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Fetal Tachycardia: Mechanisms and Predictors of Hydrops Fetalis

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Objectives. **This study had three objectives: 1) to determine the electrophysiologic mechanisms of fetal supraventricular tachycardia at presentation and postnatally; 2) to identify the clinical and electrophysiologic predictors of hydrops fetalis; and 3) to describe the medium-term follow-up (1 to 7 years) of patients with fetal supraventricular tachycardia.**

Background. **Fetal supraventricular tachycardia causes significant fetal and neonatal morbidity and mortality. Prenatal analysis and postnatal confirmation of fetal supraventricular tachycardia mechanisms have been limited.**

Methods. **Supraventricular tachycardia mechanisms were evaluated by prenatal Doppler/M-mode echocardiography, immediate neonatal surface electrocardiography and postnatal transesophageal electrophysiologic procedures in 30 consecutive patients presenting with fetal supraventricular tachycardia (17 managed prenatally, 13 first managed postnatally).**

Results. **The fetal supraventricular tachycardia mechanism was 1:1 atrioventricular conduction in 22 patients and supraventricular tachycardia with atrioventricular block (atrial flutter) in 8. At the postnatal transesophageal electrophysiologic procedure, tachycardia was induced in 27 of 30 patients; atrioventricular reentrant tachycardia in 25 (93%) of 27 and intraatrial reentrant tachycardia in only 2 (7%) of 27. Hydrops was present in 12 of 30 fetuses. Sustained supraventricular tachycardia (>12 h) and lower gestation at presentation correlated with hydrops ($p < 0.02$, $p < 0.05$), but mechanism of tachycardia and heart rate did not. Gestational age at delivery was significantly greater in those who received intrauterine management (39 ± 1.3 vs. 37 ± 2.9 weeks, $p = 0.04$) despite earlier presentation (32.6 vs. 37.1 weeks). Cesarean section deliveries were reduced in the same group (3 of 17 vs. 11 of 13, $p = 0.0006$).**

Conclusions. **Atrioventricular reentrant tachycardia was the predominant mechanism of supraventricular tachycardia in the fetus. There was a high association of supraventricular tachycardia with atrioventricular block in utero and accessory atrioventricular connections. Outcome at 1 to 7 years was excellent regardless of severity of illness at clinical presentation.**

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Fetal supraventricular tachycardia is rare and frequently leads to the development of hydrops fetalis (1–3). Despite previous studies showing successful intrauterine antiarrhythmic drug therapy for fetal tachycardia, there continues to be a high incidence of premature delivery, neonatal morbidity and mortality associated with this diagnosis (4,5). Though choice of antiarrhythmic therapy is mechanism dependent (6), few studies provide electrophysiologic analysis of fetal tachycardia (7–10). Because supraventricular tachycardia mechanisms vary with age at presentation, the frequency of the various supraventricular tachycardia mechanisms may be different in the fetus (11). Of necessity, in utero mechanisms must be assessed by noninvasive means (1,8–11).

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The objectives of this study were 1) to determine electrophysiologic mechanisms of fetal supraventricular tachycardia at presentation and postnatally, 2) to identify the clinical and electrophysiologic predictors of hydrops fetalis, and 3) to describe the outcome at medium-term follow-up of patients with fetal supraventricular tachycardia.

Methods

Study cohort. The patient group consisted of 30 consecutive neonates with documented fetal supraventricular tachycardia (fetal heart rate >200 beats/min) evaluated at our institutions between January 1, 1987 and November 30, 1993. Seventeen patients were prenatal referrals (prenatal group) and were managed at a tertiary care center by a multidisciplinary obstetric and pediatric team. Thirteen patients were postnatal referrals (postnatal group) consisting of neonates with a known history of fetal tachycardia referred for postnatal management. The study included both hydropic and nonhydropic fetuses. Hydrops fetalis was defined by the presence of fluid accumulation in two body cavities (fetal ascites, skin edema or pericardial or pleural effusions. Clinical course was

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reviewed from prenatal and postnatal records to determine the gestational age at onset of fetal tachycardia, presence of fetal hydrops, incidence of intrauterine antiarrhythmic treatment, mode of delivery, perinatal outcome and postnatal course. All patients had undergone a transesophageal electrophysiologic procedure and at least 1 year of clinical follow-up.

