

UCSF

UC San Francisco Previously Published Works

Title

Meta-analysis of right ventricular function in patients with aortic stenosis after transfemoral aortic valve replacement or surgical aortic valve replacement

Permalink

<https://escholarship.org/uc/item/8jz2q147>

Authors

Cao, Yunshan
Singh, Vikas
Wang, Aqian
[et al.](#)

Publication Date

2020

DOI

10.1177/2040622320933775

Peer reviewed

Meta-analysis of right ventricular function in patients with aortic stenosis after transfemoral aortic valve replacement or surgical aortic valve replacement

Yunshan Cao*, Vikas Singh*, Aqian Wang*, Liyan Zhang^{id}, Tingting He, Hongling Su, Rong Wei, Yichao Duan^{id}, Kaiyu Jiang, Wenyu Wu, Yan Huang, Sammy Elmariah, Guanming Qi, Xin Su, Yan Zhang and Min Zhang

Abstract

Background: Right ventricular function (RVF) is an independent predictor of prognosis for patients undergoing aortic valve replacement: transcatheter aortic valve replacement (TAVR) or surgical aortic valve replacement (SAVR). The effect of transfemoral aortic valve replacement (TF-TAVR) on RVF is uncertain. We aimed to perform a meta-analysis of the effect of TF-TAVR on RVF in patients with aortic stenosis (AS) and compare the effect of TF-TAVR with SAVR.

Methods: We searched relevant studies from PubMed, Embase, Cochrane Library databases, and Web of Science. Furthermore, two reviewers (Wang AQ and Cao YS) extracted all relevant data, which were then double checked by another two reviewers (Zhang M and Qi GM). We used the forest plot to present results. Tricuspid annular plane systolic excursion (TAPSE) was the primary outcome.

Results: This meta-analysis included 11 studies. There were 353 patients who underwent TF-TAVR, and 358 patients who were subjected to SAVR. There was no significant difference in TAPSE at 1 week and 6 months as well as right ventricular ejection fraction (RVEF) at <2 weeks and 6 months after TF-TAVR. For the SAVR group, TAPSE at 1 week and 3 months as well as fractional area change (FAC) at 3 months post procedure were significantly aggravated, while RVEF did not change significantly. Moreover, TAPSE post-TF-TAVR was significantly improved as compared with post-SAVR. The Δ TAPSE, the difference between TAPSE post-procedure and TAPSE prior to procedure, was also significantly better in the TF-TAVR group than in the SAVR group.

Conclusion: RVF was maintained post TF-TAVR. For SAVR, discrepancy in the measured parameters exists, as reduced TAPSE indicates compromised longitudinal RVF, while insignificant changes in RVEF implicate maintained RVF post procedure. Collectively, our study suggests that the baseline RV dysfunction and the effect of TF-TAVR *versus* SAVR on longitudinal RVF may influence the selection of aortic valve intervention.

Keywords: aortic valve stenosis, AS, right ventricle, right ventricular function, SAVR, surgical aortic valve replacement, TAVI, TAVR, TF-TAVR, transcatheter aortic valve implantation, transcatheter aortic valve replacement, transfemoral-aortic valve replacement

Received: 11 November 2019; revised manuscript accepted: 12 May 2020.

Ther Adv Chronic Dis

2020, Vol. 11: 1–15

DOI: 10.1177/
2040622320933775

© The Author(s), 2020.
Article reuse guidelines:
sagepub.com/journals-
permissions

Correspondence to:

Yunshan Cao
Department of Cardiology,
Gansu Provincial Hospital,
No. 204, Donggang West
Road, Chengguan District,
Lanzhou, Gansu 730000,
China

Department of Cardiology,
Shanxi Cardiovascular
Hospital affiliated with
Shanxi Medical University,
Taiyuan, China
yunshancao@126.com

Min Zhang
Department of Pathology,
Gansu Provincial Hospital,
No.204, Donggang West
Road, Chengguan District,
Lanzhou, Gansu 730000,
China
sallyzhangmin@126.com

Yan Zhang
Tianjin Key Laboratory of
Retinal Functions
and Diseases,
Tianjin International
Joint Research and
Development Center of
Ophthalmology and Vision
Science, Eye Institute
and School of Optometry,
Tianjin Medical University
Eye Hospital, No. 251,
Fukang Road, Nankai
District, Tianjin, China
yanzhang04@tjmu.edu.cn

Vikas Singh
Division of Cardiovascular
Medicine, University
of Louisville School of
Medicine, Louisville, KY,
USA

Aqian Wang
Hongling Su
Rong Wei
Yan Huang
Department of Cardiology,
Gansu Provincial Hospital,
Lanzhou, China

Liyan Zhang
Tingting He
Kaiyu Jiang
Xin Su
Clinical Medicine School,
Gansu University of
Chinese Medicine,
Lanzhou, China

Yichao Duan

Wenyu Wu

School of Clinical
Medicine, Ningxia Medical
University, Ningxia, China

Sammy Elmariah

Cardiology Division,
Department of Medicine,
Massachusetts General
Hospital, Harvard Medical
School Boston, MA, USA

Guanming Qi

Pulmonary and Critical
Care Division, Tufts
Medical Center, Boston,
MA, USA

*These authors
contributed equally.

Introduction

Aortic stenosis (AS) is the most prevalent acquired valvular disorder, affecting up to 4% of the elderly population and associating with significant morbidity and mortality.^{1–3} Surgical aortic valve replacement (SAVR) has been the conventional treatment of choice for patients with severe AS. Over the past decade, transcatheter aortic valve replacement (TAVR) has emerged as an effective alternative for patients at intermediate, high, or prohibitive risk of ongoing SAVR.^{4–6} TAVR is extensively performed worldwide and reduced rates of mortality and re-hospitalization in operable patients when compared with optimal medical treatment.⁴ In patients with severe AS and reduced left ventricular ejection fraction (LVEF), TAVR attains better recovery of EF than SAVR.⁷

Right ventricular dysfunction is a well-recognized adverse prognostic factor in patients with SAVR.⁸ In addition, right ventricular function (RVF) may further deteriorate after SAVR.⁹ The influence of RVF on TAVR and the effect of TAVR on RVF are currently uncertain. This is partly due to the complex geometry of right ventricle and the lack of a widely accepted and generally applicable index for measurement of RVF.¹⁰ Furthermore, RV size and function are not routinely measured or reported with outcomes of TAVR.¹¹ Of all the possible access sites, transfemoral transcatheter aortic valve replacement (TF-TAVR) accounts for 96% of the TAVR cases.¹² A recent meta-analysis showed that TAPSE remained unchanged following the TF-TAVR, but reduced significantly after the transapical TAVR (TA-TAVR) at the time of hospital discharge.¹³ The purpose of the current meta-analysis is to evaluate the effect of TF-TAVR as opposed to SAVR on RVF in patients with severe AS.

Methods

Data sources and search strategy

We searched the PubMed, Embase, the Web of Science and the Cochrane library for relevant articles published prior to February 14, 2020. The search strategy contained a mix of MeSH and free text terms for key concepts related to transcatheter aortic valve implantation, surgical aortic valve replacement, and RVF in patients with aortic valve stenosis. Searches were limited to the trials of human subjects, with no language

restriction. The detailed search strategy is shown in the electronic database search hedges in Appendix 1.

