

# Radio-frequency ablation of arrhythmias following congenital heart surgery

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## Abstract

**Background:** Cardiac arrhythmias as a late complication following congenital heart surgery are encountered more and more frequently in clinical practice. The use of new electrophysiological methods of visualisation and mapping improves the efficacy of radio-frequency (RF) ablation of these arrhythmias.

**Aim:** To assess patterns of atrial arrhythmias following congenital heart surgery and to examine the efficacy of RF ablation using the electro-anatomical CARTO system.

**Methods:** Electrophysiological diagnostic study and RF ablation were performed in 24 consecutive patients (mean age 36±18 years) who had atrial arrhythmias following congenital heart surgery. The mechanism of arrhythmia (ectopic or reentrant) and strategy of RF ablation procedure were based on the results of the right atrial map performed during index arrhythmia.

**Results:** The patients were divided into five groups according to the type of congenital heart surgery. The ASD group consisted of 17 patients who had undergone in the past surgery due to atrial septal defect, four patients had a history of surgery due to ventricular septal defect (VSD group), and one patient each had undergone surgery due to corrected transposition of the great arteries (ccTGA), tetralogy of Fallot (TF) or dual-outflow right ventricle (DORV). During diagnostic electrophysiological study typical atrial flutter (AFL) was diagnosed in nine patients from the ASD group, atypical AFL in three ASD patients, and ectopic atrial tachycardia (EAT) in six ASD patients. In one patient EAT was induced after ablation of typical AFL. Of the VSD patients, three had atypical AFL, and one had typical AFL. The patient following surgery for ccTGA had atypical AFL and EAT, whereas in the two remaining patients (DORV and TF) atypical AFL was demonstrated. The efficacy of the first session of RF ablation was 83% and no complications were observed. The efficacy of RF ablation of typical AFL was 90%, atypical AFL 78%, and EAT 86% (NS). During the long-term follow-up (24±17 months) arrhythmia recurrences were noted in 2 (10%) out of 20 patients who were effectively treated during the first RF ablation session.

**Conclusions:** Reentry is the most common electrophysiological mechanism of incisional tachycardias, followed by ectopic atrial tachycardia. RF ablation using the electro-anatomical CARTO system is effective and safe in this group of patients.

**Key words:** congenital heart surgery, incisional tachycardias, RF ablation, electro-anatomical system, atrial flutter, ectopic atrial tachycardia

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## Introduction

It has been estimated that 8-10 of 100,000 newborns have congenital heart disease. Progress in congenital heart surgery has resulted in decreased

mortality and improvement of quality of life. The number of patients with repaired congenital heart disease who survive till adulthood is growing, resulting in increased incidence of late complications of

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congenital heart surgery such as cardiac arrhythmias, originating mainly from the right atrium [1, 2].

Because of the variety of congenital heart disorders and types of palliative surgical procedures, the spectrum of incisional tachycardias is very wide, both with regard to the mechanisms responsible for their initiation and duration as well as clinical consequences. Antiarrhythmic drug therapy is rarely effective, which means that the use of radio-frequency (RF) ablation is increasing. Because of the complexity of arrhythmia and alterations in the atrial anatomy following surgical correction, the efficacy of classical RF ablation is rather low and the recurrence rate is high [3, 4]. It has been shown that the use of new electrophysiological methods of visualisation and mapping improves both early and late results of RF ablation in this group of patients [5, 6]. Thus, it is tempting to analyse in detail the electrophysiological nature of incisional tachycardias and to assess the efficacy of RF ablation combined with new mapping techniques in this setting.

The aim of the present paper was to analyse the electrophysiological mechanisms of incisional tachycardias and to assess the efficacy and safety of RF ablation performed with the advent of the electro-anatomical CARTO system in patients with arrhythmias following congenital heart surgery.

