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Original Article / Özgün Makale

Evaluation of pre- and postoperative corrected QT dispersion predicting the development of arrhythmias in children undergoing congenital heart surgery

Doğuştan kalp cerrahisi yapılan çocuklarda aritmi gelişiminin öngörüsünde ameliyat öncesi ve sonrası düzeltilmiş QT dispersiyonunun değerlendirilmesi

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Background: The aim of this study was to evaluate pre- and postoperative QTc dispersion variability in children undergoing congenital cardiac surgery.

Methods: Between October 2006 and March 2011, 279 consecutive patients (144 females, 135 males; mean age 56.6±5.0 months; range 15 days to 17 years) who met initial inclusion criteria and underwent congenital cardiac surgery were included. QTc dispersion measurements were calculated based on the standard 12-lead resting electrocardiograms of the patients in the preoperative (one month) and postoperative (one week) period.

Results: In 75.9% of all patients with cardiac surgery, postoperative QTc dispersion was statistically higher from preoperative QTc dispersion (p<0.001). Ventricular septal defect (VSD) (36.9%) and secundum atrial septal defect (ASD) (18.2%) were the most common congenital heart diseases in the study population. Repair of VSD, atrioventricular septal defect, tetralogy of Fallot, (TOF) and secundum ASD were the major risk factors for increased QTc dispersion. However, no statistical difference was found between pre- and postoperative QTc dispersion in children who underwent repair of VSD and pulmonary stenosis, end-to-end anastomosis of aorta for coarctation, patent ductus arteriosus ligation and division, pulmonary banding, and Glenn procedure. The occurrence of arrhythmia in prolonged QTc dispersions according to the type of cardiac surgery was statistically higher from those without prolonged QTc dispersion.

Conclusion: QTc dispersion measurement is a useful noninvasive electrocardiographic test in the evaluation of arrhythmias. The study results suggest that use of QTc dispersion in the postoperative period may be helpful in the prediction of the development of arrhythmias.

Key words: Cardiac arrhythmias; children; congenital heart surgery; QTc dispersion.

Amaç: Çalışmada doğuştan kalp cerrahisi yapılan çocuklarda ameliyat öncesi ve sonrası QTc dispersiyonu değişkenliği değerlendirildi.

Çalışma planı: Ekim 2006 - Mart 2011 tarihleri arasında doğuştan kalp cerrahisi yapılan ve ilk dahil edilme kriterlerini karşılayan ardışık 279 hasta (144 kadın, 135 erkek; ort. yaş 56.6±5.0 ay; dağılım 15 gün-17 yaş) çalışmaya alındı. QTc dispersiyon ölçümleri, hastalardan ameliyat öncesi (bir ay) ve ameliyat sonrası (bir hafta) dönemde elde edilen standart 12 derivasyonlu istirahat elektrokardiyogramlarından hesaplandı.

Bulgular: Kardiyak cerrahi yapılan tüm hastaların %75.9'unda QTc dispersiyonu, ameliyat sonrası ameliyat öncesinden istatistiksel olarak yüksek bulundu (p<0.001). Çalışma grubunda en sık tespit edilen doğuştan kalp hastalıkları ventriküler septal defekt (VSD) (%36.9) ve sekundum atriyal septal defekt (ASD) (%18.2) idi. Ventriküler septal defekt, atriyoventriküler septal defekt, Fallot tetrolojisi (TOF) ve sekundum ASD onarımları QTc dispersiyonundaki artış için majör risk faktörleriydi. Ancak, VSD ile pulmoner stenoz onarımı, koarktasyonda aortun uç uca anostomozu, patent duktus arteriozus ligasyonu ve divizyonu, pulmoner bant ve Glenn prosedürü yapılan çocuklarda ameliyat öncesi ve sonrası QTc dispersiyonları arasında istatistiksel fark bulunmadı. Yapılan kardiyak ameliyatın tipine göre ortaya çıkan aritmiler, uzun QTc dispersiyonu olan grupta, olmayanlara kıyasla, istatistiksel olarak yüksekti.

