived AV intervals were measured as the intervals from atrial contraction (Aa) to isovolumic contraction (IV) and from Aa to ventricular systole (Sa) at the right ventricular free wall. PD-derived AV intervals were measured from simultaneous left ventricular inflow/outflow (in/out) and superior vena cava/aorta (V/AO) recordings.
Results: Measurements were possible by ECG in 61%, by TDI in 100%, by in/out in 100% and by V/AO in 97% of examinations. Aa-IV correlated significantly better with PR intervals ($y = 0.67x + 38.29$, $R^2 = 0.15$, $p < 0.0001$, mean bias 8.0 ms) than did in/out ($R^2 = 0.10$, $p = 0.002$, bias 18.7 ms) and V/AO ($R^2 = 0.06$, $p = 0.02$, bias 12.4 ms). Gestational age and AV intervals were positively correlated with all imaging modalities ($R^2 = 0.19–0.31$, $p < 0.0001$).
Conclusion: This study showed the feasibility of fetal AV interval measurements by TDI, and established gestational age-specific reference data. TDI-derived Aa-IV intervals track ECG PR intervals more closely than PD-derived AV intervals and thus should be used as the ultrasound method of choice in assessing fetal AV conduction.

Isolated congenital complete atrioventricular (AV) block is associated with maternal anti-Ro/SSA and anti-La/SSB autoantibodies, which may trigger inflammatory destruction of the AV node in the susceptible fetus. Related to this insult, electrical AV conduction is progressively prolonged to complete heart block at around 20 weeks' gestation. Complete AV block may be preventable if the disease can be recognised and treated at an early stage of AV nodal damage, which is clinically characterised by a short-lived appearance of first- or second-degree AV block.[1 2] Thus, a simple, precise diagnostic tool that allows reliable detection of subtle electrical AV conduction anomalies is indispensable for the surveillance of at-risk fetuses.

Although recording fetal electrophysiological signals is possible by transabdominal fetal magnetocardiography and signal-averaged ECG,[3–5] their use is limited to a few centres. Alternatively, simultaneous pulse-wave Doppler (PD) interrogation of the mitral valve and left ventricular inflow/outflow (in/out) or the superior vena cava/ascending aorta (V/AO) have been used to study the chronology of atrial and ventricular systolic events indirectly by their mechanical consequences.[6–11] The accuracy of measurements of flow-derived AV time intervals is influenced by loading condition, intrinsic myocardial properties, heart rate and the speed of pulse-wave propagation.[12–14] In addition, there is a tendency to overestimate PD-derived measurements, as the ventricular pre-ejection period (time delay from Q wave to ventricular ejection) is longer than the atrial pre-ejection period (time delay from P wave to atrial ejection).[14] Tissue Doppler imaging (TDI) is less load dependent and allows direct analysis of segmental wall motion in any area of the heart during the same cardiac cycle.[15–17] During normal sinus rhythm, the longitudinal wall motion pattern that is obtained from the ventricular myocardium is typically composed of four wave curves (fig 1). Two diastolic curves are produced by tissue motion away from the apex of the heart during early diastolic filling (Ea) and during atrial contraction (Aa), followed by two wave curves towards the apex during isovolumic contraction (IV) and ventricular systole (Sa). In atrially paced pigs, we have shown that the Aa-IV interval of the basal right ventricular free wall correlated better over a wider heart rate range with electrical PR intervals than did in/out PD and other TDI sites.[14]

Thus, we hypothesised that right ventricular TDI would be more accurate than PD in measuring AV intervals of the human fetus. Our study objectives were, firstly, to establish gestational age-specific normal AV interval values by TDI and PD; and, secondly, to compare these measurements with signal-averaged electrical PR intervals that were used as a reference.

METHODS

The Institutional Research Ethics Board approved this study. Written informed consent was obtained from each

Abbreviations: Aa, atrial contraction; AV, atrioventricular; in/out, inflow/outflow; FEMO, fetal ECG monitor; IV, isovolumic contraction; PD, pulse-wave Doppler; Sa, ventricular systole; TDI, tissue Doppler imaging; V/AO, superior vena cava/aorta