Study selection and eligibility criteria

Two investigators (Wang AQ and Cao YS) independently searched and critically selected the articles to ensure eligibility. We utilized the following criteria: (a) the procedure was performed in the patients diagnosed as AS (defined as the aortic valve area $<1\text{ cm}^2$ or the indexed aortic valve area $<0.06\text{ cm}^2/\text{m}^2$), and only human studies were included; (b) intervention was TF-TAVR and/or SAVR; (c) the outcome was RVF as assessed by echocardiography, cardiac magnetic resonance imaging, or radionuclide angiography. The measurements of RVF included tricuspid annular plane systolic excursion (TAPSE), right ventricular ejection fraction (RVEF), and fractional area change (FAC). The primary outcome was TAPSE, the secondary outcomes included RVEF and FAC. Studies were excluded if they met one of the following criteria: (a) duplicate publication, (b) case reports and animal studies, (c) correspondence and letter, (d) published as abstracts without specific data, (e) articles that did not match inclusion criteria, or (f) papers unrelated to the topic. There were no restrictions on follow-up period.

Data extraction and management

All selected articles were assessed by two reviewers (Wang AQ and Cao YS) for relevance and eligibility by scrutinizing titles and abstracts. Full texts were reviewed and data extracted in the relevant studies assessing RVF after aortic valve replacement. Methodological disagreements were resolved by a third reviewer (Zhang M). The patients' characteristics included the traits that may influence the outcome of procedure, such as age, sex, Society of Thoracic Surgeons Predicted Risk of Mortality, coronary artery bypass grafting, chronic obstructive pulmonary disease, and so forth.

Quality assessment

Two authors (Zhang LY and He TT) independently assessed the risk of bias of randomized controlled trials using the Cochrane Risk-of-Bias tool,¹⁴ which assesses the sequence generation, allocation

concealment, masking, and incomplete outcome data. The risk of bias in cohort and case-control studies was assessed using the Newcastle–Ottawa scale, which evaluates sample representativeness and size, representativeness of the cases as compared with control group, comparability between pre- and post-procedure as well as post-TF-TAVR and post-SAVR, ascertainment of AVR, and thoroughness of descriptive statistics reporting. The studies were judged as high risk of bias when assessment score was lower than three points, and as low risk of bias when the score was higher than three points. Another co-author (Wang AQ) resolved disagreements.

Statistical analysis and data synthesis

Meta-analysis was performed using RevMan 5.3 according to the *Cochrane Handbook*. The forest plot, the standard way to illustrate results of individual studies and meta-analysis, was used to present the results in our analyses. We used means, standard deviations (SDs), and *p* values to present outcomes.

We used funnel plots to assess the publication bias. A funnel plot is a scatter plot of the effect estimates from individual studies against a measure of each study's size. For the effect estimate, the accuracy increases with the sample size. In addition, effect estimates of the small sample distribute at the bottom of the figure with a wide range; in contrast, the range of the big sample is narrow. A symmetrical distribution of the studies' effect estimates in the funnel plot would suggest the absence of publication bias.

For the studies that were included in this meta-analysis but did not report SDs in the texts, we calculated the SDs after determining the correlation coefficient from a similar study. The correlation coefficient in the experimental group was calculated according to the following formula¹⁵:

$$\text{Corr}_E = \frac{\text{SD}_{E,\text{baseline}}^2 + \text{SD}_{E,\text{final}}^2 - \text{SD}_{E,\text{change}}^2}{2 \times \text{SD}_{E,\text{baseline}} \times \text{SD}_{E,\text{final}}}$$

(Corr_E = the correlation coefficient in the experimental group, E = experiment)

We then calculated $\text{SD}_{E,\text{final}}$ using the following formula¹⁵:

$$\text{SD}_{E,\text{final}} = \sqrt{\frac{\text{SD}_{E,\text{baseline}}^2 + \text{SD}_{E,\text{final}}^2}{- (2 \times \text{Corr} \times \text{SD}_{E,\text{baseline}} \times \text{SD}_{E,\text{final}})}}$$

The heterogeneity was assessed using Chi-square test ($p < 0.10$) and the I^2 value. When the study demonstrated heterogeneity using $I^2 > 50\%$, we selected the random-effects model. Otherwise, we chose the fixed-effects model. The vertical dashed line on the forest plot represents an invalid line. The size of each box is proportional to the weight of the trial result. Diamonds represent the 95% confidence interval for the pooled estimates of the effect. The dashed vertical line through the middle of the diamond is the mean estimate of the meta-analysis and provides a reference line for an individual study.

Results

Study selection

We initially found 1537 articles by systematic literature search. After removing duplicates (316), there were 1221 studies to be screened for title and abstract. After irrelevant studies, case reports, animal studies, response to letter, meeting abstracts, reviews and meta-analyses were removed, 87 articles were evaluated in full-text. Irrelevant, correspondence only, abstracts without relevant data, articles that did not meet inclusion criteria or papers unrelated to the topic were then excluded. Finally, 11 studies met the inclusion criteria and were included in this meta-analysis (Figure 1).^{12,16–25}

The search for the meta-analysis was performed on February 14, 2020. Study descriptions and patient characteristics are summarized in Tables 1 and 2 as well as Supplemental Tables 1 and 2 online. The studies were published from 1990 to 2016. The age of all the patients who underwent TF-TAVR or SAVR ranged from 61 to 88 years old. There were 353 patients who underwent TF-TAVR; 358 patients underwent SAVR. All patient characteristics were collected.

The outcomes of RVF in the selected studies are shown in Tables 3 and 4. All trials' follow-up time included pre-procedure and post-procedure, and quantitative data were presented as mean \pm SD. The longest follow-up time was 6 months after procedure. Echocardiogram was