## Methods

### Patients

The study group consisted of 24 consecutive patients (11 females, mean age  $36 \pm 18$  years, range 11-69 years) who suffered from drug-resistant atrial arrhythmias following congenital heart surgery. All patients underwent in our centre diagnostic electrophysiological study and RF ablation between November 2001 and March 2006. In 20 patients incisional tachycardia was permanent, and in four paroxysmal.

### Electrophysiological study and RF ablation

Electrophysiological study was performed using the electro-anatomical CARTO system (Biosense-Webster). Two electrodes were used – one diagnostic multipolar electrode was introduced into the coronary sinus (CS) and was used as a reference electrode, and the second electrode (Navistar, 8F, F curve, Thermo-Cool) was used for mapping and ablation. In patients with paroxysmal form of incisional tachycardia arrhythmia was induced from the distal pole of the CS electrode. The right atrium was mapped during tachycardia. The results of mapping were used to delineate the arrhythmia mechanism (reentrant or ectopic) and to plan the ablation strategy.

Arrhythmias were classified as re-entrant (intraatrial re-entry tachycardia – IART) when a continuous

sequence of activation (the earliest activation adjacent to the latest activation) was recorded and the total activation time was equal to the arrhythmia cycle.

Arrhythmias were classified as ectopic (ectopic atrial tachycardia – EAT) when the activation wavefront was spreading out in all directions from the single, earliest site of activation and when activation time was shorter than the arrhythmia cycle.

In patients with IART, the presence and localisation of double potentials, scars (amplitude below 0.5 mA) and propagation map were used to assess the type of impulse propagation and to identify areas of slow conduction. In the majority of patients, cavo-tricuspid isthmus involvement in the tachycardia cycle was examined using entrainment technique and comparing the post-pacing interval to the tachycardia cycle length. Based on these measurements, the critical arrhythmia zone was identified and RF application lines were performed in this region. In patients with cavo-tricuspid isthmus-dependent IART, ablation was performed in the isthmus and the efficacy (creation of a bi-directional block) was evaluated according to the previously described methods [7]. In patients with isthmus-independent reentrant tachycardia, the ablation line was performed from the scar area to another anatomical barrier (inferior vena cava, superior vena cava or another scar). In patients with EAT, ablation was performed at the site of earliest activation.

RF ablation was performed using cool-tip electrodes. Maximum delivered energy was set at 60 W and temperature at 50°C. The immediate efficacy of RF ablation was assessed by programmed stimulation (8+1, 8+2) and pacing at progressively shorter cycle length up to that of the clinical arrhythmia.

### Statistical analysis

Results are presented as mean  $\pm$  standard deviation. Qualitative variables were compared using  $\chi^2$  test with Yates correction, quantitative parameters using paired Student's t-test. A p value  $<0.05$  was considered significant.

Original recordings (intracardiac signals and electroanatomical map) from a patient with typical AFL are shown in Figures 1 and 2.

## Results

### Type of congenital heart disease

Seventeen patients had undergone cardiac surgery due to atrial septal defect (ASD group) and four due to ventricular septal defect (VSD group). One patient had surgery due to tetralogy of Fallot (TF) and another one had a history of Fontan-Kreutzer procedure performed due to corrected transposition of the great

**Table I.** Types of arrhythmias diagnosed during electrophysiological study

Type of congenital anomaly	Typical AFL	Atypical AFL	EAT	Total number of arrhythmias
ASD n=17	9 (50%)	3 (16.67%)	6 (33.33%)	18
VSD n=4	1 (25%)	3 (75%)	–	4
ccTGA n=1	–	1 (50%)	1 (50%)	2
DORV n=1	–	1 (100%)	–	1
TF n=1	–	1 (100%)	–	1
Total	10 (38%)	9 (35%)	7 (27%)	26 (100%)

ASD – atrial septal defect, VSD – ventricular septal defect, ccTGA – corrected transposition of the great arteries, DORV – dual-outflow right ventricle, TF – tetralogy of Fallot, AFL – atrial flutter, EAT – ectopic atrial tachycardia