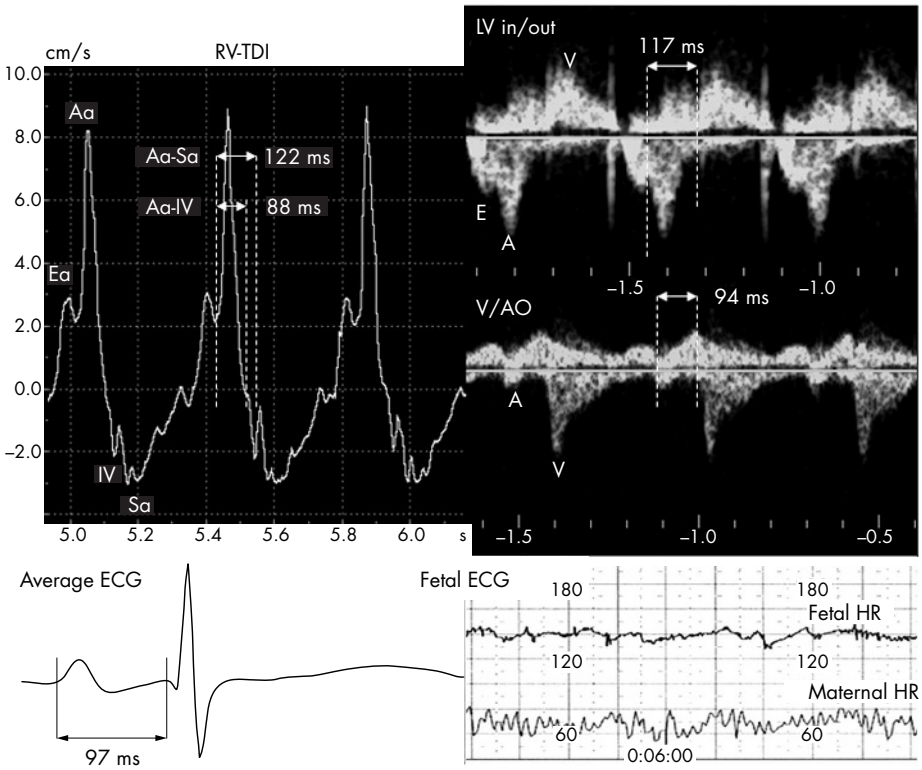

Figure 1 Example of atrioventricular (AV) interval measurements in a 21-week fetus. (Left top) Tissue Doppler imaging (TDI) of the basal right ventricular (RV) free wall. Aa-IV was measured as time interval between atrial contraction (Aa) onset and isovolumic contraction (IV) onset. IV onset was defined by the velocity curve crossing the 0 line.[14] Aa-Sa was measured as time interval between Aa onset and ventricular systole (Sa) onset. (Right top and middle) Left ventricular inflow/outflow (LV in/out) and superior vena cava/aorta (V/AO) pulse-wave Doppler recordings. The AV time intervals were measured between A wave onset and the beginning of the ventricular ejection flow wave.[8] (Bottom) Averaged fetal ECG waveform (left) and fetal and maternal heart rate (HR) monitoring (right) by fetal ECG. The PR interval was measured as time interval between P and Q waves on the averaged recording.

participant. Study inclusion criteria were singleton pregnancy with normal fetal cardiac anatomy, function and rhythm.

Study participants

Between August 2003 and January 2005, we prospectively enrolled 131 pregnant women (range 14.3–41.6 weeks), of whom 110 were recruited as healthy control participants. Twenty-one were referred because of maternal anti-Ro/La antibodies. Unlike the controls, most mothers with autoantibodies had more than one (range 1–8 studies) ultrasound study, aiming at an early diagnosis of conduction anomalies.

Study design

The study consisted of two parts. In part 1, only the echocardiograms of pregnancies without exposure to anti-Ro/La antibodies were included (117 examinations) to establish reference values on mechanical AV intervals by TDI and PD. In part 2, only fetal studies with simultaneous ultrasound and ECG recording were included (158 examinations) to compare mechanical AV interval measurements with electrical PR intervals.

Echocardiography

A detailed echocardiographic examination was performed with VingMed Vivid-7 (GE Medical Systems, Milwaukee, Wisconsin, USA) or HDI-5000CV (Philips ATL, Bothwell, Washington, USA) ultrasound systems with 3.5–7.0 MHz curved-array transducers. Biparietal diameter and femur length were measured to establish the gestational age. In/out PD velocity waves were acquired from the mitral valve and the lower part of the left ventricular outflow tract. V/AO PD velocity waves were recorded from the V/AO or alternatively from the innominate vein and transverse aortic arch if the fetus presented in an unfavourable position. The size of the PD sample volume was optimised to acquire simultaneous blood flow signals from the areas of interest. All tracings were recorded at a sweep speed of 200 mm/s. Measurements were obtained from three consecutive cardiac cycles and subsequently averaged.

Two-dimensional guided colour-coded TDIs were obtained from a cardiac four-chamber view with a multifrequency phased-array transducer (central frequency 3.5 MHz, range 2.25–5.0 MHz). For the TDI recordings, the sector width, depth and Nyquist limits (16–19 cm/s) were optimised to obtain the highest possible frame rates (mean 230.3 (SD 28.4) frames/s). TDI cine loops of at least 10 consecutive cardiac cycles were analysed off line with EchoPAC PC V3.1.3 (GE Medical Systems). All measurements were obtained from the base of the right ventricular free wall. Care was taken to keep the 1 × 1 mm TDI sample volume within the centre of the myocardial wall throughout the interrogated cardiac cycle.

Electrocardiography

The first transabdominal fetal ECG was recorded in 1906.[18] Advances in mathematical algorithms and microprocessor capabilities in signal processing have resulted in a user-friendly laptop-based system for this purpose (fetal ECG monitor (FEMO); Medco, Inc) that can be applied from about 17 gestational weeks onward. FEMO overcomes the confounding factors to the attainment of a useful transabdominal fetal ECG by optimising fetal signal to noise ratio, and

stores raw signals for post-processing with several alternative algorithms. FEMO was used for the recording and analysis of the fetal ECGs. The electrical signals were recorded twice for 8 min with different pairs of the three maternal abdominal electrodes and subsequently filtered and averaged.

Measurements and reproducibility

AV intervals were measured as fig 1 shows. Ultrasound-derived measurements were taken by a single observer (MN), who had no knowledge of the ECG findings. PR intervals were measured by a second observer (LF), who had no knowledge of the ultrasound findings. Interobserver and intraobserver variabilities in measurement were assessed in 20 randomly selected studies by two independent observers (MN, KR) and one week later by one of these observers. Reproducibility of fetal ECG data was assessed by comparing the two recordings of the same patient by using the intraclass coefficient of correlation.

Statistics

Results are expressed as mean (SD), median (range) or 95% confidence interval (CI) as appropriate. Correlation between dependent and independent variables was evaluated by linear regression. A Bland–Altman plot was used to analyse differences between the durations of echocardiographic and electrical AV intervals.[19] Measurements of the different modalities were compared by analysis of variance for repeated measures with Bonferroni correction as a post hoc test. Stepwise multivariate linear regression was used to evaluate the effect of gestational age and cardiac cycle length on AV time. Values of $p < 0.05$ and $F > 2.0$ was considered significant. All data were analysed with commercially available statistical software packages (Prism 4 for Windows, GraphPad Software Inc, San Diego, California, USA; Statcel, V.1998, OMS, Saitama, Japan).