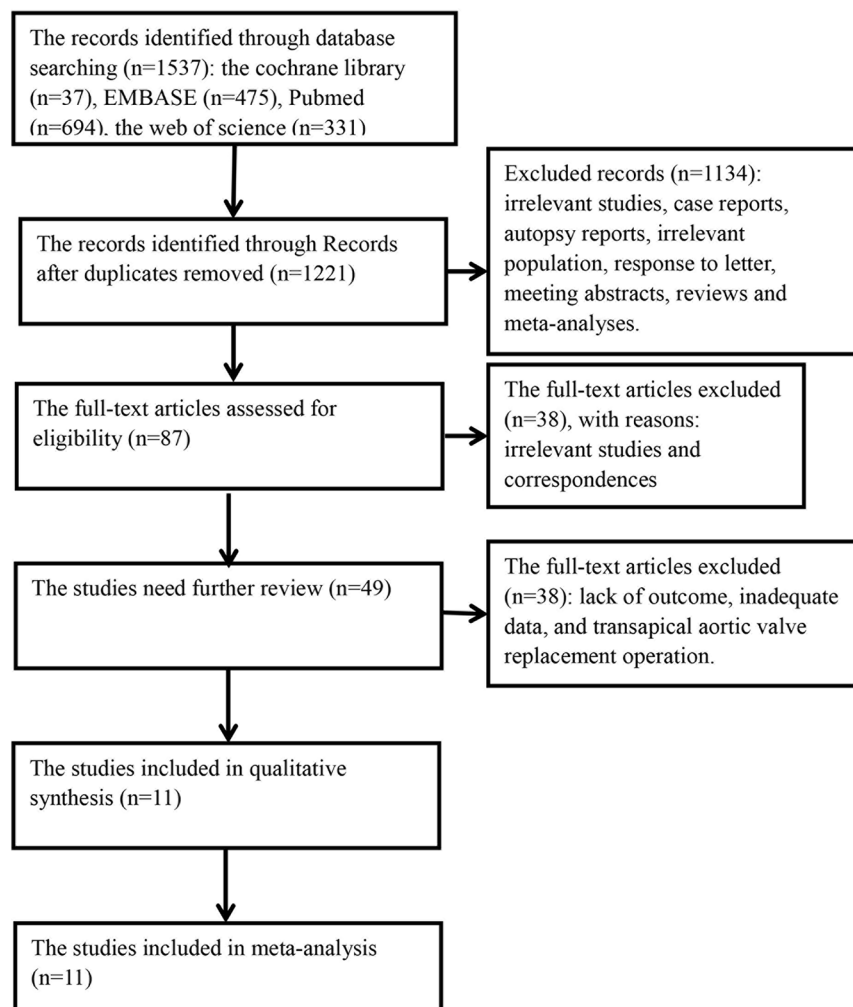


Figure 1. Flow diagram of literature search and study selection.

the most common method to measure RVF whereas three studies used cardiac magnetic resonance imaging and one used radionuclide angiocardiography.

Quality assessment

The quality of the included studies was assessed by the Cochrane Risk-of-Bias tool and shown in Supplemental Figure 1. Two trials^{12,18} did not report allocation concealment, and it was unclear how the random sequence was generated and whether there were incomplete outcome data. The Newcastle–Ottawa score components for eight cohort studies are shown in Supplemental Table 3. Eight studies^{16,17,19–24} were of high quality. All cohort studies^{16,17,19–24} did not report the

representativeness of the exposed cohort. Only two studies^{17,21} followed up long enough (≥ 6 months) to observe the outcomes. The Newcastle–Ottawa score components for case–control study are listed in Supplemental Table 4. The study was of high quality,²⁵ but it did not report the representativeness of the cases, selection of controls, and ascertainment of AVR.

Meta-analysis of RVF in patients with AS after TF-TAVR

The primary outcome. As compared with the TAPSE level pre-procedure, there were not significant differences in TAPSE at 1 week (including <8 days, 5–7 days, and 1 week; Figure 2) and 6 months (Figure 3) post TF-TAVR.

Table 1. Characteristics of transfemoral transcatheter aortic valve replacement studies.

Study	n	Patient selection	Age, years	Male	Pre-AVA, cm ²	Euro SCORE	STS score	STS mortality	NYHA			
									I	II	III	IV
Quick <i>et al.</i> ¹⁶	74	Severe and symptomatic AS	80.5 ± 4.9	27	<1	21.2 ± 10.4	8.6 ± 4.9	NR	35			39
Ayhan <i>et al.</i> ¹⁷	50 ^a	Severe calcified AS	78.1 ± 8.5	21	0.62 ± 0.17	22.2 ± 15.4	6.8 ± 5.0	NR	0	2	31	17
Okada <i>et al.</i> ¹⁸	13	Severe AS	82.4 ± 4.3	6	NR	NR	NR	NR	NR	NR	NR	NR
Crouch <i>et al.</i> ¹⁹	26	Severe AS	84.6 ± 5.6	17	NR	NR	7.7 ± 3.9	NR	2.5 ± 0.8			
Keyl <i>et al.</i> ²⁰	20	AS	83.0 ± 6.0	7	NR	11.9 ± 5.8	11.4 ± 9.4	NR	NR	NR	NR	NR
Musa <i>et al.</i> ²¹	56 ^b	Severe trileaflet degenerative AS	80.4 ± 6.6	32	0.60 ± 0.2	NR	NR	5.54 ± 3.41	NR	NR	NR	NR
Gronlykke <i>et al.</i> ¹²	114 ^c	Isolated severe AS	79.0 ± 5.1	64	NR	8.2 ± 4.1	3.0 ± 1.7	NR	5	54	53	2

Data presented as mean ± standard deviation, or number.

^aIncluded two patients who underwent trans-subclavian artery transcatheter aortic valve replacement (TAVR).

^bIncluded four patients who underwent trans-subclavian artery TAVR.

^cIncluded three patients who underwent trans-subclavian artery TAVR, one patient who underwent trans-carotid artery TAVR and one patient who underwent direct trans-aortic TAVR. AS, aortic stenosis; NR, not reported; NYHA, New York Heart Association; pre-AVA, pre-operation aortic valve area; STS, Society of Thoracic Surgery

Table 2. Characteristics of surgical aortic valve replacement studies.

Study	n	Patient selection	Age, years	Male	Pre-AVR, cm ²	Euro SCORE	STS score	STS mortality	NYHA I	NYHA II	NYHA III	NYHA IV
Harpole and Jones ²⁴	11	AS	62 ± 15	NR	0.7 ± 0.2	NR	NR	NR	NR	NR	7	
Sandstede <i>et al.</i> ²⁵	14	AS	64 ± 10	12	0.7 ± 0.2	NR	NR	NR	NR	NR	NR	NR
Zhao <i>et al.</i> ²²	30	Symptomatic, severe AS	62 ± 11	19	NR	4.0 ± 2.1	NR	NR	1	17	12	0
Kempny <i>et al.</i> ²³	22	Symptomatic, severe AS	71 ± 12	8	0.73 ± 0.24	7.2 ± 4.7	NR	NR	1	4	17	0
Quick <i>et al.</i> ¹⁶	63	Symptomatic, severe AS	73.8 ± 8.1	22	NR	6.5 ± 3.7	2.2 ± 1.8	NR	40		23	
Okada <i>et al.</i> ¹⁸	15	Severe AS	79.6 ± 5.9	9	NR	NR	NR	NR	NR	NR	NR	NR
Crouch <i>et al.</i> ¹⁹	21	Severe AS	79.6 ± 4.0	8	NR	NR	5.9 ± 3.4	NR	2.7 ± 0.6			
Gronlykke <i>et al.</i> ¹²	106	Isolated severe AS	78.4 ± 4.7	58	NR	8.7 ± 4.1	3.2 ± 1.7	NR	3	57	42	4
Keyl <i>et al.</i> ²⁰	20	AS	77 ± 4	9	NR	7.0 ± 3.3	10.7 ± 4.1	NR	NR	NR	NR	NR
Musa <i>et al.</i> ²¹	56	Severe trileaflet degenerative AS	72.8 ± 7.2	38	0.82 ± 0.4	NR	NR	2.13 ± 0.73	NR	NR	NR	NR

Data presented as mean ± standard deviation, or number.

AS, aortic stenosis; NR, not reported; NYHA, New York Heart Association; pre-AVA, pre-operation aortic valve area; STS, Society of Thoracic Surgery

Table 3. Right ventricular function of pre- and post-transfemoral transcatheter aortic valve replacement.

