International Journal of Cardiology 208 (2016) 115–119

Contents lists available at ScienceDirect

International Journal of Cardiology

journal homepage: www.elsevier.com/locate/ijcard

Outcome of direct current cardioversion for atrial arrhythmia in adult Fontan patients

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ARTICLE INFO

Article history:
Received 19 December 2015
Received in revised form 16 January 2016
Accepted 22 January 2016
Available online 23 January 2016

Keywords:
Cardioversion
Fontan
Atrial arrhythmia
Arrhythmia recurrence

ABSTRACT

Background: Limited data are available about direct current cardioversion (DCCV) in Fontan patients.
Methods: Retrospective review of adult Fontan patients that underwent DCCV for atrial arrhythmias at Mayo Clinic, 1994–2014. Study endpoints were to determine procedural success, safety, and the freedom from arrhythmia recurrence after DCCV. Procedural success was defined as termination of the presenting atrial arrhythmia prior to leaving the cardioversion suite.
Results: 86 patients underwent 152 DCCV; age 27 ± 8 years; male 49 (57%); atriopulmonary Fontan, 64 (74%); atrial flutter/interatrial reentry tachycardia 125 (82%). Freedom from recurrence was 84% and 47% at 12 and 36 months; freedom from repeat DCCV was 91% and 64% at 12 and 36 months. Procedural failure occurred in 41 (27%); predictors of procedural failure were older age (HR 1.91, CI 1.16–2.73 per decade) and prior DCCV (HR 2.71, CI 1.22–3.21). Concomitant oral class I or III antiarrhythmic medication was associated with an increased likelihood of success (HR 0.64, CI 0.41–0.87). Predictors of recurrence were older age (HR 3.26, CI 1.19–6.55 per decade); duration of arrhythmia (HR 1.87, CI 1.14–2.56 per decade); and presence of atriopulmonary Fontan (HR 1.54, CI 1.27–1.85). Procedural complications were symptomatic bradycardia in 2 cases (1%). No thromboembolic complications or deaths occurred.
Conclusion: DCCV in Fontan patients is safe but is associated with significant procedural failure and recurrence rates. Ideally, antiarrhythmic medication should be instituted prior to DCCV in stable patients and DCCV alone should be considered as a temporizing measure to maintain sinus rhythm.

1. Introduction

Atrial arrhythmias are common after a Fontan operation and the prevalence of these arrhythmias increases with the duration of Fontan circulation [1–4]. Atrial arrhythmias are associated with impaired quality of life, increased risk of thromboembolism, ventricular dysfunction and death [3,5–7]. The Fontan physiology is a 'low cardiac output' state with limited physiological reserve [8,9] and as a result, atrial arrhythmias can be less well tolerated in Fontan patients compared to those with biventricular circulation. Restoration of sinus rhythm is important in certain subsets of patients to avoid acute and chronic hemodynamic deterioration.

Direct current cardioversion (DCCV) is typically an effective therapy for the termination of arrhythmias in patients with congenital heart disease but its efficacy varies based on the underlying anatomy [10,11]. The Fontan procedure involves multiple atrial scars, fibrosis, and commonly with significant atrial dilation. The combination of these factors can provide an arrhythmogenic milieu for the initiation and maintenance of atrial arrhythmias [12,13]. In addition, the lack of a systolic forward vector in the Fontan circulation frequently leads to sluggish blood flow and associated Fontan thrombus. There is limited data on the efficacy and safety of DCCV in Fontan patients and the purpose of this study is to determine procedural success, safety and the freedom from arrhythmia recurrence after DCCV for atrial arrhythmia.

2. Methods

2.1. Patient selection and data extraction

The Mayo Clinic Institutional Review Board approved this study. We identified all adults (>18 years) with history of Fontan operation who underwent DCCV for atrial arrhythmia at Mayo Clinic from January 1994 to June 2014 using free text search software (Advanced Clinical Explorer). Patients with less than 12 months of follow-up after DCCV (n = 17) were excluded.

Atrial arrhythmias were defined as intra-atrial reentry tachycardia/atrial flutter, atrial fibrillation and ectopic atrial tachycardia. We reviewed

Abbreviations: AAD, Anti-arrhythmic drug; DCCV, Direct current cardioversion; TEE, Transesophageal echocardiogram.

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http://dx.doi.org/10.1016/j.ijcard.2016.01.209
0167-5273/

clinical notes, electrocardiograms pre- and post DCCV, Holter monitor records, echocardiograms and cardiac catheterization data.

2.2. Study design

The study endpoints were to determine procedural success, procedural safety and the freedom from arrhythmia recurrence after DCCV.

Procedural success was defined as termination of the presenting atrial arrhythmia prior to leaving the cardioversion suite. DCCV complications were defined as symptomatic bradycardia requiring pacing, new onset tachyarrhythmia immediately after DCCV, esophageal injury during intubation for transesophageal echocardiogram (TEE), death or thromboembolism (stroke/transient ischemic attack, pulmonary embolism) within 30 days of DCCV.