RESULTS

Of 196 fetal examinations, 158 included an ECG and echocardiogram and 38 had only an echocardiogram. Technically adequate recordings to measure PR intervals were obtained in 97 (61%) cases. Technically accurate recordings to measure AV intervals were obtained in 196 (100%) examinations for in/out PD and TDI, and in 191 (97%) examinations for V/AO PD. In five instances no A wave was obtained from the superior vena cava at 28, 32, 35, 36 and 39 weeks.

Study part 1: normal reference data

One hundred and seventeen studies of 110 normal control participants were assessed (range 14.3–41.6 weeks). To improve characterisation of the impact of gestational age on AV time measurements, the study population was divided into five representative subgroups of at least 20 fetuses each (14–19 weeks, 20–24 weeks, 25–29 weeks, 30–34 weeks and $\geqslant$ 35 weeks), as table 1 shows. Ultrasound-derived AV intervals were significantly positively correlated with gestational age (fig 2). Fetal cardiac cycle length had a positive correlation with gestational age (cycle length = 1.9 × weeks of gestation + 370.6; $R^2 = 0.28$, $p < 0.0001$). After stepwise regression analysis, gestational age was retained as an independent variable with a significant effect on AV duration.

Study part 2: correlation between mechanical and electrical intervals

Ninety-seven studies (range 17.1–39.6 weeks) were analysed for comparison. Significant positive correlation between the durations of PR and AV intervals was found among all modalities (fig 3). The best correlation was observed between PR and IV-Aa, whereas V/AO-derived AV times correlated the least. The mean duration of all ultrasound-derived AV measurements differed significantly from PR intervals (fig 4). When compared with PR duration, AV measurements were systematically longer with in/out PD (bias −18.7 (14.8) ms, 95% CI −47.8 to 10.3 ms), V/AO (bias −12.4 (15.8) ms, 95% CI −43.4 to 18.6 ms) and Aa-Sa (bias −32.8 (17.2) ms, 95% CI −66.5 to 0.9 ms) (fig 5). Conversely, Aa-IV duration was shorter than PR (bias 8.0 (13.9) ms, 95% CI −19.3 to 35.2 ms). Thus, the closest relationship was observed between Aa-IV and PR intervals. As PD is widely used in the assessment of fetal conduction and rhythm anomalies, the differences between in/out, V/AO and TDI measurements were further analysed. V/AO-derived AV intervals were significantly shorter than in/out (mean 6.6 ms, 95% CI of difference 3.2 to 9.9 ms, $p < 0.001$). Aa-IV was shorter than in/out (mean 26.9 ms, 95% CI of difference 23.6 to 30.3 ms, $p < 0.001$) but Aa-Sa was longer (mean difference −13.8 ms, 95% CI of difference −17.2 to −10.4 ms, $p < 0.001$).

Reproducibility

The interobserver 95% CI was −18.1% to 18.7% for in/out, −10.0% to 9.4% for V/AO and −10.6% to 6.5% for Aa-IV-derived measurements. The intraobserver 95% CI was −19.4% to 9.5% for in/out, −9.9% to 7.3% for V/AO and −16.8% to 13.9% for Aa-IV-derived measurements. For sequential measurements of the PR interval of the same patient, the intraclass coefficient was 0.71, indicating good agreement.

DISCUSSION

The classification of conduction anomalies is primarily based on the chronology of atrial and ventricular electrophysiological events. First-degree AV block as the most subtle anomaly is characterised by 1:1 AV conduction with a longer electrical PR interval than usual for age and heart rate. Various authors indicate that a delay in mechanical AV conduction is possible in the fetus and may precede the

Table 1 Normal values of mechanical atrioventricular time intervals by gestational age group

	Gestational age (weeks)				
	14–19	20–24	25–29	30–34	35–42
No of patients	26	24	21	20	23
LV in/out (ms)	113.7 (10.6)	115.6 (7.6)	121.6 (9.7)	122.7 (11.1)	123.9 (7.3)
V/AO (ms)	106.4 (10.1)	108.0 (8.9)	115.4 (12.0)	116.5 (8.8)	119.2 (10.5)
Aa-IV (ms)	83.9 (9.8)	87.5 (7.8)	94.0 (7.9)	99.9 (9.7)	98.3 (12.2)
Aa-Sa (ms)	121.4 (12.3)	129.6 (11.2)	137.3 (11.0)	142.4 (14.2)	141.7 (14.6)

Data are expressed as mean (SD).
Aa, atrial contraction; IV, isovolumic contraction; LV in/out, left ventricular inflow/outflow pulse Doppler method; Sa, ventricular systole; V/AO; superior vena cava/aorta pulse Doppler method.

