International Journal of Cardiology 223 (2016) 639–644

Contents lists available at ScienceDirect

International Journal of Cardiology

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

Right ventricular function following surgical aortic valve replacement and transcatheter aortic valve implantation: A cardiovascular MR study

Tarique Al Musa BSc MBBS [a], Akhlaque Uddin BSc MBChB [a], Timothy A. Fairbairn PhD [a], Laura E. Dobson MBChB [a], Christopher D. Steadman MD [b], Ananth Kidambi BMBCh PhD [a], David P. Ripley BSc MBChB [a], Peter P. Swoboda MBBS, PhD [a], Adam K. McDiarmid MBBS [a], Bara Erhayiem BMBS [a], Pankaj Garg MBBS [a], Daniel J. Blackman MD [c], Sven Plein MD, PhD [a], Gerald P. McCann MBChB, MD [b], John P. Greenwood MBChB, PhD [a,*]

[a] Multidisciplinary Cardiovascular Research Centre & The Division of Cardiovascular and Diabetes Research, Leeds Institute for Cardiovascular and Metabolic Medicine, University of Leeds, Leeds, UK
[b] Department of Cardiovascular Sciences, University of Leicester, Cardiovascular Research Centre and the National Institute of Health Research (NIHR), Cardiovascular Biomedical Research Unit, Glenfield General Hospital, Leicester, UK
[c] Leeds Teaching Hospitals NHS Trust, Leeds General Infirmary, Leeds, UK

ARTICLE INFO

Article history:
Received 25 March 2016
Received in revised form 1 August 2016
Accepted 3 August 2016
Available online 7 August 2016

Keywords:
Aortic stenosis
Transcatheter aortic valve implantation
Aortic valve replacement
Right ventricular function
Cross-clamp time

ABSTRACT

Objective: The response of the RV following treatment of aortic stenosis is poorly defined, reflecting the challenge of accurate RV assessment. Cardiovascular magnetic resonance (CMR) is the established reference for imaging of RV volumes, mass and function. We sought to define the impact of transcatheter aortic valve implantation (TAVI) and surgical aortic valve replacement (SAVR) upon RV function in patients treated for severe aortic stenosis using CMR.

Methods: A 1.5T CMR scan was performed preoperatively and 6 months postoperatively in 112 (56 TAVI, 56 SAVR; 76 ± 8 years) high-risk severe symptomatic aortic stenosis patients across two UK cardiothoracic centres.

Results: TAVI patients were older (80.4 ± 6.7 vs. 72.8 ± 7.2 years, $p < 0.05$) with a higher STS score (2.13 ± 0.73 vs. 5.54 ± 3.41%, $p < 0.001$). At 6 months, SAVR was associated with a significant increase in RV end systolic volume (33 ± 10 vs. 37 ± 10 ml/m^2, $p = 0.008$), and decrease in RV ejection fraction (58 ± 8 vs. 53 ± 8%, $p = 0.005$) and tricuspid annular plane systolic excursion (22 ± 5 vs. 14 ± 3 mm, $p < 0.001$). Only 4 (7%) SAVR patients had new RV late gadolinium hyper-enhancement with no new cases seen in the TAVI patients at 6 months. Longer surgical cross-clamp time was the only predictor of increased RV end systolic volume at 6 months. Post-TAVI, there was no observed change in RV volumes or function. Over a maximum 6.3 year follow-up, 18(32%) of TAVI patients and 1(1.7%) of SAVR patients had died ($p = 0.001$). On multivariable Cox analysis, the RV mass at 6 m post-TAVI was independently associated with all-cause mortality (HR 1.359, 95% CI 1.108–1.666, $p = 0.003$).

Conclusions: SAVR results in a deterioration in RV systolic volumes and function associated with longer cross-clamp times and is not fully explained by suboptimal RV protection during cardiopulmonary bypass. TAVI had no adverse impact upon RV volumes or function.

Abbreviations: AR, aortic regurgitation; AVA, aortic valve area; CABG, coronary artery bypass grafting; CMR, cardiovascular magnetic resonance; EuroSCORE, European System for Cardiac Operative Risk Evaluation; LGE, late gadolinium enhancement; LVEF, left ventricular ejection fraction; MI, myocardial infarction; MR, mitral regurgitation; NYHA, New York Heart Association; PCI, percutaneous coronary intervention; RVEF, right ventricular ejection fraction; RVESVI, right ventricular end systolic volume index; RVEDVI, right ventricular end diastolic volume index; SAVR, surgical aortic valve replacement; STS, Society of Thoracic Surgeons' risk model; TAVI, transcatheter aortic valve implantation.