Sonuç: QTc dispersiyonu ölçümü aritmilerin araştırılmasında kullanışlı ve invaziv olmayan bir elektrokardiyografik testtir. Çalışma sonuçları, QTc dispersiyonunun ameliyat sonrası dönemde kullanımının ortaya çıkacak aritmilerin öngörüsünde yardımcı olabileceğini göstermektedir.

Anahtar sözcükler: Kardiyak aritmiler; çocuklar; doğuştan kalp cerrahisi; QTc dispersiyonu.

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Prolonged measurements of QT and corrected QT (QTc) dispersions show the electrical instability of the myocardium and predisposition to arrhythmias associated with sudden cardiac death.[1] In adult patients who undergo cardiopulmonary bypass (CPB), positive correlations, such as ventricular extrasystoles and bigeminy, have been found between prolonged QTc and arrhythmia.[2] In addition, QTc prolongation is seen among some children who undergo open heart surgery in order to treat congenital cardiac disease.[3] Punn et al.[3] suggested that prolonged QTc is associated with longer cross-clamp time but not the duration of mechanical ventilation or length of hospital stay. The aim of our study was to prospectively determine whether there is a change in QTc with preoperative versus postoperative electrocardiograms (ECGs) following surgery for congenital cardiac disease. In addition, we hypothesized that this prolongation of QTc dispersion may be related to the type of operation. Finally, we sought to determine whether there is a difference in outcome variables, for example the incidence rate and the type of postoperative arrhythmias associated with perioperative QTc changes.

PATIENTS AND METHODS

Subjects

Routinely performed pre- and postoperative ECGs were prospectively analyzed by evaluating 559 patients under the age of 18 who underwent operations for congenital cardiac disease between October 2006 and March 2011 at a single center. Two hundred and seventy-nine consecutive patients (144 females, 135 males, mean age 56.6±5.0 months; range 15 days to 17 years) who met the initial inclusion criteria were included in the study. For these patients, serial ECGs in accordance with standard clinical practice were analyzed as part of the study during their hospital stay. The preoperative ECGs were collected one month before the cardiac surgery while the postoperative ECGs were performed one week after the surgery. None of the patients received antiarrhythmic medications or other agents known to prolong the QT interval in the perioperative period.

Exclusion criteria

The exclusion criteria for this study included the following: an intraoperative decision for no cardiac surgery, uninterpretable T waves for QTc, postoperative ventricular pacing, missing postoperative or preoperative ECGs, and a history of antiarrhythmic medication usage and endocrinological problems, i.e. hyperthyroidism and exitus, due to cardiac or noncardiac problems in a one-week period after the operation. According to these criteria, 280 patients were excluded from the study.

Calculation of QTc dispersion

Corrected QT dispersion measurements were calculated and arrhythmias were evaluated from a standard 12-lead resting ECGs of the patients. These ECG records were obtained from each patient in the morning (between 7 and 9 am) while they were under continuous ECG monitoring. The measurements were taken from standard 12-lead ECGs recorded at a speed of 25 mm/s at rest or sleeping. A patient monitor with a three-channel electrocardiographic recorder (Petas KMA 460-R, Ankara, Turkey) was used. The QT and RR intervals were measured manually with calipers by two blinded observers. The QT intervals were measured from the onset of the QRS complex to the end of the T wave, with the end of the T wave being defined as the point of return to the isoelectric line. When U waves were present, the QT interval was measured according to the nadir of the curve between the T and U waves,[4] and QT dispersion was defined as the difference between the maximum and minimum QT intervals occurring in any of the 12-lead ECGs that could be reliably measured. In addition, both the maximum QT interval and QT dispersion measurements were corrected for the heart rate according to Bazett's formula (QTc = QT/MRR).[5]

Evaluation of arrhythmias

Before performing the ECG, bedside monitoring was performed for all patients with standard recorders (Petas KMA 800, Ankara, Turkey) to evaluate the arrhythmias after surgery. Even if there were arrhythmias during monitoring, ECG was performed. Also, a Holter monitor (Del Mar Reynolds Medical, Irvine, California, USA) was used if needed, and if more than one arrhythmia was detected, the patient was included in only one type of arrhythmia group. Postoperative arrhythmias were diagnosed according to the following definitions:[6-8]

Supraventricular extrasystoles: Premature atrial or junctional contractions occurring more frequently than 49 beats/24 hours.