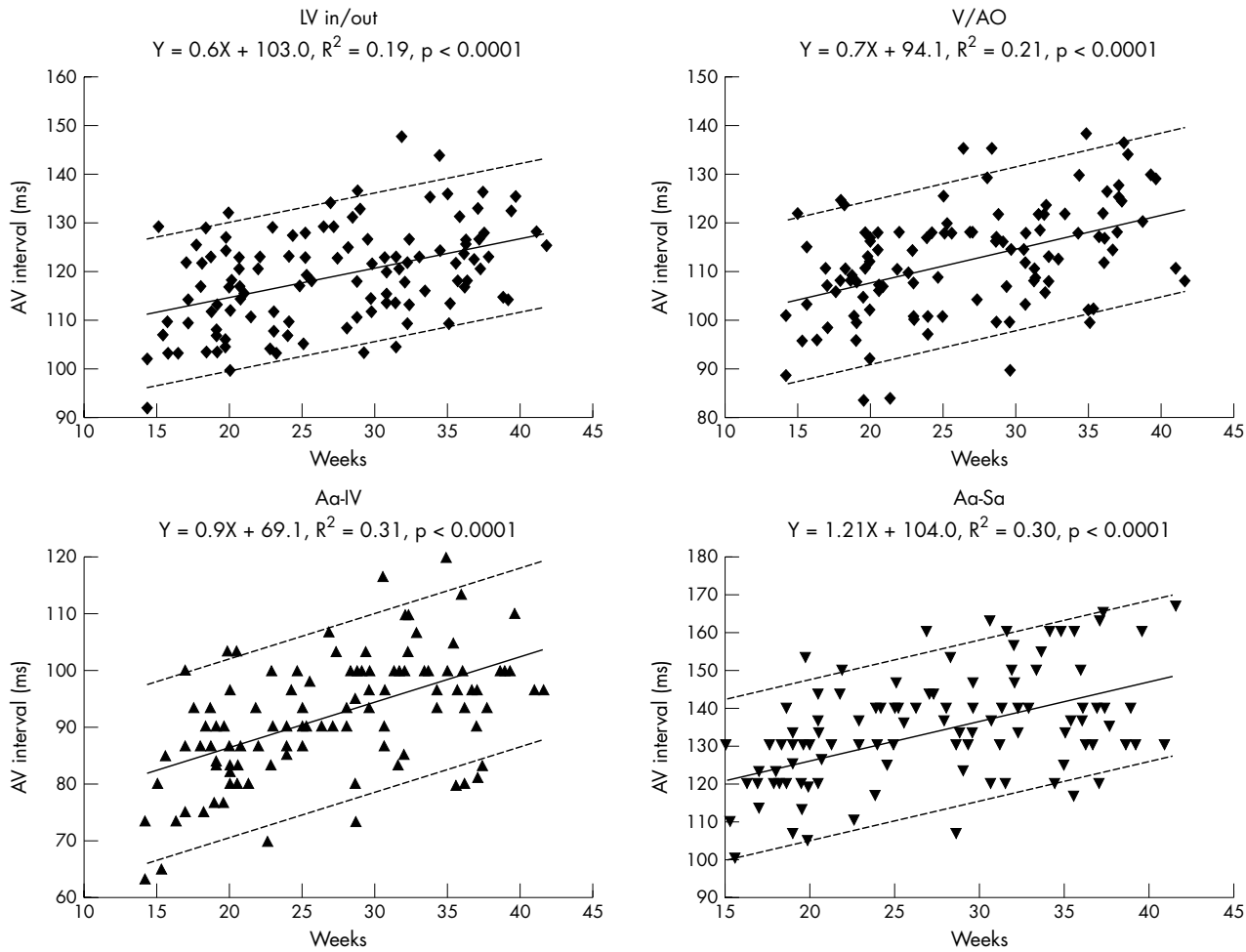

Figure 2 Linear regressions between mechanical atrioventricular (AV) intervals and gestational age (weeks). Lines denote regressions and 95% confidence limits for individual observations. Aa, atrial contraction; IV, isovolumic contraction; LV in/out, left ventricular inflow/outflow pulse Doppler method; Sa, ventricular systole; V/AO, superior vena cava/aorta pulse Doppler method.

development of irreversible complete AV block.[1 7 10] This concept has been challenged recently by the findings of Sonesson *et al*.[10] They diagnosed transient first-degree AV block and normal PR intervals after birth in 25% of fetuses exposed to maternal anti-Ro/La antibodies. The relevance of these findings has been disputed by others, which raises general questions about the accuracy of ultrasound-derived AV time measurements by different observers or about the accuracy of the fetal reference values that were used for comparison.[8 20 21]

Correlation between mechanical and electrical AV intervals

At least theoretically, fetal ECG should provide the most useful information on PR duration.[5 22–24] Recorded fetal ECG signals are signal averaged and thus beat-to-beat analysis of the underlying cardiac rhythm is not possible. Consequently, fetal ECG is not helpful in diagnosing rhythm anomalies that are associated with irregular heart rates. Another limitation would be that the low-amplitude P waves are often undetectable on the ECG tracings. For example, Chia *et al*[24] were unable to detect P and QRS waves in 25% and 9%, respectively, fetal ECG recordings; in this study we could not measure PR intervals in 39% of attempted recordings.

Unlike ECG, ultrasound signals that relate in real time to fetal atrial and ventricular systolic events and that may be used to assess the temporal AV relationship are readily obtained as confirmed in this study.[5–9 25 26] Indeed, simultaneous in/out PD and V/AO PD is nowadays routinely used to determine the functional integrity of the fetal AV conduction, and this study is the first to validate the use of TDI in this context. Myocardial depolarisation, contraction and blood flow occur sequentially with region-specific time delays. The correlation between electrical and mechanical AV time measurements depends on the difference in delay between atrial (P wave) and ventricular (Q wave) electrical depolarisation and their respective regional atrial (A; Aa) and ventricular (aorta; IV; Sa) mechanical consequences.[14 26] The present study in human fetuses showed that Aa-IV indeed correlates significantly better with PR duration than do all other ultrasound surrogates. PR intervals were on average 8 ms longer than Aa-IV intervals but were 12.4 ms, 18.7 ms and 32.8 ms shorter than the AV time measurements by V/AO, in/out and Aa-Sa, respectively.

