Magnetophysiologic and echocardiographic comparison of blocked atrial bigeminy and 2:1 atrioventricular block in the fetus

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BACKGROUND Blocked atrial bigeminy (BAB) and second-degree atrioventricular block with 2:1 conduction block (2:1 AVB) both present as ventricular bradycardia and can be difficult to distinguish by echocardiography. Since the prognosis and clinical management of these rhythms are different, an accurate diagnosis is essential.

OBJECTIVE To identify magnetic and mechanical heart rate and rhythm parameters that could reliably distinguish BAB from 2:1 AVB.

METHODS A retrospective study of ten BAB and seven 2:1 AVB subjects was performed, using fMCG and pulsed Doppler ultrasound.

RESULTS Distinguishing BAB from 2:1 AVB by using fMCG was relatively straightforward because in BAB the ectopic P wave (P′) occurred early, resulting in a bigeminal (short-long) atrial rhythm. The normalized coupling interval of the ectopic beat (PP′ of the blocked beat to PP of the conducted beat) was 0.29 ± 0.03. In contrast, the echocardiographic assessment of inflow-outflow gave a normalized mechanical coupling interval (AA′/AA) near 0.5, which made it difficult to distinguish BAB from 2:1 AVB. Heart rate distinguished most subjects with BAB from those with 2:1 AVB (82 ± 5.7 beats/min vs 69 ± 4.2 beats/min), but was not a completely reliable indicator. In most subjects, BAB alternated with sinus rhythm or other rhythms, resulting in complex heart rate and rhythm patterns.

CONCLUSIONS Fetal BAB and 2:1 AV block can be difficult to distinguish using echocardiography because in many fetuses with BAB the mechanical rhythm does not accurately reflect the magnetic rhythm. fMCG provides a more reliable means of making a differential diagnosis.

KEYWORDS Fetal magnetocardiography; Bigeminy; Atrioventricular block; Blocked atrial bigeminy; Fetal arrhythmia

ABBREVIATIONS 2:1 AVB = 2-to-1 atrioventricular block; **AA** = interval between A waves of consecutive sinus beats; **AA′** = interval from the A wave of the sinus beat to the A wave of the premature beat; **AV** = atrioventricular; **AVB** = atrioventricular block; **BAB** = blocked atrial bigeminy; **BAC** = blocked atrial couplet; **FHR** = fetal heart rate; **fMCG** = fetal magnetocardiography; **PP** = interval between P waves of consecutive sinus beats; **PP′** = interval from the P wave of the sinus beat to the P wave of the premature beat; **PAC** = premature atrial contraction; **QTc** = corrected QT interval; **SVT** = supraventricular tachycardia; **VSA** = ventriculophasic sinus arrhythmia

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Introduction

Blocked atrial bigeminy (BAB) and second-degree atrioventricular block with 2:1 conduction block (2:1 AVB) are among the most common forms of bradycardia in the fetus. BAB results from premature atrial contractions (PACs) that are blocked at the atrioventricular (AV) node and reset the sinoatrial node. Although the PACs can come from an automatic focus, it is believed that the vast majority of cases of fetal BAB are due to an accessory connection that gives rise to reentrant PACs. 2:1 AVB results from the block of every other sinus beats and shows a regular atrial rhythm. The prognosis and the clinical management of BAB and 2:1 AVB differ markedly. BAB spontaneously resolves in the vast majority of fetuses without treatment and warrants only diligent rhythm surveillance. On the other hand, 2:1 AVB signifies either ongoing immune-mediated damage from maternal anti-Ro antibodies, a cardiac channelopathy, congenital heart disease, or long QT syndrome. Rarely, it is

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idiopathic or acquired due to drugs or disease. In utero treatment with fluorinated steroids may halt the progression of immune-mediated second-degree AVB to complete AVB,[1] and lidocaine/magnesium can restore sinus rhythm in fetal long QT syndrome.[2]

Although the mechanisms of these 2 rhythms are different, distinguishing between them by using fetal echocardiography is not always straightforward. Sonesson[3] reported that there was a high degree of resemblance during mid-gestation, which is the peak time when differentiation of the 2 rhythms would be most critical to the clinician, given the disparate therapies and clinical follow-up.

