Comparison of postoperative outcomes following multidetector computed tomography based vs transesophageal echocardiography based annulus sizing for transcatheter aortic valve replacement: A systematic review and meta-analysis

Guozhang Tang MD | Qifeng Lv MD | Xiangqin He MD

Abstract

Background: The purpose of this paper was to evaluate the difference in postoperative outcomes following multidetector computed tomography (MDCT) and transesophageal echocardiography (TEE)-based annulus sizing for transcatheter aortic valve replacement (TAVR).

Methods: Electronic search of PubMed, Biomed Central, Scopus, and Google Scholar databases was conducted until August 15, 2019. We included all types of studies comparing MDCT-based annulus sizing with TEE-based annulus sizing and assessing paravalvular regurgitation (PVR). Data were summarized using the Mantel-Haenszel odds ratio (OR) with 95% confidence intervals (CI).

Results: A total of six studies were included. Pooled analysis of 431 participants in the MDCT group and 509 participants in the TEE group demonstrated that MDCT-based annulus sizing is associated with a significantly lower incidence of more than moderate PVR as compared to 2DTEE-based sizing (OR: 0.31, 95% CI: 0.18-0.54, \(P < .0001\); \(I^2 = 0\%\)). There was no statistical difference in annulus rupture (OR: 0.57, 95% CI: 0.12-2.66, \(P = .91\); \(I^2 = 0\%\)), procedural mortality (OR: 0.97, 95% CI: 0.19-4.86, \(P = .97\); \(I^2 = 0\%\)), and 30-day mortality (OR: 0.63, 95% CI: 0.26-1.50, \(P = .29\); \(I^2 = 0\%\)) with MDCT or 2DTEE-based annulus sizing. Compared with 3DTEE, the incidence of PVR in the MDCT group was lower, but there was no statistical difference in 30-day mortality.

Conclusion: Use of MDCT in comparison with 2DTEE is associated with significantly lower incidence of more than moderate PVR after TAVR. There seems to be no difference in annulus rupture and 30-day mortality with either imaging modality.

Keywords

aortic valve, complications, computed tomography, echocardiography, transcatheter aortic valve replacement
1 | INTRODUCTION

Transcatheter aortic valve replacement (TAVR) is an effective therapeutic modality in managing patients with severe aortic stenosis.\(^1\) Though a highly successful procedure, complications like paravalvular aortic regurgitation (PVR) can be seen in up to 38% of patients undergoing TAVR.\(^1,2\) The occurrence of PVR consequently results in poor clinical outcomes and a significant increase in mortality. Tamburino et al\(^3\) reported PVR to be an independent predictor of mortality between 30 days and 1 year, in a sample of 663 patients. The authors observed a fourfold increased risk of mortality in patients demonstrating more than moderate postprocedural PVR.\(^3\)

Incongruous sizing of the aortic annulus resulting in inappropriate valve selection is a major reason for postoperative PVR. The junctional nadirs of the aortic leaflets at the distal part of the left ventricular outflow tract form a virtual ring that is regarded as the aortic annulus during TAVR.\(^4\) In the absence of a discrete anatomical structure, accurate assessment of the annulus via appropriate imaging is critical in preventing PVR. On the other hand, oversizing of the prosthetic valve can lead to significant complications like annulus rupture, coronary obstruction, and conduction disturbances.\(^5\)