Mechanisms of supraventricular tachycardia (prenatal vs. postnatal). Prenatal fetal echocardiograms, noninvasive electronic fetal heart rate monitoring, neonatal electrocardiogram during tachycardia and postnatal transesophageal pacing procedures were reviewed to define the mechanism of tachycardia. In the postnatal group (n = 13), the mechanism of fetal tachycardia was deduced from surface electrocardiograms obtained within 24 h after emergent delivery for the indication of persistent fetal tachycardia.

Based on prenatal and immediate postnatal characteristics, patients were divided into two groups: supraventricular tachycardia with 1:1 atrioventricular conduction and supraventricular tachycardia with atrioventricular block. Supraventricular tachycardia with 1:1 atrioventricular conduction was diagnosed prenatally by the presence of a 1:1 atrioventricular contraction sequence during tachycardia, abrupt onset and terminations and minimal heart rate variability. Supraventricular tachycardia with block was diagnosed prenatally by the presence of atrioventricular block during tachycardia on Doppler flow analysis in the systemic veins, foramen ovale, and ventricular inflow/outflow regions as well as by direct observation of atrial wall contraction and stable atrial cycle length (7,8). Postnatal 12-lead electrocardiograms were obtained within 24 h of delivery, and mechanism was assigned as supraventricular tachycardia with 1:1 atrioventricular conduction or supraventricular tachycardia with variable atrioventricular block (atrial flutter).

Postnatally, supraventricular tachycardia was further divided into three major mechanisms by electrophysiologic criteria. 1) Atrioventricular reentrant tachycardia was defined as supraventricular tachycardia with 1:1 atrioventricular relationship and a ventriculoatrial interval during transesophageal pacing-induced tachycardia of >70 ms* (11). Localization of accessory connections was determined by prolongation of tachycardia cycle length and ventriculoatrial interval during ipsilateral bundle branch block (11). 2) Atrioventricular nodal reentrant tachycardia had a ventriculoatrial interval <70 ms at transesophageal procedure with exclusion of evidence of an accessory connection (11). 3) Intraatrial reentrant tachycardia was defined by presence of atrioventricular block during supraventricular tachycardia and pace initiation and termination of atrial tachycardia.

Postnatal transesophageal electrophysiologic procedure records were reviewed for age at procedure, interval from in utero presentation to transesophageal pacing procedure, inducibility, mechanism and atrial and ventricular cycle lengths of supraventricular tachycardia. The extrastimulus testing protocol has been described (11). Median age at transesophageal pacing procedure was 1 week. Mean interval from onset of fetal supraventricular tachycardia to transesophageal pacing procedure was 5 weeks (range <1 to 20.5 weeks).

Intrauterine treatment. Only fetuses with hydrops fetalis or chronic fetal tachycardia with associated ventricular dysfunction received intrauterine treatment. Transplacental treatment was initially employed. In cases of advanced hydrops fetalis, abnormal biophysical profile or multiple drug failure, direct intramuscular fetal therapy with digoxin was employed. Cordocentesis was not routinely used. Treatment strategy was identical for supraventricular tachycardia with and without atrioventricular block. Protocol included the initial use of digoxin, followed by addition of quinidine or verapamil. If ineffective, second-line drugs were discontinued, and amiodarone was initiated, followed by drug combinations utilizing amiodarone.

Hydrops and tachycardia characteristics. Mechanism, duration and cycle length of tachycardia were assessed in correlation with hydrops fetalis. "Sustained" fetal supraventricular tachycardia (at initial assessment) was defined as prolonged uninterrupted tachycardia of >12-h duration. Tachycardia with intermittent sinus rhythm was defined as "nonsustained."

Postnatal course. Postnatal records were reviewed to determine postnatal antiarrhythmic treatment, neonatal complications, spontaneous tachycardia recurrences, clinical outcome and intermediate term follow-up. Supraventricular tachycardia was considered "clinically quiescent" if >6 months had elapsed with no episodes of supraventricular tachycardia.