Recently, fetal magnetocardiography (fMCG), a non-invasive electrophysiological technique, has been shown to be highly effective for detecting fetal arrhythmias.[4–7] Like fetal electrocardiography, fMCG directly records rhythm but it also exhibits a much higher signal-to-noise ratio, allowing fetuses as early as 20 weeks' gestation to be evaluated with a high success rate. While a number of studies of fetal AVB have been published recently[8,9] there is a paucity of studies of fetal BAB. In this study, we used fMCG to evaluate the characteristics of BAB and 2:1 AVB for the purpose of improving the accuracy of differential diagnosis.[10]

Methods

fMCG

We searched our fMCG database for subjects referred with fetal bradycardia by echocardiogram or auscultation. We found 10 fetuses with BAB and 7 with 2:1 AVB, which were studied between 2002 and 2012. Three of the fetuses with BAB were thought to have 2:1 AVB at the time of referral. The gestational ages ranged from 21 to 29.3 weeks for the subjects with BAB (Table 1) and from 25 to 37.2 weeks for the subjects with 2:1 AVB (Table 2). Of the 7 cases of 2:1 AVB, 6 were associated with maternal SSA/SSB antibodies and 1 was associated with structural disease. The institutional review board approved the experimental protocol, and informed consent was obtained from each participant.

A 37-channel axial gradiometer (Magnes, 4D Neuroimaging, Inc, San Diego, CA) or a 21-channel (Tristan Technologies, San Diego, CA) vector gradiometer was used to record the fMCG. Several 10-minute recordings were taken from each subject in a magnetically shielded room.

The fMCG was recorded in a 0.1–200 Hz passband and was sampled at 520 Hz. A digital filter was applied to further band limit the signals to 1.0–80 Hz. Spatial filtering was used to remove maternal interference from the fMCG recordings.[11] The fetal heart rate (FHR) was computed from the RR intervals, and the fMCG averaged waveforms were computed by averaging 20–50 consecutive beats.

The interval between the conducted and the blocked P waves (PP′) was measured in each subject. In BAB, P′ is due to a PAC. In 2:1 AVB, P′ is due to a blocked sinus beat (Figure 1). The baseline FHR was measured during quiescence when the FHR tracing was relatively flat. The QT intervals were measured from the onset of the QRS complex

Table 1 Characterization of blocked atrial bigeminy subjects using fMCG

fMCG										Echo/Doppler	
Fetus #	GA (weeks)	FHR (beats/min)	Conducted PACs	PP′ during conducted PACs (ms)	PP′(ms)	PP′/PP ratios	QTc during BAB (ms)	Other rhythms	%BAB	AA′(ms)	AA′/AA (ratio)
1	21	81	No	–	214	0.29	460	–	95	400	0.42
2	23.4	85	No	–	199	0.29	502	BAC	98	–	–
3	24.2	71	Yes	NM	225	0.27	418	BAT,BAC	<1	–	–
4	24.3	79	Yes	257	224	0.29	495	–	30	360	0.45
5	25	86	Yes	242	219	0.29	519	SVT	50	400	0.51
6	26	91	No	–	154	0.23	477	–	99	374	0.47
7	27	78	No	–	196	0.25	542	–	93	400	0.44
8	28.5	87	No	–	232	0.34	528	BAT	50	–	–
9	29	85	No	–	204	0.29	502	BAT	88	400	0.50
10	29.3	79	Yes	300	227	0.30	491	WPW	45	360	0.47
Average	26 ± 3	82 ± 5.7	–	249 ± 30	209 ± 23	0.29 ± 0.03	493 ± 35.6	–	–	384 ± 18.3	0.47 ± 0.03

AA = the interval between two consecutive mechanical atrial contractions; AA′ = interval from A-wave of sinus beat to A-wave of premature beat; %BAB = percent time in blocked atrial bigeminy; BAC = blocked atrial couplets; BAT = blocked atrial trigeminy; FHR = fetal heart rate; GA = gestational age; NM = not measurable normal conducted PACs; PACs = premature atrial contractions; PP′ = interval from P-wave of sinus beat to P-wave of premature beat; QTc= corrected QT interval; SVT = supraventricular tachycardia; WPW = Wolff Parkinson White syndrome. Fetus #7's ultrasound data was obtained three days before the fMCG session, and fetus #9's ultrasound data was obtained thirteen days after the fMCG session. For subject #10, the 300 ms measurement corresponds to PP′ for aberrantly conducted PACs. PP′ could not be measured for the normally conducted PACs.