**Table II.** Procedural success, duration and fluoroscopic exposure

	Typical AFL (n=10)	Atypical AFL (n=9)	EAT (n=7)	All arrhythmias (n=26)	p
RF ablation effective	90% (n=9)	78% (n=7)	86% (n=6)	85% (n=22)	NS
Mean duration of procedure (min)	173±58 (80-270)	147±76 (45-255)	169±72 (80-255)	159±63 (45-270)	NS
Fluoroscopy time (min)	29.5±12.9 (10-51)	26.1±27.9 (4-80)	19.8±16.5 (8-51)	25±18 (4-80)	NS

Abbreviations: see Table I.

vessels with a common ventricle and pulmonary stenosis (ccTGA). The last remaining patient, who had double-outflow right ventricle (DORV), VSD and pulmonary stenosis, underwent surgery using Rastelli method and redo surgery due to homograft stenosis. The mean time from surgery to RF ablation was 17±15 years (range 1-35 years).

#### Types of arrhythmias (Table I)

Of the 17 ASD patients, 16 had single arrhythmias – 11 had IART (cavo-tricuspid isthmus dependent in 8, and isthmus independent in 3) whereas the remaining 5 patients had EAT. The last patient had two arrhythmias (EAT was inducible after successful ablation of typical atrial flutter, AFL). Thus, in 17 patients from the ASD group a total of 18 arrhythmias were diagnosed.

Of four VSD patients, one had typical AFL, and three atypical AFL. The TF patient and the DORV patient had atypical AFL, whereas in the ccTGA patient two arrhythmias were detected – atypical AFL and EAT.

In summary, in 24 patients 26 arrhythmias were diagnosed and treated by RF ablation – 10 (38%) typical AFL, 9 (35%) atypical AFL and 7 (27%) EAT.

#### Results of RF ablation (Table II)

A single RF ablation session was effective in 20 (83%) patients. Ineffective procedures were performed in patients with a single arrhythmia. The mean duration of the procedure was 159±63 min (range 45-270 min) and mean fluoroscopy time was 25±18 min (range 4-80 min). There were no significant differences in procedure

efficacy, duration and fluoroscopy time between patients with typical AFL, atypical AFL or EAT.

Of 26 tachycardias, 22 (85%) were effectively cured by RF ablation. No peri-procedural complications were noted. During a long-term follow-up (24±17 months, range 1-54 months), arrhythmias recurred in two (10%) of 20 patients effectively treated during a single RF ablation session.

#### Discussion

Regarding the type of arrhythmia, the most frequent was IART – 19 (79%) patients, including 9 patients in whom cavo-tricuspid isthmus was involved in the arrhythmia circuit. The remaining 7 (29%) patients had EAT, and in two (8%) patients two separate arrhythmias were detected. IART is characteristic for patients following cardiac surgery and occurs quite often. The underlying mechanism is re-entry using anatomical barriers in the atrium, frequently involving scars which are due to surgical incisions. This type of tachycardia is only rarely seen in patients with normal hearts and it is also unusual to induce sustained IART during electrophysiological study in this group of patients. Garson et al. [8] in their retrospective analysis of 380 patients with IART, aged from one to 25 years, showed that 80% of patients had congenital heart disease, including also those after surgical correction, whereas only 8% had normal anatomy of the heart.

The incidence of IART following congenital heart surgery depends on the type of procedure and duration of follow-up. Gelatt et al. showed that of 269 patients