2.3. Anticoagulation

Therapeutic anticoagulation was defined as partial thromboplastin time ≥ 55 s (while on unfractionated Heparin) or international normalized ratio ≥ 2.0 (while in Warfarin) within 48 h prior to DCCV. TEE-guided DCCV was performed in the patients with subtherapeutic anticoagulation, and in the patients considered to be at high risk for intracardiac thrombi.

2.4. Sedation and procedural data

Fentanyl and midazolam were used for conscious sedation during TEE. After TEE was performed, an anesthesiologist administers anesthesia using thiopental or propofol. DCCV was performed using a standardized protocol. Defibrillator pads were placed to the right of the sternum anteriorly and over the left scapula posteriorly. Synchronized DCCV was performed in all cases starting from 75 J and successively increased to 150, 300, and 360 J if DCCV was unsuccessful. A 12-lead electrocardiogram was obtained after a successful DCCV. If atrial arrhythmia recurred less than 5 min after an initial success, one more shock at the energy level that was previously successful was performed.

2.5. Statistical analysis

All statistical calculations were performed with the JMP version 10.0 software (SAS Institute Inc., Cary, NC, USA). Categorical variables were expressed as percentages while continuous variables were expressed as mean ± standard deviation. Comparison of categorical variables was performed using chi-square test or Fisher exact test, while comparison of continuous variables was performed with two-sided unpaired Student *t*-test or Wilcoxon rank sum test as appropriate. We used total number of patients (n = 86) for censor of recurrence and total number of procedure (n = 152) for censor of procedural failure. Univariable and multivariable Cox proportional-hazard models were used to identify predictors of procedural failure and arrhythmia recurrence. The risk for each variable was expressed in hazard ratio (HR) and 95% confidence interval (CI). The freedom from arrhythmia recurrence and repeat DCCV were calculated with the Kaplan–Meier method and compared using the log-rank test. All p values were two sided, and p values < 0.05 were considered significant.

3. Results

3.1. Baseline patient characteristics

We identified 86 adult Fontan patients who underwent DCCV for atrial arrhythmias at Mayo Clinic from 1994 to 2014 and met inclusion criteria. The mean age was 27 ± 8 years; mean age at the time of Fontan operation was 14 ± 9 years; and 49 (57%) were males. The most common type of Fontan connection was atriopulmonary Fontan, 64 (74%); most common ventricular morphology was the left ventricle, 63 (73%); and the most common diagnosis was tricuspid atresia, 34 (40%), Table 1.

3.2. Procedural success

There were 152 DCCV performed within the study period; 57 patients (66%) underwent 2 DCCV and 9 patients (10%) underwent ≥3 DCCV for arrhythmia recurrence. For 131 (86%) of the DCCV, the patient was on an AAD at the time of the DCCV, of which 112 (74%) were either on class I or III AAD. The most common atrial arrhythmia was atrial flutter/IART, 125 (82%). Out of 152 DCCV, 111 (73%) were successful, Table 2.

3.3. Procedural safety

Eighty-eight (58%) of all DCCV in our cohort were TEE-guided (TEE performed on the day of DCCV); additional 47 (31%) had TEE performed within 48 h prior to DCCV; and the 17 (11%) patients who did not have TEE within 48 h had documented therapeutic INR. All TEEs were negative for intracardiac thrombus. A total of 104 patients had INR assays within 48 h prior to DCCV, and 91 (87%) of these assays showed therapeutic INR. All 13 patients (13%) with subtherapeutic INR were on heparin (unfractionated heparin, n = 12; and low molecular weight heparin, n = 1).

Table 1
Baseline characteristics.

Number of patients	86
Age, year	27 ± 8
Age at onset of arrhythmia, year	24 ± 11
Age at Fontan, year	14 ± 9
Time from Fontan operation, year	13 ± 8
Male (%)	49 (57%)
FU post DCCV, months	48 ± 21
H/o of prior catheter ablation	4 (5%)
Fontan type	
Atrio-pulmonary Fontan	64 (74%)
LTF/IAC	16 (19%)
Extracardiac Fontan	6 (7%)
Ventricular morphology	
Left ventricle	63 (73%)
Right ventricle	19 (22%)
Indeterminate	4 (5%)
Initial diagnosis	
Tricuspid atresia	34 (40%)
Mitral atresia	3 (4%)
Common inlet ventricle	10 (12%)
Double inlet left ventricle	29 (33%)
Pulmonary atresia	5 (5%)
Others	5 (5%)
Echocardiography (n = 86)	
M/S right atrial enlargement	56 (65%)
M/S ventricular dysfunction	33 (38%)
M/S AVV regurgitation	13 (15%)
Cardia catheterization data (n = 61)	
Fontan pressure, mm Hg	16 ± 3
VEDP, mm Hg	11 ± 4
Cardiac index, L/min/m^2	2.0 ± 0.3
Systemic saturation	89 ± 5
PVRi, WU ∗ m^2	2.5 ± 0.7

DCCV: Direct current cardioversion.
FU: Follow up.
H/o: History of.
IAC: Intraatrial conduit.
LTF: Lateral tunnel Fontan.
M/S: Moderate–severe.
AVV: Atrioventricular valve.
VEDP: Ventricular end-diastolic pressure.
PVRi: Pulmonary vascular resistance index.
WU ∗ m^2: Wood units × meters squared.