Study	Measure method	n	TAPSE (mm)		RVEF (%)		FAC (%)		
			Pre-	Post- <2 ws 3-6 ms	Pre-	Post- <2 ws 3-6 ms	Pre-	Post- <2 ws 3-6 ms	
Quick <i>et al.</i> ¹⁶	Echo	74	21.7 ± 5.0	22.1 ± 4.9 (<8ds)	NR	NR	NR	NR	
Ayhan <i>et al.</i> ¹⁷	Echo	50 ^a	16.8 ± 0.3	17.9 ± 0.3 (24h)	18.7 ± 0.2 (6ms) (n=47)	51.6 ± 10.1	53.7 ± 9.8 (24h)	45.3 ± 7.6	50.1 ± 9.3 (24h)
Okada <i>et al.</i> ¹⁸	Echo	13	18 ± 5	19 ± 5 (1w [#])	NR	NR	NR	35 ± 10	42 ± 10 (1w [#])
Crouch <i>et al.</i> ¹⁹	Echo/CMR	26	NR	NR	NR	61 ± 11	54 ± 13 (<2ws)	NR	NR
Keyl <i>et al.</i> ²⁰	3D echo	20	24 ± 5	24 ± 7 (5-7ds)	NR	54 ± 7	56 ± 8 (5-7 ds)	NR	NR
Musa <i>et al.</i> ²¹	CMR	56 ^b	19 ± 6	NR	19 ± 7 (6ms)	52 ± 10	NR	NR	52 ± 10 (6ms)
Gronlykke <i>et al.</i> ¹²	Echo	114 ^c	24 ± 5.1 (n=107)	NR	24 ± 4.9 (3ms) (n=107)	NR	NR	45 ± 9 (n=97)	NR

Data presented as mean ± standard deviation.
[#]Median.
^aIncluded two patients who underwent trans-subclavian artery transcatheter aortic valve replacement (TAVR).
^bIncluded four patients who underwent trans-subclavian artery TAVR.
^cIncluded three patients who underwent trans-subclavian artery TAVR, one patient who underwent trans-carotid artery TAVR and one patient who underwent direct trans-aortic TAVR.
 ds, days; FAC, fractional area change; ms, months; NR, not reported; RVEF, right ventricular ejection fraction; CMR, cardiac magnetic resonance imaging; TAPSE, tricuspid annular plane systolic excursion; ws, weeks

Table 4. Right ventricular function of pre- and post-surgical aortic valve replacement.

Study	Measure method	n	TAPSE (mm)		RVEF (%)		FAC (%)				
			Pre-	Post-	Pre-	Post-	Pre-	Post-			
Harpole and Jones ²⁴	Radionuclide	11	NR	NR	54 ± 13	64 ± 6 (18–24h)	58 ± 8 (3.5 ms)	NR	NR	NR	NR
Sandstede et al. ²⁵	MR	14	NR	NR	66 ± 10	NR	62 ± 10 (3 ms)	NR	NR	NR	NR
Zhao et al. ²²	Echo	30	21.6 ± 5.0	9.2 ± 3.2 (1 w)	NR	NR	NR	NR	NR	NR	NR
Kempny et al. ²³	Echo	22	24.1 ± 5.0	15.9 ± 4.1 (100 ds)	NR	NR	NR	47.0 ± 7.0	NR	NR	39.8 ± 10.7 (100 ds)
Quick et al. ¹⁶	Echo	63	23.7 ± 4.0	15.6 ± 2.9 (<8 ds)	NR	NR	NR	NR	NR	NR	NR
Okada et al. ¹⁸	Echo	15	18 ± 5	11 ± 7 (1 w [#])	NR	NR	NR	38 ± 12	-1 ± 5* (1 w [#])	NR	NR
Crouch et al. ¹⁹	Echo/CMR	21	NR	NR	59 ± 8	58 ± 8 (<2 ws)	NR	NR	NR	NR	NR
Keyl et al. ²⁰	3D echo	20	26 ± 4	13 ± 2 (5–7 ds)	NR	55 ± 7	55 ± 6 (5–7 ds)	NR	NR	NR	NR
Musa et al. ²¹	CMR	56	22 ± 5	NR	14 ± 3 (6 ms)	58 ± 8	NR	53 ± 9 (6 ms)	NR	NR	NR
Gronlykke et al. ¹²	Echo	106	24 ± 5.2 (n = 99)	NR	16 ± 4.2 (3 ms) (n = 91)	NR	NR	NR	44 ± 11 (n = 91)	NR	39 ± 10 (3 ms) (n = 72)

Data presented as mean ± standard deviation.

*Mean change.

#Median.

CMR, cardiac magnetic resonance imaging; ds, days; FAC, fractional area change; ms, months; NR, not reported; RVEF, right ventricular ejection fraction; TAPSE, tricuspid annular plane systolic excursion; ws, weeks

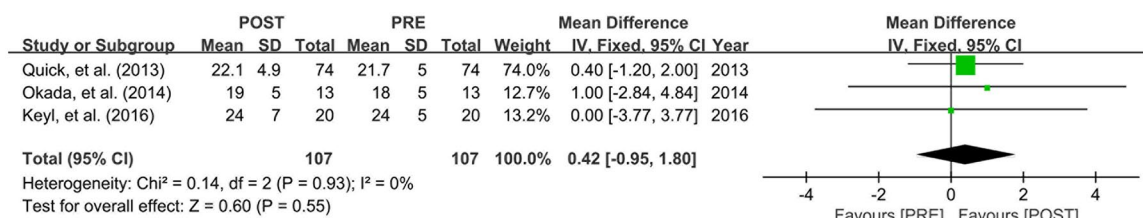


Figure 2. Fixed-effects meta-analysis of TF-TAVR post-procedure *versus* pre-procedure for the primary outcome of TAPSE at 1 week (including 5–7 days, 1 week and <8 days) follow-up. CI, confidence interval; IV, inverse variance; SD, standard deviation; TAPSE, tricuspid annular plane systolic excursion; TF-TAVR, transfemoral transcatheter aortic valve replacement

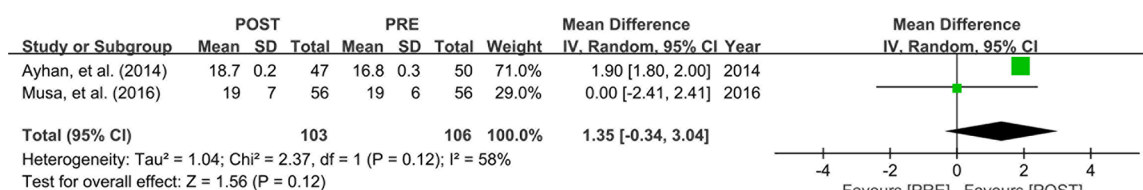


Figure 3. Random-effects meta-analysis of TF-TAVR post-procedure *versus* pre-procedure for the primary outcome of TAPSE at 6 month follow-up. CI, confidence interval; IV, inverse variance; SD, standard deviation; TAPSE, tricuspid annular plane systolic excursion; TF-TAVR, transfemoral transcatheter aortic valve replacement