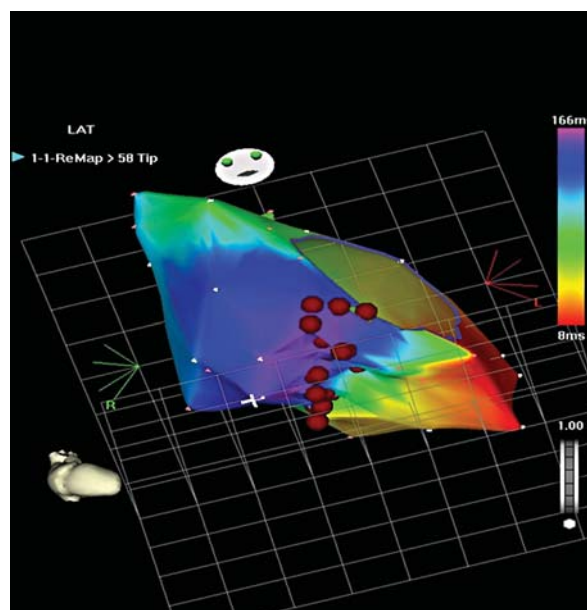


**Figure 1.** Standard ECG (leads I, II, III, V1 and V6) and intracardiac recordings during typical AFL (cycle length 240 ms).

CS 1,2 – bipolar signal from the distal part of the electrode placed in the coronary sinus  
 CS 3,4 – bipolar signal from the proximal part of the electrode placed in the coronary sinus

who underwent Fontan procedure, 14-29% developed IART during a 4-year follow-up period. The incidence of IART depended on the type of anastomosis. Factors influencing IART occurrence included the presence of IART prior to surgery, longer follow-up period and type of anastomosis [9]. Other investigators reported a similar incidence of IART in this group of patients, ranging from 16 to 17%. They also showed that factors effecting arrhythmia development included, besides those mentioned above, age at the time of surgery and function of the atrio-ventricular valves. Esscher et al. reported a 14% incidence of IART among 166 patients following surgical ASD correction [10]. In patients who underwent Mustard surgery, the IART rate was reported to be 27% during a mean of 20 years of follow-up, whereas Roos-Hesselink et al. documented the presence of IART in about one third of patients who underwent surgery due to tetralogy of Fallot [11].

Besides affecting quality of life, incisional tachycardias also worsen prognosis. In patients with IART following Mustard surgery, Gellat et al. documented a 6.5% incidence of sudden cardiac death (SCD) during an 11-year follow-up. Another study, which included a larger group of patients, documented a 6% incidence of SCD among 229 patients with IART following the Fontan, Mustard and Senning procedures during a three-year follow-up [2]. For comparison, in the whole population of patients after Mustard surgery the incidence of SCD was also reported to reach 6%, albeit during a 12-year follow-up period [9]. These authors postulated that the



**Figure 2.** Electro-anatomical map of the right atrium constructed after RF ablation of the cavo-tricuspid isthmus during atrial pacing from CS in a patient with typical AFL following ASD correction. Red spots – RF application sites

occurrence of IART following congenital heart surgery significantly increases risk of SCD. These findings suggest that IART is a clinically significant arrhythmia, both because of its high incidence and potential dangerous complications. Whether an effective cure of IART, besides improving quality of life and obviating the need for prolonged antiarrhythmic drug therapy, decreases the risk of SCD has not yet been established.

Ablation procedures in patients following congenital heart surgery are technically demanding, as is documented by longer procedure time and fluoroscopy duration. This is mainly due to the usually enlarged right atrium and the presence of scars as well as surgical incisions. The use of electro-anatomical mapping systems facilitates elucidation of arrhythmia mechanism and helps in planning the ablation strategy. Analysis of the results of pacing within cavo-tricuspid isthmus, assessment of scars, double potentials and propagation maps helps to identify slow conducting areas and critical regions for arrhythmia. Analysis of a standard 12-lead ECG is also helpful, as is the knowledge about cardiac anomaly and surgical technique used to treat a defect.

According to published data, localisation of critical areas of IART re-entry circles may be predicted based on the knowledge about the type of surgical correction performed to repair a defect. Based on the results of successful ablation procedures, in patients following

Mustard and Senning procedures this area most frequently is localised in the cavo-tricuspid isthmus, whereas following Fontan procedures the critical zone of arrhythmia is located at various sites, usually on the lateral wall of the right atrium [12-16]. In approximately 30% of patients with IART, the ECG pattern of arrhythmia is the same as for AFL, suggesting the involvement of the cavo-tricuspid isthmus in the arrhythmia reentrant circle [17]. In our study, complex analysis of the arrhythmia mechanisms, based on ECG analysis, data concerning cardiac defect and type of surgery performed as well as details from the electro-anatomical mapping system, enabled effective treatment of incisional tachycardias during a single RF ablation session in 20 (83%) patients and curative ablation of 22 (85%) tachyarrhythmias.