Ventricular extrasystoles: Premature ventricular contractions occurring more frequently than 49 beats/24 hours.

Atrial flutter: Atrial flutter is identified by so-called sawtooth waves, representing the rapid atrial rate with typically normal QRS duration.

Atrial fibrillation: Atrial fibrillation demonstrates chaotic irregular atrial activity with an "irregularly irregular" ventricular rate with typically normal QRS duration.

Supraventricular tachycardia (SVT): This is defined as a paroxysmal tachyarrhythmia manifested by the

absence of P waves and the presence of normal QRS complexes.

Junctional rhythm: This is defined as junctional escape rhythm with normal QRS morphology at a rate not exceeding the maximum normal junctional escape rate for age (50-80 beats/min up to 3 years, and 40-60 beats/min over 3 years) and slower than the atrial escape rhythm (80-100 beats/min up to 3 years, and 50-60 beats/min over 3 years).

Wandering pacemaker: An "irregularly irregular" rhythm caused by the random discharge of multiple ectopic atrial foci. By definition, the heart rate is ≤100 beats/min. The presence of P waves distinguishes a wandering atrial pacemaker from atrial fibrillation.

Statistical analysis

The results were presented as mean value ± standard deviation (SD). Intergroup variables were compared with both a paired and an unpaired t-test using the SPSS for Windows 7.0 release (SPSS Inc., Chicago, Illinois, USA). *P* values of <0.05 were considered to be statistically significant.

RESULTS

Subject characteristics

Demographic findings of the study population are given in Table 1. Ventricular septal defect (VSD) (36.9%) and secundum atrial septal defect (ASD) (18.2%) are common types of congenital heart diseases in the study population (Table 2).

QTc measurements

A total of 212 patients (75.9%) had prolonged QTc dispersion, and the pre- and postoperative mean QTc dispersion rates were 36.7±9.1 and 52.9±18.8, respectively (p<0.001). The postoperative measurements of QTc were significantly higher in the patients who underwent repair of the VSD, atrioventricular septal defect (AVSD), tetralogy of Fallot (TOF), and secundum ASD (p<0.001). Also, the statistical difference was significant in the repair of ASD regarding the partial anomalous pulmonary venous return (PAPVR), double outlet right ventricle (DORV), Blalock-Taussig (BT) shunt, the Rastelli operation, and pulmonary valve commissurotomy (p<0.01). However, no statistical differences were detected in patients who underwent repair of the VSD with pulmonary stenosis (PS), end-to-end anastomosis of the aorta for coarctation, patent ductus arteriosus (PDA) ligation or division, pulmonary banding, and the Glenn procedure (p>0.05; Table 3).

Postoperative arrhythmias

Arrhythmias developed in a total of 104 patients (54 female and 50 male). The types detected after the postoperative period were supraventricular extrasystoles (65.4%), ventricular extrasystoles (VES) (24%), supraventricular tachyarrhythmia (2.9%), atrial fibrillation (2.9%), atrial flutter (1.9%), wandering pacemaker (1.9%), and junctional rhythm (1%). All of these types of arrhythmias developed in the patients after repair of the VSD (41.4%), secundum ASD (24.1%), TOF (11.5%), AVSD (9.6%), ASD with PAPVR (4.8%), VSD with PS (1.9%), DORV (1.9%), BT shunt (1.9%), pulmonary valve commissurotomy (1.9%) and the Rastelli operation (1%) (Table 4). In addition, occurrence of arrhythmia in prolonged QTc dispersions classified by the type of cardiac operation was statistically different from the QTc dispersions that were not prolonged (p<0.01).