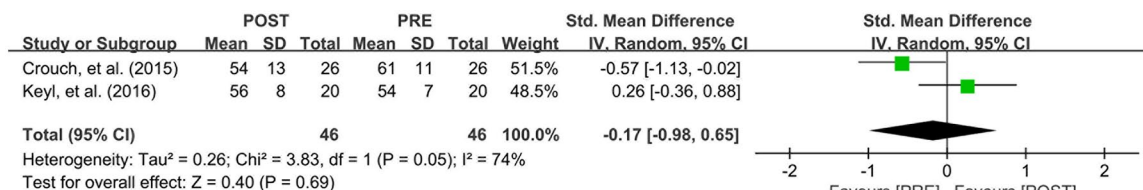


Figure 4. Random-effects meta-analysis of TF-TAVR post-procedure *versus* pre-procedure for the secondary outcome of RVEF at <2 week (including 5–7 days and <2 weeks) follow-up. CI, confidence interval; IV, inverse variance; RVEF, right ventricular ejection fraction; SD, standard deviation; TF-TAVR, transfemoral transcatheter aortic valve replacement

The secondary outcome. The RVEF at <2 weeks (including 5–7 days and <2 weeks; Figure 4) and 6 months (Figure 5) post TF-TAVR were not significantly different from those at the baseline, respectively.

Meta-analysis of RVEF in patients with AS after SAVR

The primary outcome. Compared with baseline, there was significant deterioration in TAPSE at 1 week (including <8 days, 5–7 days, and 1 week; Figure 6) and 3 months (including 100 days and 3 months; Figure 7) after SAVR.

The secondary outcome. The RVEF at <2 weeks (including 5–7 days and <2 weeks; Figure 8) and 3 months (including 3.5 months and 3 months; Figure 9) post SAVR did not significantly differ from the baseline levels, respectively; however, the FAC was significantly worse at 3 months (including 100 days and 3 months) post SAVR than that before SAVR (Figure 10).

Meta-analysis of RVEF in patients with AS after TF-TAVR versus SAVR

TAPSE post-TF-TAVR was significantly better than TAPSE post-SAVR at 1 week and 3–6 month

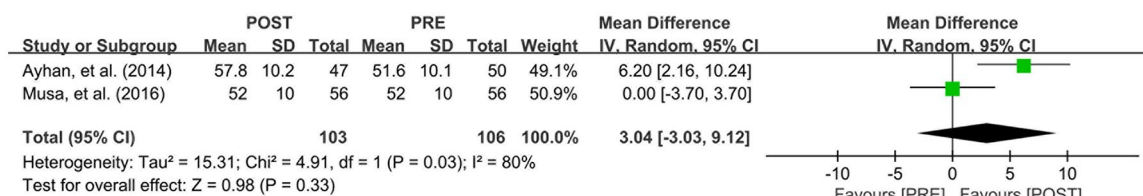


Figure 5. Random-effects meta-analysis of TF-TAVR post-procedure *versus* pre-procedure for the secondary outcome of RVEF at 6 month follow-up. CI, confidence interval; IV, inverse variance; RVEF, right ventricular ejection fraction; SD, standard deviation; TF-TAVR, transfemoral transcatheter aortic valve replacement

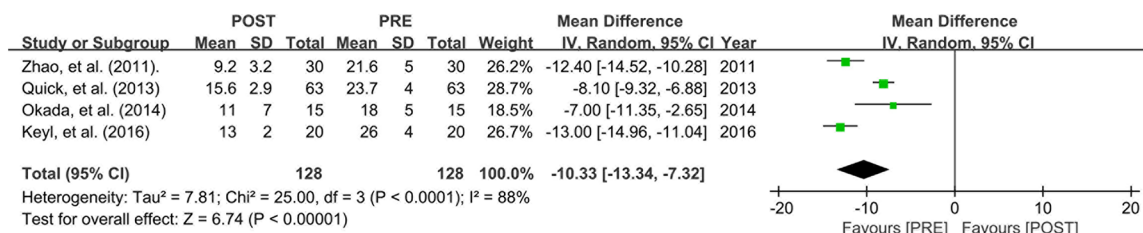


Figure 6. Random-effects meta-analysis of SAVR post-procedure *versus* pre-procedure for the primary outcome of TAPSE at 1 week (including 5–7 days, 1 week and <8 days) follow-up. CI, confidence interval; IV, inverse variance; SAVR, surgical aortic valve replacement; SD, standard deviation; TAPSE, tricuspid annular plane systolic excursion

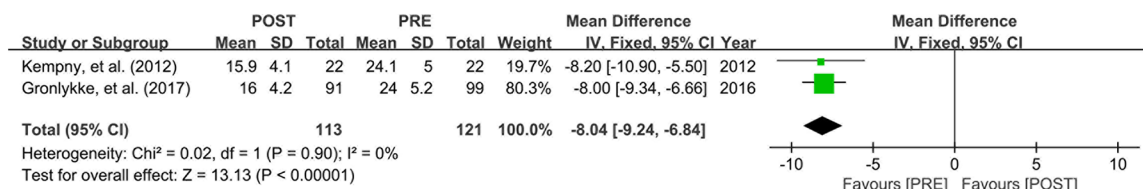


Figure 7. Fixed-effects meta-analysis of SAVR post-procedure *versus* pre-procedure for the primary outcome of TAPSE at 3 month (including 100 days and 3 months) follow-up. CI, confidence interval; IV, inverse variance; SAVR, surgical aortic valve replacement; SD, standard deviation; TAPSE, tricuspid annular plane systolic excursion

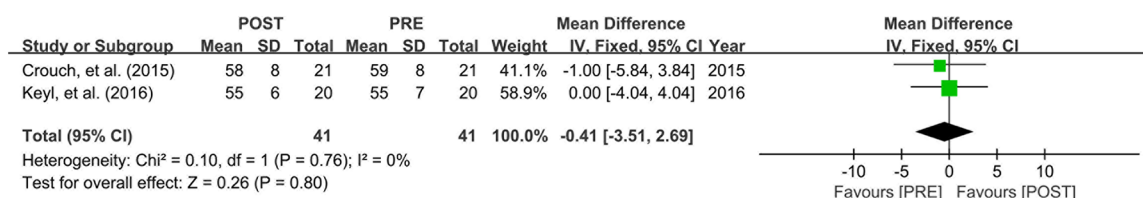


Figure 8. Fixed-effects meta-analysis of SAVR post-procedure *versus* pre-procedure for the secondary outcome of RVEF at <2 week (including 5–7 days and <2 weeks) follow-up. CI, confidence interval; IV, inverse variance; RVEF, right ventricular ejection fraction; SAVR, surgical aortic valve replacement; SD, standard deviation

follow-ups (Supplemental Figures 2 and 3). Furthermore, ΔTAPSE, the difference of TAPSE between post- and pre-procedure, was significantly

improved in TF-TAVR group in comparison with SAVR group at 1 week and 3–6 months following procedure (Figures 11 and 12).