Data analysis. To correlate cycle length of clinical tachycardia prenatally and at the transesophageal pacing procedure, the paired *t* test and regression analysis were used. To determine differences in atrial or ventricular cycle lengths in the hydropic and nonhydropic groups, the unpaired *t* test assuming unequal variance was used. Differences in gestation at fetal presentation and at delivery for patients in the prenatal and postnatal management groups were determined using the unpaired *t* test. Logistic regression was performed to determine whether gestation at presentation, mechanism of tachycardia, cycle length or duration of tachycardia in utero correlated independently with hydrops fetalis. The Fisher exact test was used to determine whether tertiary care management of the fetus influenced the incidence of intrauterine treatment, mode of delivery, and resolution of tachycardia in the prenatally and postnatally managed groups or hydropic and nonhydropic groups.

Results

Patient groups. The mean gestational age at presentation of the prenatal group was 32.6 ± 1.3 weeks, and that of the postnatal group 37.1 ± 3.0 weeks (p = 0.008). The youngest fetus was 19.5 weeks at presentation. All patients had normal cardiac anatomy.

*This definition does not exclude the diagnosis of slow, slow atrioventricular node reentry tachycardia in patients in whom pre-excitation was not apparent; however, the rarity of atrioventricular node reentry tachycardia in this age group is emphasized.

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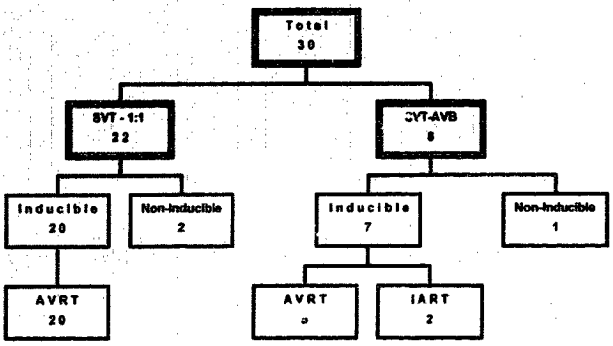

Figure 1. The mechanisms of prenatal fetal supraventricular tachycardia based on prenatal and postnatal transesophageal electrophysiologic evaluation in 30 patients are shown. AVRT = atrioventricular reciprocating tachycardia; IART = intraatrial reentrant tachycardia; SVT-AVB = prenatal supraventricular tachycardia with atrioventricular block; SVT-1:1 = prenatal supraventricular tachycardia with 1:1 atrioventricular conduction; **bold borders** = prenatal diagnosis; **light borders** = postnatal diagnosis.

Mechanisms of supraventricular tachycardia (prenatal and postnatal). Figure 1 depicts the prenatal and postnatal tachycardia mechanisms based on echocardiographic, electrocardiographic and transesophageal electrophysiologic assessment. The predominant mechanism was supraventricular tachycardia with 1:1 atrioventricular conduction. Of 30 patients, 22 (73%) had supraventricular tachycardia with 1:1 conduction (13 by echocardiography and 9 by electrocardiography), and 8 (27%) of 30 had supraventricular tachycardia with block (4 by echocardiographic and 4 by electrocardiographic criteria). Twenty-seven of 30 patients had inducible supraventricular tachycardia at the transesophageal pacing procedure; 3 were noninducible. Prenatal and postnatal tachycardia mechanisms were concordant in all atrioventricular reciprocating tachycardia (20 of 20) patients and in 2 (2 of 7) patients with intraatrial reentrant tachycardia. The remaining five patients with supraventricular tachycardia and atrioventricular block had atrioventricular reciprocating tachycardia at postnatal transesophageal pacing procedure. Prenatal and postnatal atrioventricular reciprocating tachycardia cycle lengths were 240 ± 35 and 230 ± 30 ms, respectively ($r = 0.78$, $p < 0.005$). In 19 patients with atrioventricular reciprocating tachycardia, accessory connection localization by transesophageal pacing procedure found accessory connections to be left-sided in 16 and right-sided in 3. Pre-excitation was present on surface electrocardiogram within the first year in 8 of 30 patients. No patients had atrioventricular node reentrant tachycardia.

