International Journal of Cardiology 175 (2014) 455–463

Contents lists available at ScienceDirect

International Journal of Cardiology

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

Durability of large diameter right ventricular outflow tract conduits in adults with congenital heart disease

Jonathan Buber [a,*], Gabriele Egidy Assenza [a], Alice Huang [a], Anne Marie Valente [a], Sitaram M. Emani [b], Kimberlee Gauvreau [a], Audrey C. Marshal [a], Doff B. McElhinney [a], Michael J. Landzberg [a]

[a] Department of Cardiology, Boston Children's Hospital, Boston, MA, United States
[b] Department of Cardiac Surgery, Boston Children's Hospital, Boston, MA, United States

ARTICLE INFO

Article history:
Received 23 February 2014
Received in revised form 3 May 2014
Accepted 20 June 2014
Available online 28 June 2014

Keywords:
Outflow tract conduit
Adults
Congenital heart disease

ABSTRACT

Background: Subpulmonary ventricular outflow conduits are utilized routinely to repair complex congenital cardiac abnormalities, but are limited by the inevitable degeneration and need for reintervention. Data on conduit durability and propensity to dysfunction in the adult population are limited.
Methods: The study included 288 consecutive patients ≥18 years of age who were evaluated between 1991 and 2010 after placement of a ≥18 mm conduit. Freedom from hemodynamic conduit dysfunction served as our primary outcome. Freedom from reintervention, overall mortality and heart transplantation were also evaluated.
Results: Median age at conduit implant was 19 years and median follow-up duration was 13 years. Probabilities of survival without conduit dysfunction and reintervention at 5, 10 and 15 years were 87%, 63%, and 49%, and 95%, 81%, and 56%, respectively. Smaller conduit diameter (18–20 mm) was associated with lower probability of survival without dysfunction in the entire study cohort, with prominent effects in patients in both the lowest and the highest age quartiles. Other parameters with similar associations were higher BMI, native anatomy of tetralogy of Fallot or truncus arteriosus, and active smoking.
Conclusions: Adult congenital heart disease patients with conduit diameter ≥18 mm had an approximately 50% chance of developing hemodynamic conduit dysfunction and undergoing conduit reintervention by 15 years of post-implant, and a 30% likelihood of undergoing conduit reoperation in the same time frame. The importance of these data is underscored by the increasing number of adults with congenital heart diseases seeking care and the recent advances in transcatheter valve replacement for dysfunctional conduits.

1. Introduction

It has been nearly five decades since an artificial conduit connecting the right ventricle (RV) and the pulmonary artery (PA) was first placed at surgery in a 6-year-old child with pulmonary atresia [1]. As survival among patients with complex congenital heart disease continues to improve and adults have become the fastest growing segment of the congenital heart disease population [2], the performance of RV outflow tract (RVOT) and RV to PA conduits in adults has become increasingly important.

A principal shortcoming of the artificial conduits is limited durability, which inevitably leads to the need for reintervention. In data derived mainly from pediatric literature, variables repeatedly shown to be associated with shorter time to reintervention include younger age, higher RVOT pressure gradient, conduit type (mainly homografts), underlying anatomy [mainly tetralogy of Fallot (TOF)], and multiple surgeries [3–9]. Data on conduit-related adverse outcomes in adult congenital heart disease (ACHD) patients are more limited, and are insufficient to counsel conduit-implanted adults about the expected durability of their conduit, whether it was implanted during adulthood or earlier in life. The aim of this study was therefore to evaluate conduit durability and factors associated with the development of conduit dysfunction or reintervention among ACHD patients, regardless of the age at implantation. The intention of this design was to provide focused data on patients that are either transitioning from pediatric to adult cardiac care, or undergoing a conduit implant procedure in adulthood.