Reference values

Reference data of AV time intervals differed significantly between the PD and TDI approaches. Irrespective of the ultrasound methods, however, AV duration was positively correlated with gestational age, which is comparable with previously published fetal data obtained by PD, ECG or magnetocardiography.[3 8 9 24] The gradual prolongation in AV conduction is probably related to the increase in cardiac size and in parasympathetic tone with advancing gestation.[27]

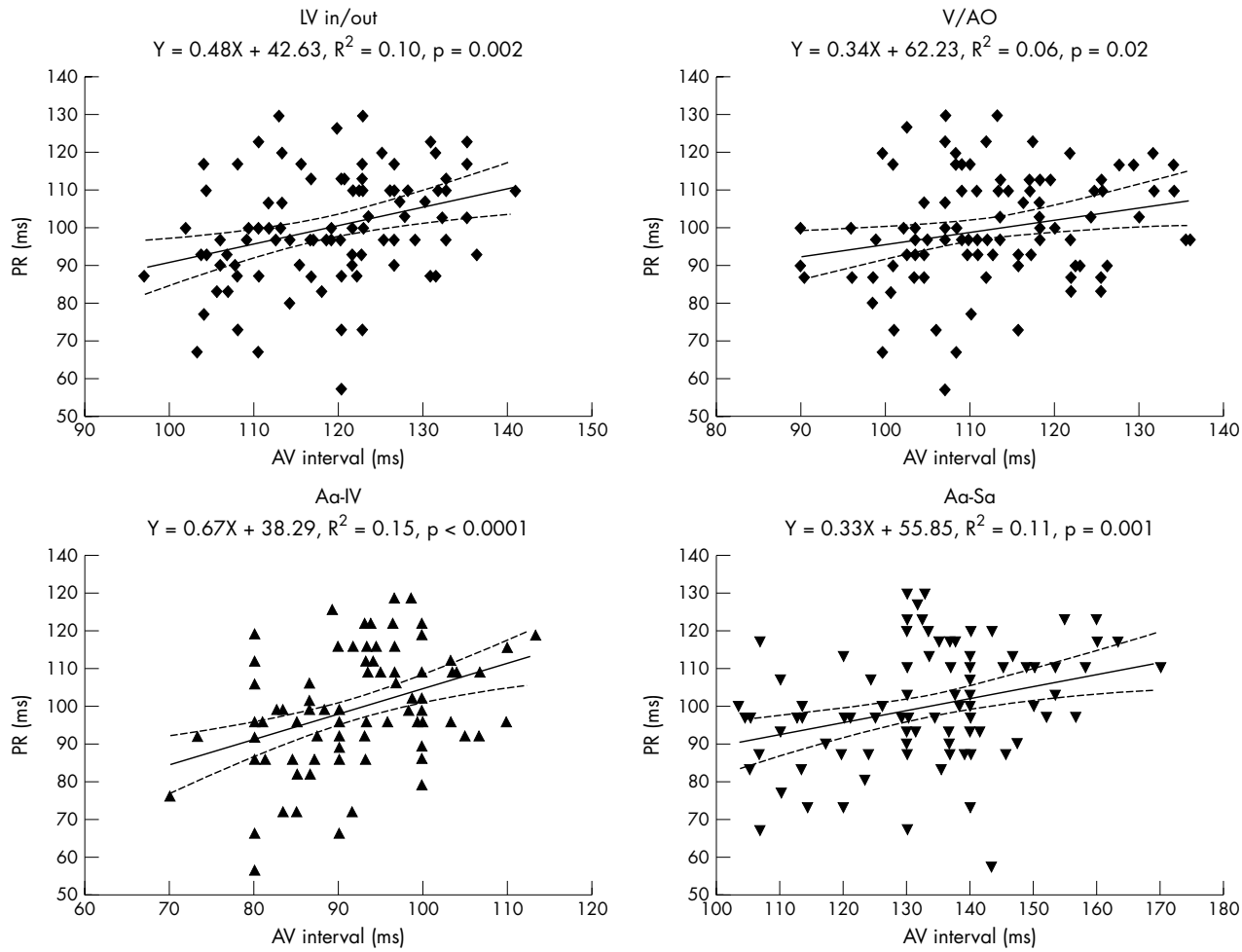

Figure 3 Correlations of mechanical atrioventricular (AV) and electrical PR intervals. Aa, atrial contraction; IV, isovolumic contraction; LV in/out, left ventricular inflow/outflow pulse Doppler method; PR, PR interval from fetal ECG; Sa, ventricular systole; V/AO, superior vena cava/aorta pulse Doppler method.

Interestingly, however, the slope of increase in AV duration was less important with PD than with TDI, as fig 2 shows. This may be explained by a relative overestimation of PD-derived AV time measurements of the young fetus with faster rates.[14]

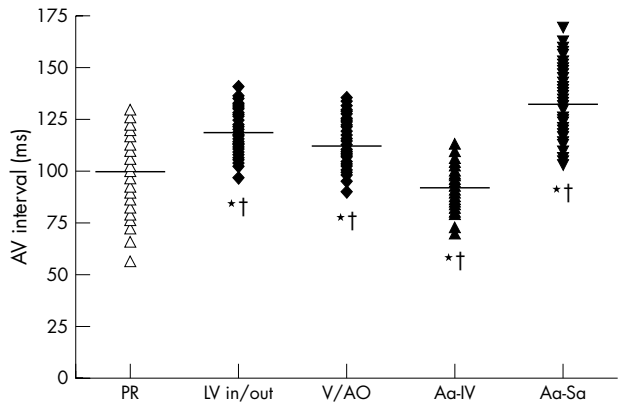

Figure 4 Comparison of atrioventricular (AV) interval measurements between the different modalities. Horizontal bar represents mean. Aa, atrial contraction; IV, isovolumic contraction; LV in/out, left ventricular inflow/outflow method; PR, PR interval from fetal ECG; Sa, ventricular systole; V/AO, superior vena cava/aorta pulse Doppler method. *$p < 0.001$ *v* PR; †$p < 0.001$ *v* LV in/out.