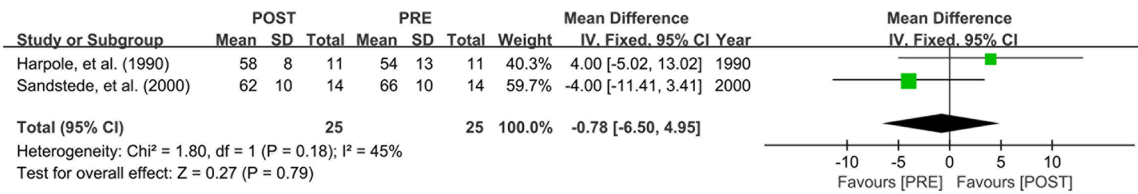


Figure 9. Fixed-effects meta-analysis of SAVR post-procedure *versus* pre-procedure for the secondary outcome of RVEF at 3 month (including 3.5 months and 3 months) follow-up. CI, confidence interval; IV, inverse variance; RVEF, right ventricular ejection fraction; SAVR, surgical aortic valve replacement; SD, standard deviation

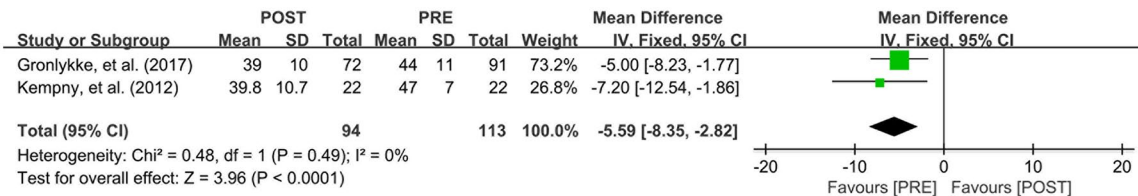


Figure 10. Fixed-effects meta-analysis of SAVR post-procedure *versus* pre-procedure for the secondary outcome of FAC at 3 month follow-up. CI, confidence interval; FAC, fractional area change; IV, inverse variance; SAVR, surgical aortic valve replacement; SD, standard deviation

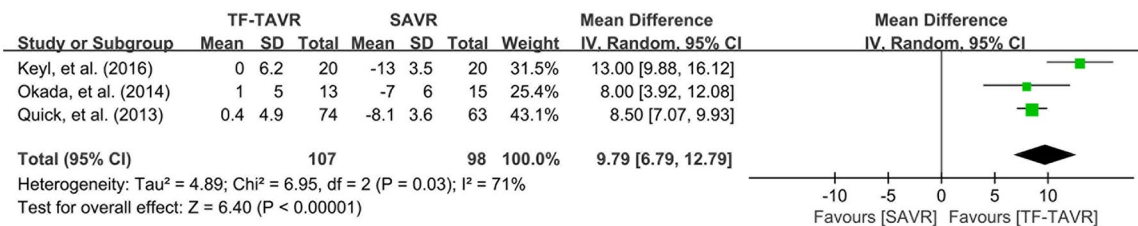


Figure 11. Random-effects meta-analysis of TF-TAVR *versus* SAVR for the primary outcome of ΔTAPSE at 1 week (including <8 days, 5–7 days and 1 week) follow-up. Δ, post-pre; CI, confidence interval; IV, inverse variance; SAVR, surgical aortic valve replacement; SD, standard deviation; TAPSE, tricuspid annular plane systolic excursion; TF-TAVR, transfemoral-transcatheter aortic valve replacement

Discussion

This is the first meta-analysis evaluating the effect of TF-TAVR on RVF evaluated by a variety of parameters and comparing it with that of SAVR. Our main findings are: longitudinal RVF, indicated by TAPSE, is not adversely affected at 1 week and 6 months post TF-TAVR as compared with the baseline level. Moreover, RVEF (<2 weeks and 6 months) did not exhibit significant deterioration post TF-TAVR, either. On the other hand, TAPSE at 1 week and 3 months post SAVR and FAC at 3 months post SAVR were significantly aggravated, but RVEF did not show significant deterioration. Furthermore, both post-procedure TAPSE and ΔTAPSE were significantly improved in TF-TAVR group as compared with those in SAVR group.

RV dysfunction has been reported in one out of four patients with severe AS.^{26,27} RV dysfunction at baseline has been associated with an elevated risk of cardiovascular mortality after SAVR.²⁸ Several explanations have been proposed for this association. Thoracotomy and pericardiotomy impact RV myocardial blood flow and may further result in RV failure.²⁹ Alternatively, the negative impact of cardiopulmonary bypass on inflammatory and coagulation cascades following SAVR may cause exacerbation in the RVF.^{30,31} Other potential contributing factors may include loss of cardioprotection and atrioventricular synchrony, air embolism of right coronary, and increased pulmonary artery pressure as a result of impaired pulmonary perfusion.⁸ On the other hand, the studies evaluating the effect of RV dysfunction at baseline

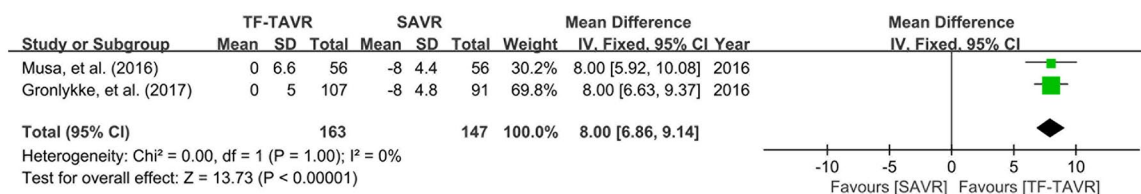


Figure 12. Fixed-effects meta-analysis of TF-TAVR versus SAVR for the primary outcome of Δ TAPSE at 3–6 month follow-up.

Δ , post-pre; CI, confidence interval; IV, inverse variance; SAVR, surgical aortic valve replacement; SD, standard deviation; TAPSE, tricuspid annular plane systolic excursion; TF-TAVR, transfemoral-transcatheter aortic valve replacement

on the patients undergoing TAVR have yielded conflicting results. Studies including sub-analysis of the PARTNER trial showed no influence of baseline RV dysfunction on outcomes of TAVR; whereas others have observed up to 2-fold increase in post-TAVR mortality in patients with baseline RV dysfunction.^{32–34} Therefore, the effect of baseline RV dysfunction on TF-TAVR outcomes remains controversial.

A recent meta-analysis has shown that TAPSE remains unchanged post TAVR while it decreases by 12 months after SAVR; however, the inclusion of cases that have undergone alternative access TAVR may influence the results and no comparison was made specifically between the TF-TAVR and SAVR in that study.¹³ In the present study, despite more comorbidities were presented in the TF-TAVR group than in the SAVR group,³⁵ TF-TAVR was superior to SAVR in regard to maintaining TAPSE level. This is similar to the findings reported by Quick *et al.* in a small observational study,¹⁶ in which marked deterioration of TAPSE after SAVR (23.7 ± 4 mm versus 15.6 ± 2.9 mm, $p < 0.001$) and TA-TAVR (21.1 ± 4.7 mm versus 19.1 ± 4.7 mm, $p = 0.02$) was observed. TAPSE remained unchanged in the TF-TAVR group (21.7 ± 5 mm versus 22.1 ± 4.9 mm, $p = 0.38$).¹⁶ Likewise, in 27 pairs of TAVR (TA-TAVR and TF-TAVR) and SAVR patients matched by gender, age, and LV function, Forsberg and colleagues demonstrated that TF-TAVR was associated with better longitudinal RVF than TA-TAVR; whereas SAVR was associated with worse longitudinal RVF than TAVR.³⁶ In addition, a sub-analysis from the randomized CoreValve US high-risk Clinic Study showed that RV systolic function was significantly compromised in the patients subjected to SAVR ($p < 0.001$) and was inferior to that in the patients