2. Materials and methods

2.1. Study population and data collection

This study included consecutive patients with biventricular congenital heart diseases who underwent conduit placement between the RV and the PA at surgery and evaluated at age ≥ 18 years at our institution between 1/1/91 and 12/31/10. For convenience, the

* Corresponding author at: Adult Congenital Heart Disease Service, Department of Cardiology, Boston Children's Hospital, Boston, MA 02115, United States. Tel.: +1 617 355 5072; fax: +1 617 739 8632.
E-mail address: yonibuber@gmail.com (J. Buber).

http://dx.doi.org/10.1016/j.ijcard.2014.06.023
0167-5273/

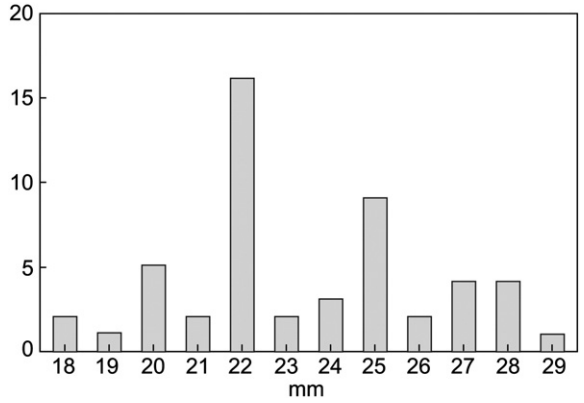

Fig. 1. Conduit diameters from a sample of 60 patients aged >18 at the time of conduit replacement surgery.

term RVOT conduits is used throughout this manuscript, although RVOT conduits and RV to PA conduits can be placed at different locations in the RV. (RVOT conduits are defined as conduits anastomosing between the apical part of the RV infundibulum and the PA's, whereas RV–PA conduits are conduits that connect the RV mass to the PA's.)

Only patients with a conduit diameter size of ≥18 mm were included, a size chosen based on an exploratory analysis on a random sample who underwent last RVOT conduit implantation at age ≥18 years (Fig. 1). This allowed patients with an "adult sized" conduit implanted at a younger age to be included in the analysis. Patients were included regardless of where the surgery was performed, but for purposes of adequate and complete data acquisition, follow-up visits and conduit-directed interventions (if performed) had to take place at our institution. Any type of conduit was allowed, yet patients with bioprosthetic valves without a conduit were excluded; accordingly, when a conduit is described as a "bioprosthetic valve" in this cohort, that always indicates a conduit that contains a bioprosthetic valve. Patients were also excluded if: 1) the pulmonary ventricle was a morphologic left ventricle; 2) the conduit was deliberately banded; or 3) demographic, clinical and follow-up data were incomplete.

Clinical, imaging, and interventional data from the follow-up period and from the time of conduit dysfunction and reintervention (if occurred) were collected from medical records. For outcome analysis, patients born with TOF (with/without pulmonary valve atresia) and those born with truncus arteriosus (TA) were grouped together due to similar surgical consideration and conduit location within the mediastinum.

The study protocol, including waiver of consent for retrospective medical record review and angiographic reviews, was approved by the Institutional Committee for Clinical Investigation.

2.2. Definitions

The "index surgery", the surgery in which the first conduit ≥18 mm in diameter was placed, was considered as "time zero" for freedom from event analyses. The internal conduit diameters were recorded from manufacturer specifications; nominal diameters were used for homograft conduits. The "last" echocardiographic and MRI studies were the latest studies obtained during follow-up, or the last prior to conduit-related intervention (if performed).

Mild conduit (pulmonary) regurgitation (PR) was defined as one or both of the following: regurgitant jet width <1/3 of the width of the RVOT diameter and retrograde pressure drop maintained throughout diastole. Moderate PR was defined as one or both of the following: jet width between 1/3 and 2/3 of the RVOT and equilibration between pulmonary artery and RV pressures in late diastole. Severe PR was defined as one or more of the following: jet width >2/3 of RVOT, regurgitation duration/total diastole duration ratio >0.77, pressure half time <100 ms or presence of diastolic flow reversal in branch pulmonary arteries [10–12]. Severe conduit (pulmonary) stenosis (PS) was defined as a mean Doppler gradient >40 mm Hg [13].

The presence of branch pulmonary stenosis (unilateral or bilateral) was determined based on either an echocardiogram or an MRI study, when such was obtained. Severity was determined based on both the cross sectional area and the relative flow (in unilateral stenosis) as demonstrated by either lung perfusion scans or differential flow evaluation in patients who had MRI studies.