* Corresponding author at: Multidisciplinary Cardiovascular Research Centre, Leeds Institute for Cardiovascular and Metabolic Medicine, University of Leeds, LS2 9JT, UK.
E-mail addresses: t.a.musa@leeds.ac.uk (T.A. Musa), a.uddin@leeds.ac.uk (A. Uddin), timothy.fairbairn@lhch.nhs.uk (T.A. Fairbairn), l.dobson@leeds.ac.uk (L.E. Dobson), chris.steadman@poole.nhs.uk (C.D. Steadman), a.kidambi@leeds.ac.uk (A. Kidambi), d.ripley@leeds.ac.uk (D.P. Ripley), p.swoboda@leeds.ac.uk (P.P. Swoboda), a.k.mcdiarmid@leeds.ac.uk (A.K. McDiarmid), b.erhayiem@leeds.ac.uk (B. Erhayiem), p.garg@leeds.ac.uk (P. Garg), daniel.blackman1@nhs.net (D.J. Blackman), s.plein@leeds.ac.uk (S. Plein), gerry.mccann@uhl-tr.nhs.uk (G.P. McCann), j.greenwood@leeds.ac.uk (J.P. Greenwood).

http://dx.doi.org/10.1016/j.ijcard.2016.08.065
0167-5273/

1. Introduction

Surgical aortic valve replacement (SAVR) is first-line therapy for symptomatic patients with severe aortic valve stenosis. Transcatheter aortic valve implantation (TAVI) has emerged as a clinical and cost-effective treatment for patients deemed inoperable or with too high predicted mortality [1]. Reverse remodelling of the left ventricle observed following both TAVI and SAVR has been well documented [2]. However, much less is understood about the response of the right ventricle (RV) in these settings.

RV dysfunction is thought to occur following cardiac surgery for both valvular [3] and coronary disease [4] and is an independent predictor of late survival and adverse clinical outcomes [5]. The precise mechanism of this dysfunction remains to be elucidated; a number of theories have been proposed based on conflicting evidence. The EuroSCORE II and the STS models for calculating operative mortality of cardiac surgery do not incorporate preoperative RV dysfunction, despite its' association with a high mortality [6]. This in part reflects the challenging nature of reliably evaluating RV performance [7] with its asymmetric and variable 3D geometry.

Cardiovascular magnetic resonance (CMR) is the established reference modality for imaging of both left and right ventricular volumes and function. CMR affords reproducible 3D volume acquisition, can image in any plane, has excellent blood-tissue contrast and can detect subtle wall motion abnormalities [8].

Studies directly comparing the impact of SAVR with TAVI upon RV function are limited [6,9,10] and have depended upon 2D transthoracic echocardiographic (TTE) parameters with relatively short follow-up. This study was designed specifically to determine the impact of SAVR and TAVI upon RV performance using CMR at 6 months. We hypothesised that SAVR, but not TAVI (which obviates the need of cardiopulmonary bypass and pericardiotomy), would be associated with decline in RV function. Furthermore, we sought to elucidate potential mechanisms, by defining the contribution of procedural factors and CMR derived parameters to any observed change in RV performance.

2. Methods

2.1. Study population

This study prospectively recruited 167 patients with severe trileaflet degenerative AS (TTE valve area ≤ 1.0 cm^2 or peak velocity > 4 m/s) who were referred for either TAVI (n = 101) or SAVR (n = 66) at the University Hospitals of Leeds and Leicester, UK, between July 2008 and December 2013. Higher-risk (higher EuroSCORE) SAVR patients were recruited in preference to ensure that baseline demographics were more comparable to the TAVI group. Exclusion criteria included any contraindication to CMR. The study was approved by a national ethics committee, complied with the Declaration of Helsinki and all patients provided written informed consent.

2.2. Transcatheter aortic valve implantation

TAVI was performed under general anaesthesia. Either an 18F CoreValve Revalving system (CVR, Medtronic, Minneapolis, Minnesota, USA) or an 18F or 20F Lotus™ Aortic Valve system (Boston Scientific Corporation, Natick, MA, USA) were deployed.