subjected to TAVR at discharge and 1 month post procedure. However, RVF was not significantly different between the treatment groups at 6-month ($p = 0.83$) or 1-year ($p = 0.14$) follow-up.³⁷ Studies have indicated that the reduction in the TAPSE following SAVR was presumably due to conformational rather than functional changes in the RV after cardiac surgery, and such a reduction in most cases occurred shortly after weaning from cardiopulmonary bypass.³⁸ However, the present study showed that both the TAPSE, representing longitudinal RVF, and the FAC, reflecting the whole RVF, were significantly exacerbated as long as 3 months following SAVR, implicating the possible functional impairments elicited by the surgical procedure. Admittedly, one should also note that RVEF did not show statistically significant aggravation following SAVR. This could be due to the compensated latitudinal RVF in the face of reduced longitudinal RVF, as reflected by the diminished TAPSE post SAVR. Therefore, further study might be needed to evaluate the RVEF using cardiac magnetic resonance imaging or 3D echocardiography. Taken together, these results indicate that TF-TAVR might avoid the acute insults to the RV likely caused by conformational changes, cardioplegia, and cardiopulmonary bypass that are entailed in SAVR.^{16,38,39}

Limitations

The heterogeneity among trials was significant, which was related to the type of study. Some studies were not randomized control trials and the sample size was small.^{16,20,22} We chose random effects based solely on I^2 more than 50, which may increase the risk of Type 2 error due to lack of power. Secondly, there are discrepancies in follow-up time periods and outcomes among the selected studies.

Conclusion

TAPSE and RVEF were maintained post TF-TAVR; whereas TAPSE and FAC were significantly deteriorated post SAVR, while RVEF did not exhibit significant deterioration. In addition, post-TAPSE and Δ TAPSE are significantly improved in TF-TAVR group as compared with those in SAVR group. These results implicate that RVF is maintained post TF-TAVR and at least longitudinal RVF is compromised post SAVR. Therefore, baseline RV dysfunction should be considered when selecting TF-TAVR or SAVR, and TF-TAVR could be a preferred option in patients with RV dysfunction.


Conflict of interest statement

The authors declare that there is no conflict of interest.

Funding

The authors disclosed receipt of the following financial support for the research, authorship, and/or publication of this article: This work was supported by the National Natural Science Foundation of China (81770300, 81860059, 81460072); CAS “Light of West China” Program; International Joint Research Program of Gansu Province (18YF1WA046); Innovation and Entrepreneurship Program of Lanzhou City (2018-RC-78); the Science Foundation of Gansu Provincial Hospital (18GSSY5-4)

ORCID iDs

Liyan Zhang  <https://orcid.org/0000-0001-8410-9262>

Yichao Duan  <https://orcid.org/0000-0001-8463-1093>

Supplemental material

Supplemental material for this article is available online.

References

1. Wenaweser P and O’Sullivan CJ. Aortic stenosis and the right heart at risk: is transcatheter aortic valve implantation the better option? *Heart* 2012; 98: 1265–1266.
2. Freeman RV and Otto CM. Spectrum of calcific aortic valve disease: pathogenesis, disease progression, and treatment strategies. *Circulation* 2005; 111: 3316–3326.
3. Badheka AO, Singh V, Patel NJ, *et al.* Trends of hospitalizations in the United States from 2000 to 2012 of patients >60 years with aortic valve disease. *Am J Cardiol* 2015; 116: 132–141.
4. Leon MB, Smith CR, Mack M, *et al.* Transcatheter aortic-valve implantation for aortic stenosis in patients who cannot undergo surgery. *N Engl J Med* 2010; 363: 1597–1607.
5. Reardon MJ, Van Mieghem NM, Popma JJ, *et al.* Surgical or transcatheter aortic-valve replacement in intermediate-risk patients. *N Engl J Med* 2017; 376: 1321–1331.
6. Smith CR, Leon MB, Mack MJ, *et al.* Transcatheter versus surgical aortic-valve replacement in high-risk patients. *N Engl J Med* 2011; 364: 2187–2198.
7. Clavel MA, Webb JG, Rodes-Cabau J, *et al.* Comparison between transcatheter and surgical prosthetic valve implantation in patients with severe aortic stenosis and reduced left ventricular ejection fraction. *Circulation* 2010; 122: 1928–1936.
8. Poliacikova P, Cockburn J, Pareek N, *et al.* Prognostic impact of pre-existing right ventricular dysfunction on the outcome of transcatheter aortic valve implantation. *J Invasive Cardiol* 2013; 25: 142–145.
9. Praz F and Windecker S. Effect of right ventricular function and tricuspid regurgitation on outcomes after transcatheter aortic valve implantation: forgotten side of the heart. *Circ Cardiovasc Interv* 2015; 8: e002577.
10. Greyson CR. Evaluation of right ventricular function. *Curr Cardiol Rep* 2011; 13: 194–202.
11. Cavalcante JL, Simon MA and Chan SY. Comprehensive right-sided assessment for transcatheter aortic valve replacement risk stratification: time for a change. *J Am Soc Echocardiogr* 2017; 30: 47–51.
12. Gronlykke L, Ihlemann N, Ngo AT, *et al.* Measures of right ventricular function after transcatheter versus surgical aortic valve replacement. *Interact Cardiovasc Thorac Surg* 2017; 24: 181–187.
13. Ren B, Spitzer E, Geleijnse ML, *et al.* Right ventricular systolic function in patients undergoing transcatheter aortic valve implantation: a systematic review and meta-analysis. *Int J Cardiol* 2018; 257: 40–45.
14. Cook DJ, Sackett DL and Spitzer WO. Methodologic guidelines for systematic reviews of randomized control trials in health care from the potsdam consultation on meta-analysis. *J Clin Epidemiol* 1995; 48: 167–171.
15. Higgins JPT, Thomas J, Chandler J, *et al.* Cochrane handbook for systematic reviews of