Hypertension and diabetes were defined in accordance with the corresponding guidelines at the time of the clinic visit. Renal dysfunction was defined as glomerular filtration rate <60 ml/min. Lifestyle habits, including smoking, were recorded during all clinic visits via either verbal or written questionnaires.

2.3. Statistical analysis

The primary endpoint of this study was hemodynamically significant conduit dysfunction, defined as severe PS and/or severe PR. Additional outcomes evaluated included conduit-related reintervention (surgical or percutaneous) and death and heart transplantation. For patients who underwent non-valved conduit implantation at the index surgery, time to reintervention was the only primary endpoint, given the free PR that per definition exists after utilization of these conduits at surgery. Continuous demographic, clinical, and procedure-related data are presented as median (minimum–maximum, interquartile range). Categorical data are presented as frequencies and percentages. Time-related outcomes including freedom from hemodynamic conduit dysfunction and freedom from conduit-directed reintervention, as defined above, were depicted with Kaplan–Meier curves. Patients not experiencing the primary endpoint were censored event-free at the time of the last clinical evaluation within the study period, death, or reintervention undertaken before the occurrence of conduit dysfunction. Demographic, historical, procedural and diagnostic features were assessed for association with time-related outcomes using the log-rank test. Age at the time of surgery was evaluated both by quartile and as a continuous variable by 1-year increments. Body mass index (BMI) at the last follow-up visit/visit prior to diagnosis of conduit dysfunction was evaluated as a continuous variable with 1 kg/m^2 increments. Interaction-term analysis was carried to assess the probability of survival without conduit dysfunction by conduit diameter group among patients within the 4 age quartile groups by including an interaction term for conduit diameter (18–20, 21–24, and >24 mm). Interactions with age quartile were similarly performed for type of conduit (homografts and bioprosthetic valved conduits), BMI, and native anatomy (TOF + TA, D-loop transposition of the great vessels, conduit after Ross procedure, and other). Multivariable Cox regression analysis was performed with forward stepwise selection of covariates that were significant to p less than 0.10 on univariable analysis or were deemed to have important clinical significance by the

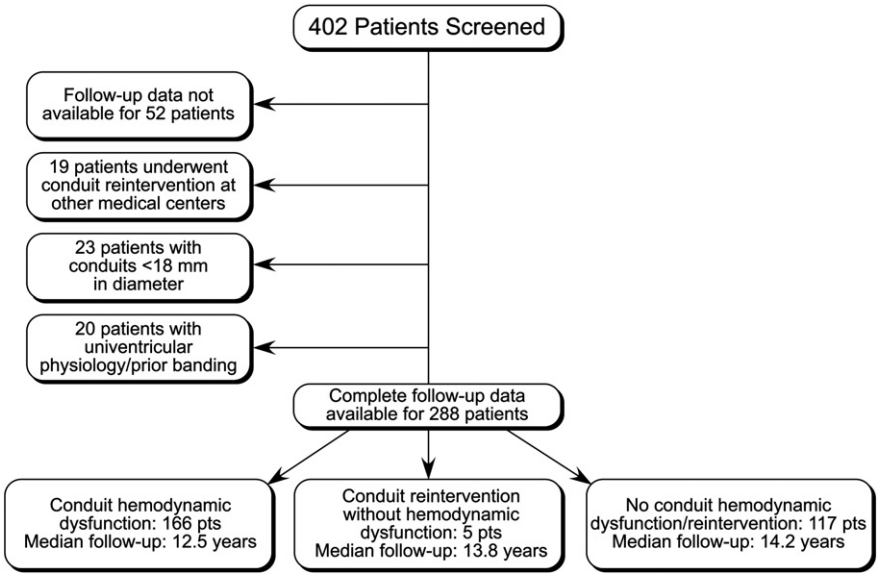

Fig. 2. Flow chart depicting inclusion/exclusion of patients aged >18 years with conduits measuring ≥18 mm in diameter.