In the three patients with noninducible supraventricular tachycardia, the intervals from presentation to transesophageal pacing procedure were 5 days, 11 days and 9 weeks. One of these three had clinical recurrence of atrioventricular reciprocating tachycardia within 2 weeks.

Clinical characteristics associated with hydrops. Twelve of 30 patients were hydropic (9 in the prenatal group, 3 in the postnatal group). The mean gestational age at presentation in the hydropic fetuses was 33 ± 1 week and was significantly lower than the mean of 38 ± 1 week for the nonhydropic fetuses ($p < 0.001$). The duration of tachycardia was "sustained" (>12 h) in 23 and nonsustained in 7 fetuses. Of fetuses with sustained tachycardia, 12 of 23 were hydropic compared to 0 of 7 fetuses without sustained tachycardia. There was no significant difference in the distribution of prenatal mechanisms between the hydropic and nonhydropic fetuses. In the atrioventricular reciprocating tachycardia group with hydrops fetalis ($n = 9$), the mean prenatal tachycardia cycle length was 240 ± 30 ms compared with 253 ± 32 ms in the nonhydropic atrioventricular reciprocating tachycardia group ($n = 13$, $p = 0.17$). Hydrops resolved after therapy in all nine patients. Logistic regression performed on clinical and electrophysiologic variables suggested that gestational age at presentation ($p = 0.05$) and duration of tachycardia ($p = 0.02$) correlated independently with presence of fetal hydrops, but mechanism and ventricular cycle length of tachycardia did not.

Perinatal outcome. No mortality was encountered in either the prenatal or postnatal group. The mean gestational age at delivery in the prenatal group was 39.2 ± 1.3 weeks, compared to the mean gestational age at delivery in the postnatal group of 37.3 ± 2.9 weeks ($p = 0.04$). All 13 patients in the postnatal group were delivered emergently for the indication of fetal tachycardia, 11 by cesarean section, as opposed to 3 of 17 cesarean section deliveries in the prenatal group ($p = 0.0006$), all 3 for obstetric indications other than fetal tachycardia. Eleven of 17 (prenatal group) and 2 of 13 (postnatal group) patients received intrauterine treatment ($p = 0.01$). Two complications of prenatal treatment occurred: amiodarone-related reversible thyroid dysfunction and intramuscular digoxin-related superficial fetal laceration. In the postnatal group, 2 of 13 had morbidity related to prematurity, and 1 experienced an out-of-hospital cardiac arrest at 10 days of age while receiving empiric digoxin therapy before our evaluation.

Postnatal course. Postnatal follow-up ranged from 1.0 to 7.25 years (mean 3.6 years). Twenty-three patients had clinical resolution of tachycardia by 1 year of age. There was no significant difference in resolution of tachycardia between fetuses with and without hydrops fetalis. Patients with noninducible supraventricular tachycardia at the transesophageal pacing procedure, supraventricular tachycardia difficult to initiate in the baseline state and nonsustained clinical episodes of

supraventricular tachycardia were not given prophylactic antiarrhythmic treatment. With these criteria, 15 of 30 patients with fetal tachycardia avoided neonatal drug therapy, including 5 of 30 neonates with documented rare episodes of postnatal tachycardia. Of the 13 patients treated in utero, only 5 received neonatal therapy. In 12 (52%) of 23 patients with clinical resolution by 1 year, follow-up extended beyond 3 years. One patient had late recurrence of atrioventricular reciprocating tachycardia after a tachycardia-free interval of 6 years.

Discussion

The major finding of this study was that atrioventricular reciprocating tachycardia was the predominant mechanism of supraventricular tachycardia in the fetus. Supraventricular tachycardia with atrioventricular block in utero was associated with accessory atrioventricular connections in five of eight patients. Hydrops fetalis was more likely in those with longer supraventricular tachycardia duration and earlier gestational age presentation but did not relate to supraventricular tachycardia mechanism or ventricular cycle length. Intrauterine therapy decreased perinatal morbidity. Transesophageal pacing allowed either no treatment or early discontinuation of antiarrhythmic treatment in 15 of 30 patients. The medium-term outcome was excellent in both hydropic and nonhydropic fetuses with supraventricular tachycardia.