Table 1. Demographic findings of patients

	n	Mean±SD	Range
Age (months)		56.6±5.0	15 days-17 years
Gender			
Female	144		
Male	135		
Weight		15.29±1.16	3.1-64 kg

SD: Standard deviation.

Table 2. Classification of congenital heart diseases in children

Type of congenital heart disease	n	%
Ventricular septal defect	103	36.9
Secundum atrial septal defect	51	18.2
Patent ductus arteriosus	37	13.2
Tetralogy of Fallot	17	6.1
Aortic coarctation	17	6.1
Atrial septal defect with PAPVR	13	4.6
Atrioventricular septal defect	13	4.6
Ventricular septal defect with PS	6	2.2
Subaortic membrane	4	1.4
Pulmonary stenosis	3	1.1
Double outlet right ventricle	3	1.1
Truncus arteriosus type 4	3	1.1
Tricuspid atresia	2	0.7
Interrupted aortic arch	2	0.7
Transposition of great arteries	1	0.4
Single ventricle	1	0.4
Double outlet left ventricle	1	0.4
Pulmonary atresia	1	0.4
Aortic stenosis	1	0.4
Total	279	100.0

PAPVR: Partial anomalous venous return anomaly; PS: Pulmonary stenosis.

Table 3. Preoperative and postoperative QTc dispersions and *p* values in the patients who underwent congenital cardiac surgery

Procedure	QTc dispersion (ms)		
	Preoperation	Postoperation	
	Mean±SD	Mean±SD	*p*
All patients (n=279)	36.65±9.10	52.88±18.79	p<0.001
Repair of ventricular septal defect (n=100)	37.33±10.32	55.00±15.89	p<0.001
Repair of atrioventricular septal defect (n=13)	36.66±10.29	72.50±20.50	
Repair of tetralogy of Fallot (n=14)	35.71±8.51	64.28±11.57	
Repair of secundum atrial septal defect (n=56)	38.21±6.90	58.21±17.59	
Repair of atrial septal defect with PAPVR (n=13)	35.00±9.25	52.50±18.32	p<0.01
Blalock-Taussig shunt (n:8)	35.00±9.25	62.50±24.92	
Rastelli operation (n=1)	35.00±9.25	56.50±21.92	
Commissurotomy (n=4)	36.00±7.25	52.50±24.92	
Repair of double outlet right ventricle (n=3)	35.00±9.25	52.50±22.92	
Repair of ventricular septal defect and pulmonary stenosis (n=6)	33.33±10.32	46.66±20.65	p>0.05
End-to-end anostomosis of the aorta (n=19)	34.73±9.04	35.78±10.70	
Patent ductus arteriosus ligation (n=25)	36.80±7.48	36.80±7.48	
Pulmonary banding (n=3)	30.00±11.54	45.00±19.14	
Patent ductus arteriosus division (n=12)	31.66±10.29	33.33±9.84	
Glenn procedure (n=2)	50.00±14.14	85.00±7.07	

SD: Standard deviation; PAPVR: Partial anomalous venous return anomaly.

DISCUSSION

Prolongation of QTc occurs in a proportionate number of children after cardiothoracic surgery for congenital cardiac disease. It is generally believed that this degree of prolongation may put patients at risk for ventricular arrhythmias.[9,10] The study by Krasner et al.[2] showed that prolongation of QTc is transient in nature. As previously stated, Punn et al.[3] also suggested that significant QTc prolongation was associated with longer cross-clamp time. Thus, we can speculate that this association of the longer cross-clamp time with new QTc prolongation is related to transient ischemia during the surgical intervention. The hypothesis that QTc prolongation may be related to the length of ischemia is in keeping with other studies that have shown transient prolongation of QTc during myocardial infarction and balloon coronary angioplasty in adult patients.[11,12] In addition, there are case reports of patients presenting with QT prolongation during myocardial ischemia that resolved after a coronary intervention.[13,14] Our study