Clinical implications

This study showed the feasibility of measuring fetal AV intervals by TDI across a wide gestational age range. Reference data were established for TDI and PD methods that may prove useful for the diagnosis of fetal first-degree AV block. Right ventricular Aa-IV intervals correlated significantly better with PR intervals than did other imaging approaches, and should be preferred for measuring fetal AV intervals if ECG or magnetocardiography is unavailable.

Study limitations

Several limitations need to be addressed. Signal-averaged fetal ECG was compared with ultrasound measurements. Only 61% (n = 97) of 158 attempted examinations were of useful quality with clearly delineated P and QRS waves to measure the PR duration, which is comparable with the experience reported by Chia and colleagues.[24] Moreover, we used two different sites for V/AO recording, which may explain the poorer correlation of this method with PR intervals than, for example, in/out. In our study, V/AO-derived AV intervals were, on average, 6.6 ms shorter than the in/out equivalent. This is in contrast to the findings of Andelfinger *et al*,[8] who found no significant time difference between these two methods when the distal superior vena

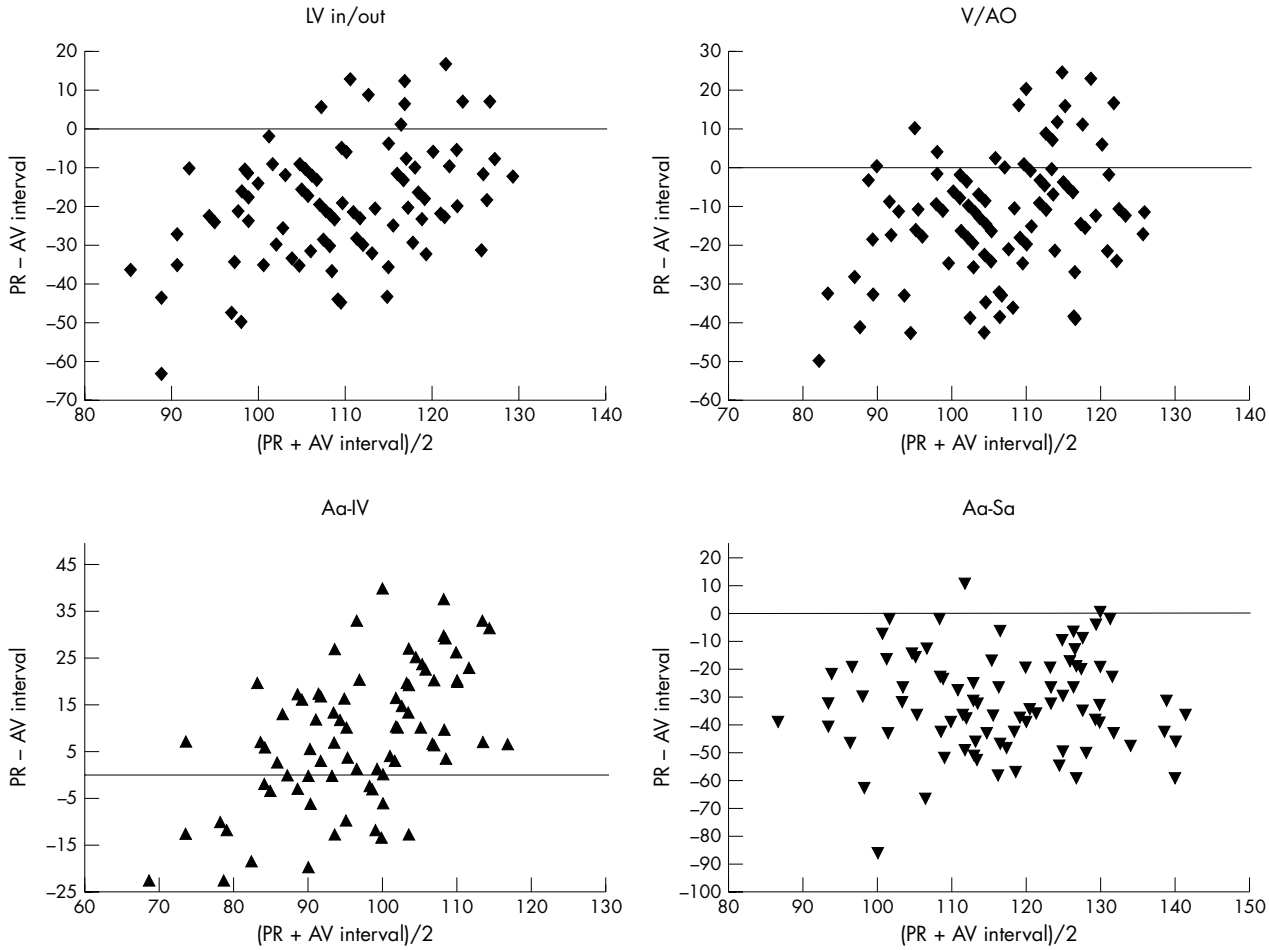

Figure 5 Bland–Altman plot of electrical and mechanical atrioventricular (AV) time intervals. Aa, atrial contraction; IV, isovolumic contraction; LV in/out, left ventricular inflow/outflow pulse Doppler method; PR, PR interval from fetal ECG; Sa, ventricular systole; V/AO, superior vena cava/aorta pulse Doppler method.

cava was exclusively used for the V/AO recordings. Pressure pulse propagates at a speed of 2.6–3.4 m/s in the aorta of a human fetus,[28 29] whereas A wave reversal propagates at a velocity of 1.1 m/s in the vena cava, at least in fetal sheep.[30] Assuming that the central venous pulse-wave propagation speed is similar in the human fetus, the temporal AV relationship between the aorta and central vein should shorten by a 5–6 ms/cm distance from the heart. Thus, the time difference between innominate vein and distal superior vena cava measurements is to become more important with increasing fetal size and age. Interestingly, despite this potential study limitation, the linear correlations of AV interval with gestational age were almost identical in our study and that of Andelfinger *et al*[8] for V/AO ($y = 0.7x + 94.1$; $y = 0.78x + 94.4$), whereas our in/out PD-derived AV intervals ($y = 0.6x + 103$; $y = 0.44x + 104$) differed, on average, by −2 ms at 20 weeks and by 10 ms at 40 weeks of gestation.