- interventions. Version 6.0. Cochrane, <https://www.training.cochrane.org/handbook> (2019).
16. Quick S, Speiser U, Pfluecke C, *et al.* Aortic stenosis: right and left ventricular function in the early postprocedural phase. Comparison between transcatheter and surgical aortic valve implantation. *Acta Cardiol* 2013; 68: 583–589.
 17. Ayhan H, Durmaz T, Keles T, *et al.* Improvement of right ventricular function with transcatheter aortic valve implantation. *Scand Cardiovasc J* 2014; 48: 184–188.
 18. Okada DR, Rahmouni HW, Herrmann HC, *et al.* Assessment of right ventricular function by transthoracic echocardiography following aortic valve replacement. *Echocardiography* 2014; 31: 552–557.
 19. Crouch G, Bennetts J, Sinhal A, *et al.* Early effects of transcatheter aortic valve implantation and aortic valve replacement on myocardial function and aortic valve hemodynamics: insights from cardiovascular magnetic resonance imaging. *J Thorac Cardiovasc Surg* 2015; 149: 462–470.
 20. Keyl C, Schneider J, Beyersdorf F, *et al.* Right ventricular function after aortic valve replacement: a pilot study comparing surgical and transcatheter procedures using 3D echocardiography. *Eur J Cardiothorac Surg* 2016; 49: 966–971.
 21. Musa TA, Uddin A, Fairbairn TA, *et al.* Right ventricular function following surgical aortic valve replacement and transcatheter aortic valve implantation: a cardiovascular MR study. *Int J Cardiol* 2016; 223: 639–644.
 22. Zhao Y, Lindqvist P, Nilsson J, *et al.* Transcatheter aortic valve implantation – early recovery of left and preservation of right ventricular function. *Interact Cardiovasc Thorac Surg* 2011; 12: 35–39.
 23. Kempny A, Diller GP, Kaleschke G, *et al.* Impact of transcatheter aortic valve implantation or surgical aortic valve replacement on right ventricular function. *Heart* 2012; 98: 1299–1304.
 24. Harpole DH and Jones RH. Serial assessment of ventricular performance after valve replacement for aortic stenosis. *J Thorac Cardiovasc Surg* 1990; 99: 645–650.
 25. Sandstede JJ, Beer M, Hofmann S, *et al.* Changes in left and right ventricular cardiac function after valve replacement for aortic stenosis determined by cine MR imaging. *J Magn Reson Imaging* 2000; 12: 240–246.
 26. Galli E, Guirette Y, Feneon D, *et al.* Prevalence and prognostic value of right ventricular dysfunction in severe aortic stenosis. *Eur Heart J Cardiovasc Imaging* 2015; 16: 531–538.
 27. Koifman E, Didier R, Patel N, *et al.* Impact of right ventricular function on outcome of severe aortic stenosis patients undergoing transcatheter aortic valve replacement. *Am Heart J* 2017; 184: 141–147.
 28. Ternacle J, Berry M, Cognet T, *et al.* Prognostic value of right ventricular two-dimensional global strain in patients referred for cardiac surgery. *J Am Soc Echocardiogr* 2013; 26: 721–726.
 29. Schosser R, Forst H, Racenberg J, *et al.* Open chest and open pericardium affect the distribution of myocardial blood flow in the right ventricle. *Basic Res Cardiol* 1990; 85: 508–518.
 30. Haddad F, Couture P, Tousignant C, *et al.* The right ventricle in cardiac surgery, a perioperative perspective: II. Pathophysiology, clinical importance, and management. *Anesth Analg* 2009; 108: 422–433.
 31. Davidson MJ. Can the off-pump coronary artery bypass debate shed light on postoperative right heart dysfunction? *Circulation* 2008; 117: 2181–2183.
 32. Asami M, Stortecky S, Praz F, *et al.* Prognostic value of right ventricular dysfunction on clinical outcomes after transcatheter aortic valve replacement. *JACC Cardiovasc Imaging* 2019; 12: 577–587.
 33. Lindman BR, Maniar HS, Jaber WA, *et al.* Effect of tricuspid regurgitation and the right heart on survival after transcatheter aortic valve replacement: insights from the placement of aortic transcatheter valves II inoperable cohort. *Circ Cardiovasc Interv* 2015; 8: e002073.
 34. Griese DP, Kerber S, Barth S, *et al.* Impact of right and left ventricular systolic dysfunction on perioperative outcome and long-term survival after transcatheter aortic valve replacement. *J Interv Cardiol* 2017; 30: 217–225.
 35. Siontis GC, Praz F, Pilgrim T, *et al.* Transcatheter aortic valve implantation vs. surgical aortic valve replacement for treatment of severe aortic stenosis: a meta-analysis of randomized trials. *Eur Heart J* 2016; 37: 3503–3512.
 36. Forsberg LM, Tamas E, Vanky F, *et al.* Differences in recovery of left and right ventricular function following aortic valve interventions: a longitudinal echocardiographic study in patients undergoing surgical, transapical

- or transfemoral aortic valve implantation. *Catheter Cardiovasc Interv* 2013; 82: 1004–1014.
37. Little SH, Oh JK, Gillam L, *et al.* Self-expanding transcatheter aortic valve replacement versus surgical valve replacement in patients at high risk for surgery: a study of echocardiographic change and risk prediction. *Circ Cardiovasc Interv* 2016; 9: e003426.
38. Korshin A, Gronlykke L, Nilsson JC, *et al.* Tricuspid annular plane systolic excursion is significantly reduced during uncomplicated coronary artery bypass surgery: a prospective observational study. *J Thorac Cardiovasc Surg* 2019; 158: 480–489.
39. Wranne B, Pinto FJ, Hammarstrom E, *et al.* Abnormal right heart filling after cardiac surgery: time course and mechanisms. *Br Heart J* 1991; 66: 435–442.

Appendix 1

Electronic database search hedges


Four databases were used to identify the study. The search strategies of PubMed are as follows:

PubMed (694 records) 2/14/2020

((((((((((SAVR[Title/Abstract]) OR surgical aortic valve replacement[Title/Abstract]) OR ((Aortic Valve Stenosis[Title/Abstract]) AND Heart Valve Prosthesis Implantation[Title/Abstract]

AND Surgical Procedures, Operative[Title/Abstract]))) OR aortic valve replacement[Title/Abstract])) AND (((((((Supravalvar aortic stenosis, eisenberg type[Title/Abstract]) OR (Subvalvular aortic stenosis, Eisenberg type)) OR Bicuspid Aortic Valve[Title/Abstract]) OR Aortic Stenosis, Subvalvular[Title/Abstract]) OR Aortic Stenosis, Supravalvular[Title/Abstract]) OR “Aortic Valve Stenosis”[Mesh]) OR Aortic Valve Stenosis[Title/Abstract])))) OR (((((((TAVR[Title/Abstract]) OR transcatheter aortic valve implantation [Title/Abstract]) OR TAVR[Title/Abstract]) OR Transcatheter Aortic Valve Replacement[Title/Abstract]) OR “Transcatheter Aortic Valve Replacement”[Mesh])) OR aortic valve replacement [Title/Abstract])) AND (((((((Supravalvar aortic stenosis, eisenberg type[Title/Abstract]) OR (Subvalvular aortic stenosis, Eisenberg type)) OR Bicuspid Aortic Valve[Title/Abstract]) OR Aortic Stenosis, Subvalvular[Title/Abstract]) OR Aortic Stenosis, Supravalvular[Title/Abstract]) OR “Aortic Valve Stenosis”[Mesh]) OR Aortic Valve Stenosis[Title/Abstract])))) AND (((((((right ventricular[Title/Abstract]) OR right[Title/Abstract]) OR ventricular functions, right[Title/Abstract]) OR ventricular function, right[Title/Abstract]) OR functions, right ventricular[Title/Abstract]) OR function, right ventricular[Title/Abstract]) OR right ventricular functions[Title/Abstract]) OR right ventricular function[Title/Abstract]) OR “Ventricular Function, Right” [Mesh])

Visit SAGE journals online
journals.sagepub.com/
home/taj

 SAGE journals