Predictors of hydrops fetalis. Previous studies have attempted to assess the factors correlating with the development of congestive heart failure in the fetus but have come to different conclusions. Valerius and Jacobsen (12) reported increased incidence of hydrops fetalis with rates of supraventricular tachycardia greater than 230 beats/min; however, Newburger and Keane (13) reported that neither the duration nor the heart rate was predictive of clinical status at birth. Levkoff (14) reported that prolonged fetal tachycardia, even of several months' duration, did not adversely affect the fetus. Zales et al. (15) demonstrated that neonates with prenatal hydrops fetalis secondary to supraventricular tachycardia appeared to develop heart failure from multiple episodes recurring at relatively slow heart rates, whereas postnatal heart failure secondary to supraventricular tachycardia was caused by sustained episodes with relatively fast heart rates (15). The results of our study are in agreement with those of Maxwell et al. (4), who demonstrated no correlation between heart rate (ventricular rate) or mechanism of fetal supraventricular tachycardia and hydrops fetalis. But we also found a significant positive correlation of hydrops to "sustained" duration of supraventricular tachycardia. Conversely, the absence of sustained supraventricular tachycardia was uniformly correlated with absence of hydrops fetalis. We speculate that nonsustained brief episodes may not require intrauterine treatment. Prospective controlled studies to further define this approach are needed.

Association of accessory connections with atrial reentrant tachycardia. Atrioventricular reentrant tachycardia was the predominant mechanism of supraventricular tachycardia in the fetus. It was present in 25 of 27 patients with inducible supraventricular tachycardia. Five of seven patients with supraventricular tachycardia and atrioventricular block had accessory atrioventricular connections. The association between atrial flutter and accessory atrioventricular connections has previously been observed (16–18). It has been shown that simultaneous ventriculoatrial contraction, atrial distension and functional atrioventricular valve incompetence from annular enlargement occur during atrioventricular reciprocating tachycardia (3,19). We speculate that this may predispose the fetal or neonatal atrium to the development of intraatrial reentrant tachycardia and that the immature myocardium may be uniquely susceptible to this phenomenon.

Fetal versus neonatal tachycardia. Electrophysiologic and clinical features suggested a high degree of similarity between fetal and neonatal tachycardia. These features included high incidence of atrioventricular reciprocating tachycardia, clinical resolution of supraventricular tachycardia episodes in 77% of patients by 1 year of age, presence of preexcitation in 26% of patients, high incidence of left-sided accessory connections and evidence of late spontaneous recurrences (20–22).

Prenatal interventions. We found a high incidence of premature interruption of pregnancy related to fetal tachycardia in the population of patients near term and managed outside tertiary care facilities. Although prompt referral for evaluation and treatment at tertiary centers has been routine for the immature hydropic fetus with tachycardia, referral and prenatal management of the term or near-term fetus has not been strongly advocated. In this study, prenatal consultation resulted in a decrease in both premature and cesarean section delivery.

Study limitations. This study was limited by its retrospective nature. There are many sources of selection bias that make the prenatally referred group and the postnatally referred group not strictly comparable.

Conclusions. Atrioventricular reciprocating tachycardia, primarily utilizing a concealed left-sided accessory connection, was the predominant mechanism of fetal tachycardia based on postnatal electrocardiographic interpretation and transesophageal pacing procedure. Supraventricular tachycardia with block (atrial flutter) in the fetus was highly associated with atrioventricular accessory connections. Although duration of sustained tachycardia and gestation at tachycardia onset were associated with hydrops fetalis, ventricular cycle length and mechanisms of tachycardia were not. Tertiary care management, including intrauterine drug therapy, appeared to decrease morbidity related to hydrop fetalis, prematurity and cesarean section delivery.

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