2.3. Surgical aortic valve replacement

SAVR was performed by standard midline sternotomy with cardiopulmonary bypass and mild hypothermia. Biological or mechanical prostheses of varying sizes were used according to surgical preference; concomitant coronary artery bypass grafting (CABG) was performed as indicated.

2.4. CMR protocol

For each individual patient, identical baseline preoperative and 6 month postoperative scans were performed on the same 1.5T MRI vendor platform (Intera, Phillips Healthcare, Best, Netherlands or Avanto, Siemens Medical Systems, Erlangen, Germany). Both sites used the identical CMR protocol as previously described [2].

2.5. CMR image analysis

Image analysis was performed blinded off-line, using commercially available software (QMass 7.5 and QFlow 7.2, Medis Medical Imaging Systems, Leiden, The Netherlands – used for LV and RV chamber quantification and valvular haemodynamics; CVI42, Circle Cardiovascular Imaging, Calgary, Alberta, Canada – used for assessment of LGE). Standard ventricular and valvular assessment was performed as previously described [2].

For patients in normal sinus rhythm, the left atrium emptying fraction was determined, defined as $(LAVol_{max} - LAVol_{min}) \times 100 / LAVol_{max}$. Similarly, the right atrium emptying fraction was determined, defined as $(RAVol_{max} - RAVol_{min}) \times 100 / RAVol_{max}$.

The tricuspid annular plane systolic excursion (TAPSE) was measured as the maximum apical displacement of the lateral tricuspid valve annulus from end-diastole to end-systole (Fig. 1A and B). Delayed late gadolinium enhanced images were reviewed by two experienced observers for focal myocardial fibrosis and scarring (secondary to infarction) and then reported qualitatively, as either present or absent, and, for the LV, quantified using the full-width half-maximum technique.

2.6. Statistical analysis

Based on published data, 45 patients per group were required to detect a 7 ml change in RVEDV or 2% difference in EF between the two treatments (80% power and an α error of 0.05) [8]. Continuous variables are presented as mean ± SD. Normality was determined by the Shapiro–Wilk test. Frequencies are reported as number (%). The Student *t*-test and Wilcoxon signed rank test were used for continuous variables. Changes over time were assessed for differences between the treatment groups and clinical variables by two-way repeated measures ANOVA. Predictors of functional change were calculated by a stepwise multiple linear regression model with baseline measurements entered as covariates. Variables with a univariate $p < 0.05$ were deemed significant. All statistical analyses were performed using the PASW software package (V.21.0 SPSS, IBM, Chicago, Illinois, USA), with a two-sided significance level of $p < 0.05$ considered statistically significant. Intra-observer (12 data sets 6 months apart) and inter-observer (12 data sets) agreement was assessed and expressed as coefficient of variation.

3. Results

3.1. Patient population

A total of 112 patients (56 TAVI and 56 SAVR) completed both preoperative and 6 month post-operative scans. Reasons for non-completion of the CMR protocol were varied (Fig. 2). Baseline characteristics of the final study population are reported in Table 1. TAVI patients were older, with a higher STS score and greater frequency of coronary intervention. There was no difference in baseline pulmonary pressure, as estimated by echocardiography, between the two intervention groups ($p = 0.159$).

3.2. Procedural data

For the TAVI group, 46(82%) patients received a Medtronic CoreValve and 10(18%) a Boston Scientific Lotus valve. The femoral artery was the route of access for 51(91%) patients. Three TAVIs were performed via the subclavian artery, one via the carotid artery and one via a direct aortic approach. Procedural success was 100% with an average catheterisation time of 162 ± 53 min, fluoroscopy time 25 ± 7 min and 147 ± 50mls of contrast agent. One patient had concomitant PCI at the time of TAVI.

For the surgical group, seven patients received a mechanical prosthesis and the remaining 49(88%) a tissue bioprosthesis. Sixteen (29%) received concomitant CABG, of which 9 involved use of the left internal mammary artery. None of the surgical patients received a concomitant tricuspid or mitral valve annuloplasty ring and none underwent surgical closure of the pericardium. For the group as a whole, the average bypass time was 104 ± 47 min and cross clamp time 76 ± 40 min. The average length of stay in intensive care was 3.1 ± 2.5 days.

3.3. Haemodynamics, valvular function and LV reverse remodelling

Baseline and follow-up CMR scan results are shown in Table 2. Comparable degrees of reduction in aortic valve gradient and LV reverse remodelling were seen following TAVI and SAVR.