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Competing interests: None declared.

The study was approved by the Research Ethics Board of The Hospital for Sick Children, and written informed consent was obtained from each participating woman.

REFERENCES

1 **Saleeb S**, Copel J, Friedman D, *et al*. Comparison of treatment with fluorinated glucocorticoids to the natural history of autoantibody-associated congenital heart block: retrospective review of the research registry for neonatal lupus. *Arthritis Rheum* 1999;**42**:2335–45.
2 **Raboisson MJ**, Fouron JC, Sonesson SE, *et al*. Fetal Doppler echocardiographic diagnosis and successful steroid therapy of Luciani-Wenckebach phenomenon and endocardial fibroelastosis related to maternal anti-Ro and anti-La antibodies. *J Am Soc Echocardiogr* 2005;**18**:375–80.
3 **Stinstra J**, Golbach E, van Leeuwen P, *et al*. Multicentre study of fetal cardiac time intervals using magnetocardiography. *BJOG* 2002;**109**:1235–43.
4 **Wakai RT**, Strasburger JF, Li Z, *et al*. Magnetocardiographic rhythm patterns at initiation and termination of fetal supraventricular tachycardia. *Circulation* 2003;**107**:307–12.
5 **Taylor MJ**, Smith MJ, Thomas M, *et al*. Non-invasive fetal electrocardiography in singleton and multiple pregnancies. *BJOG* 2003;**110**:668–78.
6 **Fouron JC**, Proulx F, Miro J, *et al*. Doppler and M-mode ultrasonography to time fetal atrial and ventricular contractions. *Obstet Gynecol* 2000;**96**:732–6.
7 **Rosenthal D**, Friedman DM, Buyon J, *et al*. Validation of the Doppler PR interval in the fetus. *J Am Soc Echocardiogr* 2002;**15**:1029–30.
8 **Andelfinger G**, Fouron JC, Sonesson SE, *et al*. Reference values for time intervals between atrial and ventricular contractions of the fetal heart measured by two Doppler techniques. *Am J Cardiol* 2001;**88**:1433–6.
9 **Glickstein JS**, Buyon J, Friedman D. Pulsed Doppler echocardiographic assessment of the fetal PR interval. *Am J Cardiol* 2000;**86**:236–9.
10 **Sonesson SE**, Salomonsson S, Jacobsson LA, *et al*. Signs of first-degree heart block occur in one-third of fetuses of pregnant women with anti-SSA/Ro 52-kd antibodies. *Arthritis Rheum* 2004;**50**:1253–61.

11 **Van Bergen AH**, Cuneo BF, Davis N. Prospective echocardiographic evaluation of atrioventricular conduction in fetuses with maternal Sjogren's antibodies. *Am J Obstet Gynecol* 2004;**191**:1014–8.
12 **Weissler AM**. Current concepts in cardiology. Systolic-time intervals. *N Engl J Med* 1977;**296**:321–4.
13 **Kettunen R**, Timisjarvi J, Kouvalainen E, *et al*. Electromechanical delay in the intact dog heart. *Int J Cardiol* 1985;**9**:161–71.
14 **Nii M**, Shimizu M, Roman KS, *et al*. Doppler tissue imaging in the assessment of atrioventricular conduction time: validation of a novel technique and comparison with electrophysiologic and pulsed wave Doppler-derived equivalents in an animal model. *J Am Soc Echocardiogr* 2006;**19**:314–21.
15 **Sohn DW**, Chai IH, Lee DJ, *et al*. Assessment of mitral annulus velocity by Doppler tissue imaging in the evaluation of left ventricular diastolic function. *J Am Coll Cardiol* 1997;**30**:474–80.
16 **Vogel M**, Schmidt MR, Kristiansen SB, *et al*. Validation of myocardial acceleration during isovolumic contraction as a novel noninvasive index of right ventricular contractility: comparison with ventricular pressure-volume relations in an animal model. *Circulation* 2002;**105**:1693–9.
17 **Isaaz K**, Thompson A, Ethevenot G, *et al*. Doppler echocardiographic measurement of low velocity wall motion of the left ventricular posterior wall. *Am J Cardiol* 1989;**64**:66–75.
18 **Cremer M**. Uber die direkte Ableitung der Aktionsstrome des menschlichen Herzens vom Oesophagus and uber das Elektrokardiogramm des Foetus. *Münch Med Wochenschr* 1906;**53**:811–3.
19 **Bland JM**, Altman DG. Statistical methods for assessing agreement between two methods of clinical measurement. *Lancet* 1986;**847**:307–10.
20 **Rein AJ**, Mevorach D, Perles Z, *et al*. Fetal first-degree heart block, or where to set the confidence limit: comment on the article by Sonesson *et al*. *Arthritis Rheum* 2005;**52**:366–8.
21 **Buyon JP**, Askanase AD, Kim MY, *et al*. Identifying an early marker for congenital heart block: when is a long PR interval too long? Comment on the article by Sonesson *et al*. *Arthritis Rheum* 2004;**50**:1253–61.
22 **Abboud S**, Barkai G, Mashiach S, *et al*. Quantification of the fetal electrocardiogram using averaging technique. *Comput Biol Med* 1990;**20**:147–55.
23 **Peters M**, Crowe J, Pieri JF, *et al*. Monitoring the fetal heart non-invasively: a review of methods. *J Perinat Med* 2001;**29**:408–16.
24 **Chia EL**, Ho TF, Rauff M, *et al*. Cardiac time intervals of normal fetuses using noninvasive fetal electrocardiography. *Prenat Diagn* 2005;**25**:546–55.
25 **Jaeggi ET**, Silverman ED, Yoo SJ, *et al*. Is immune-mediated complete fetal atrioventricular block reversible by transplacental dexamethasone therapy? *Ultrasound Obstet Gynecol* 2004;**23**:602–5.
26 **Rein AJJT**, O'Donnell CP, Colan SD, *et al*. Tissue velocity Doppler assessment of atrial and ventricular electromechanical coupling and atrioventricular time intervals in normal subjects. *Am J Cardiol* 2003;**92**:1347–50.
27 **Wheeler T**, Murrills A. Patterns of fetal heart rate during normal pregnancy. *Br J Obstet Gynaecol* 1978;**85**:18–27.
28 **Struijk PC**, Wladimiroff JW, Hop WCJ, *et al*. Pulse pressure assessment in the human fetal descending aorta. *Ultrasound Med Biol* 1992;**18**:39–43.
29 **Hu J**, Nijhuis IJM, ten Hof J, *et al*. Dependence of aortic pulse wave assessments on behavioural state in normal term fetus. *Early Hum Dev* 1997;**48**:59–70.
30 **Schroder HJ**, Tchirikov M, Rybakowski C. Pressure pulses and flow velocities in central veins of the anesthetized sheep fetus. *Am J Physiol Heart Circ Physiol* 2003;**284**:H1205–11.