Table 4. Type of cardiac operations and associated arrhythmias after surgery in children

Type of operation	Type of arrhythmia						
	SVT	Supraventricular extra-systole	Junctional rhythm	Atrial fibrillation	Atrial flutter	VES	Wandering pacemaker
Repair of ASD with PAPVR	1	4	–	–	–	–	–
Repair of VSD with PS	–	2	–	–	–	–	–
Repair of Secundum ASD	1	22	1	–	1	–	–
Pulmonary valve commissurotomy	–	2	–	–	–	–	–
Repair of VSD	–	17	–	–	–	25	1
Rastelli operation	1	–	–	–	–	–	–
Repair of AVSD	–	8	–	2	–	–	–
Repair of tetralogy of Fallot	–	10	–	1	–	–	1
Blalock-Taussig shunt	–	1	–	–	1	–	–
Repair of DORV	–	2	–	–	–	–	–

SVT: Supraventricular tachycardia; VES: Ventricular extra-systols; ASD: Atrial septal defect; PAPVR: Partial anomalous venous return anomaly; VSD: Ventricular septal defect; PS: Pulmonary stenosis; AVSD: Atrioventricular septal defect; DORV: Double outlet right ventricle.

showed an association between procedures such as the repair of TOF with coronary anomalies requiring direct coronary artery manipulation and QT prolongation. In a recent study, most of the congenital cardiac surgerical procedures were found to be associated with prolonged QTc dispersion.[3] Similarly, our results indicated that ventricular and atrial surgical procedures, such as the repair of ASD, VSD, AVSD, ASD with PAPVR, DORV and BT shunt, the Rastelli operation, and pulmonary valve commissurotomy, are associated with long QTc dispersions. On the other hand, no statistical difference in QTc prolongation was shown for procedures not needed during CPB, for instance end-to-end anastomosis of the aorta for coarctation, PDA ligation or division, pulmonary banding, and the Glenn procedure. However, our study showed a statistical difference associated with the BT shunt procedure, which is an extracardiac operation. In our study, supraventricular and ventricular extrasystoles were the most common type of arrhythmias associated with repair of the secundum ASD, VSD, and TOF. Additionally, VES was typically observed after repair of the VSD. Furthermore, most of the atrial and ventricular arrhythmias were detected in prolonged QTc groups, and the statistical differences in these groups were significant ($p<0.01$). These findings suggest that the type of operation may be a predictive parameter for arrhythmias developed after congenital cardiac surgery in children. Moreover, prolongation of QTc dispersion after cardiac surgery may show predisposition to postoperative arrhythmias in children. In individuals in which QT prolongation persists after hospital discharge, careful follow-up with repeat ECG seems prudent for documenting normalization of the QT interval. Further research on this subject is needed.

Limitations

Our study was limited by the fact that the ECGs were obtained only once during the study period. Other associated factors, such as the longer cross-clamp time, were also not evaluated. Finally, this study did not address follow-up after discharge from the hospital, and it did not assess genetic abnormalities that may predispose certain individuals to longer QT intervals.

In conclusion, corrected QT dispersion measurement is a useful noninvasive electrocardiographic test for evaluating arrhythmias. A modest transient increase in QTc is seen in the majority of children who undergo operative intervention for the treatment of congenital cardiac disease. In almost 75.9% of the study population, QTc prolongation was exceeded, and its precise etiology in this setting is unknown. However, prolonged QTc appears to be associated with the type of cardiac surgery performed. We showed that the occurrence of arrhythmia in prolonged QTc dispersions classified by the type of cardiac operation was statistically different from QTc dispersions that were not prolonged ($p<0.01$). Finally, our study suggests that the use of QTc dispersion in the postoperative period may be useful for predicting the development of arrhythmias.

Declaration of conflicting interests

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