### Conclusions

Among tachycardias occurring after congenital heart surgery, reentrant mechanisms are the most frequent, followed by EAT. The use of RF ablation with the electro-anatomical mapping system is effective and safe in this patient population.

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## Ablacja RF w leczeniu zaburzeń rytmu serca po kardiochirurgicznej korekcji wad serca

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### Streszczenie

**Wstęp:** U pacjentów poddanych kardiochirurgicznym korekcjom wrodzonych wad serca coraz częściej spotykamy późne powikłania w postaci arytmii. Zastosowanie nowych elektrofizjologicznych metod wizualizacji i mapowania poprawia u tych chorych wyniki leczenia ablacją prądem o częstotliwości radiowej (RF).

**Cel:** Ocena typów arytmii przedsionkowych u chorych po kardiochirurgicznej korekcji wrodzonych wad serca i wyników ich leczenia ablacją RF z zastosowaniem systemu CARTO.

**Metodyka:** U 24 kolejnych chorych (średni wiek 36±18 lat) po kardiochirurgicznej korekcji wrodzonych wad serca, z udokumentowanymi arytmiami przedsionkowymi, wykonano badanie elektrofizjologiczne oraz jednocześnie ablacją RF. Wykonując prawopredsionkową mapę w trakcie arytmii, określano jej mechanizm (nawrotny lub ektopowy) i strategię zabiegu.

**Wyniki:** Chorych podzielono na 5 grup ze względu na przyczynę operacji. Były to: grupa ASD (n=17) – chorzy po operacjach z powodu ubytku przegrody międzyprzedsionkowej (*atrial septal defect*, ASD), grupa VSD (n=4) – chorzy po operacjach z powodu ubytku przegrody międzykomorowej (*ventricular septal defect*, VSD), grupa ccTGA (n=1) – z powodu skorygowanej transpozycji wielkich naczyń, grupa TF (n=1) – z powodu tetralogii Fallota i grupa DORV (n=1) – z powodu dwuodpływowej prawej komory. Podczas badania elektrofizjologicznego w grupie ASD u 9 chorych rozpoznano typowe trzepotanie przedsionków (AFL), u 3 atypowe AFL, zaś u 6 ektopowy częstoskurcz przedsionkowy (EAT). U jednego chorego po ablacji typowego AFL wystymulowano EAT. W grupie VSD u jednego chorego obserwowano typowe AFL, u 3 – atypowe AFL; w grupie ccTGA u jednego rozpoznano atypowe AFL i EAT, w grupie DORV (n=1) i w grupie TF (n=1) zdiagnozowano atypowy AFL. Nie wystąpiły żadne powikłania w okresie okołozabiegowym. W pierwszej sesji skuteczność ablacji RF wyniosła 83%. Skuteczność ablacji typowego AFL wyniosła 90%, atypowego AFL 78%, zaś EAT 86% (NS). W obserwacji odległej (24±17 mies.) nawroty arytmii wystąpiły u 2 (10%) spośród skutecznie leczonych w pierwszej sesji 20 chorych.

**Wnioski:** Po kardiochirurgicznej korekcji wrodzonych wad serca dominują arytmie w mechanizmie fali nawrotnego pobudzenia. Ważną klinicznie arytmia w tej populacji jest również EAT. Ablacja RF z wykorzystaniem CARTO jest skuteczną i obciążoną niskim ryzykiem powikłań metodą leczenia.

**Słowa kluczowe:** wady wrodzone serca, ablacja RF, trzepotanie przedsionków, ektopowy częstoskurcz przedsionkowy

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