IMAGES IN CARDIOLOGY

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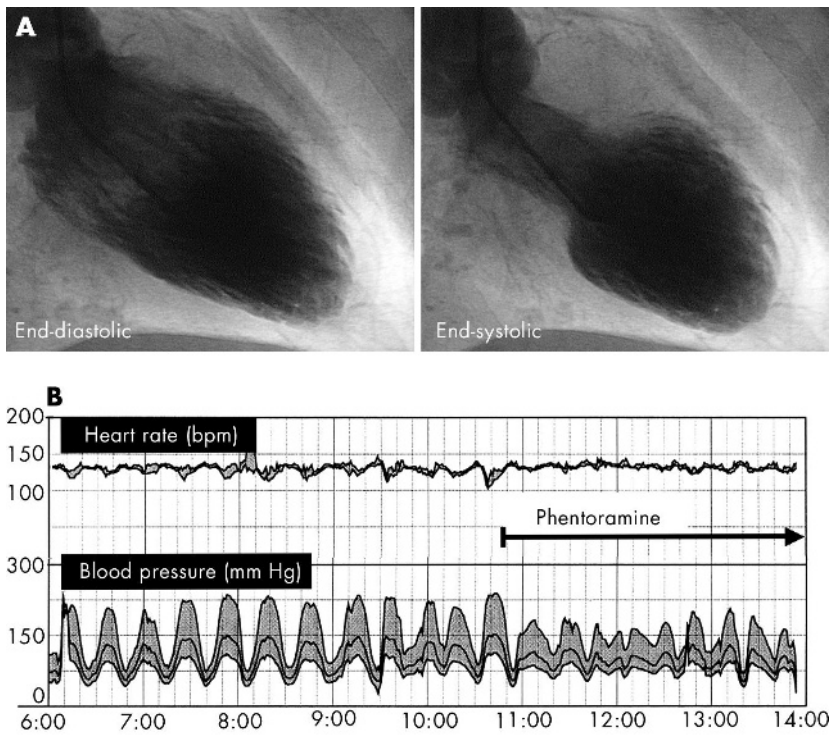
Periodic fluctuation of blood pressure and transient left ventricular apical ballooning in pheochromocytoma

A 63-year-old woman with a history of hypertension was presented to our emergency department because of substernal chest pain and ST segment elevation in 12 lead ECG. On presentation, troponin T was positive and an echocardiogram showed a pronounced left ventricular (LV) apical asynergy. We suspected acute coronary syndrome, and an emergent cardiac catheterisation was performed. However, the coronary angiography revealed no obstructive coronary lesion, and left ventriculography demonstrated akinesia of the mid-to-distal portion of the LV chamber—that is, ''apical ballooning'' (panel A). After admission to the intensive care unit, her haemodynamics were subsequently unstable. The direct blood pressure monitoring showed cyclic change at 20 minute intervals. Therefore, we started treatment with continuous intravenous phentoramine. Just after administration of this infusion, the periodic fluctuation of blood pressure diminished effectively (panel B). The plasma catecholamine values were high, and 24-hour urine collection for catecholamines also showed notably high values, such as an epinephrine (adrenaline) concentration of 7020 μg (normal < 30 μg/day). Further examination with an abdominal computed tomographic (CT) scan identified a left adrenal mass, and iodine-123-metaiodobenzylguanidine scintigram showed an uptake in the corresponding region. Consequently, the patient was diagnosed with pheochromocytoma. After the medical management with α and β adrenergic blockade for two weeks, her blood pressure stabilised. Interestingly, a repeat echocardiogram showed the LV wall motion reverting to normal. Conclusively, the transient LV apical ballooning was thought to be caused by the pheochromocytoma crisis. Thereafter the patient underwent a left adrenalectomy uneventfully.



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