Traditionally, two-dimensional (2D) transesophageal echocardiography (TEE) has been used for evaluating annulus size for TAVR.\(^6\) However, it is increasingly recognized that 2DTEE may not accurately measure the oval three-dimensional (3D) annulus structure and considerable sizing variations may occur depending upon the axis of orientation.\(^4,7\) The use of 3DTEE has been described to overcome the limitations of 2DTEE with significantly higher annulus diameters achieved with exclusive use of 3DTEE for valvular sizing.\(^8\) Over the last decade, multidetector computed tomography (MDCT) has been increasingly used for annulus sizing before TAVR, as it provides a detailed understanding of the valvular anatomy with a superior spatial resolution.\(^9\) Studies have demonstrated that annulus measurements with 2DTEE frequently result in valve undersizing as compared to MDCT-based measurements.\(^10\) On the other hand, a recent meta-analysis by Rong et al\(^11\) has shown that measurements by 3DTEE may be comparable to that of MDCT and may lead to reduced contrast exposure. While multiple studies have compared differences in annulus sizing with TEE and MDCT,\(^10,12,13\) evidence on the effect of imaging modality on the postoperative outcomes has not been summarized to date. Therefore, the purpose of this systematic review and meta-analysis was to evaluate the difference in postoperative outcomes following MDCT and TEE-based annulus sizing for TAVR. TAVR associate with a lower incidence of PVR and improved clinical outcomes as compared to TEE-based measurements?

2 | METHODS

The guidelines of the PRISMA statement (Preferred Reporting Items for Systematic Reviews and Meta-analyses)\(^14\) and the Cochrane Handbook for Systematic Reviews of Intervention were followed during the conduct of this review.\(^15\) The research question to be answered was the following: Does using MDCT-based annulus sizing in

2.1 | Search strategy

A computerized literature search of PubMed, Biomed Central, Scopus, and Google Scholar databases was carried out. The last literature search was conducted on August 15, 2019. Two independent reviewers performed the electronic search using the following keywords: "Multidetector Computed Tomography," "Computed Tomography," “MDCT,” “Transesophageal Echocardiography,” “Echocardiography,” “TEE,” “transcatheter aortic valve replacement,” “transcatheter aortic valve implantation,” “paravalvular regurgitation,” “paravalvular leak,” and “clinical outcomes.” The search strategy and results of the PubMed search are presented in Table S1. We also performed a manual search of references of included studies and review articles on the subject for identification of any additional studies. After assessing the studies by their titles and abstracts, full texts of selected articles were retrieved. Both the reviewers assessed individual studies based on inclusion criteria. Disagreements, if any, were resolved by mutual agreement.

2.2 | Inclusion criteria and outcomes

Utilizing the PICOS (Population, Intervention, Comparison, Outcome, and Study design) outline, we included all types of studies conducted on patients undergoing TAVR (Population), comparing MDCT-based annulus sizing (Intervention) with TEE-based annulus sizing (Comparison) and assessing PVR and other clinical outcomes (Outcomes). At the protocol stage, we aimed to include studies comparing both 2DTEE and 3DTEE with MDCT for annulus valve sizing in TAVR patients. Studies comparing MDCT and TEE-based annulus measurements on the same group of patients were excluded. We also excluded single-arm studies, case reports, review articles, and non-English language studies.

Using an abstraction form, two reviewers retrieved data from selected studies. The following details were sourced: Authors, publication year, sample size, inclusion/exclusion criteria, baseline characteristics, MDCT and TEE protocol, PVR, and any other clinical outcomes. The primary outcome was the incidence of moderate-severe PVR. Secondary outcomes were the incidence of annulus rupture, procedural mortality, and 30-day mortality.

2.3 | Risk of bias assessment

Retrospective cohort studies were analyzed using the risk of bias assessment tool for nonrandomized studies (RoBANS).\(^16\) Studies were rated as low risk, high risk, or unclear risk of bias for the following: selection of participants, confounding variables, intervention measurements, blinding of outcome assessment, incomplete outcome
data, selective outcome reporting. Quality of randomized control trials (RCTs) was assessed using the "Cochrane Collaboration risk assessment tool". Studies were rated as low risk, high risk, or unclear risk of bias for the following: random sequence generation, allocation concealment, blinding of participants and personnel, blinding of outcome assessment, incomplete outcome data, selective reporting, and other biases.

2.4 Statistical analysis

Because of significant heterogeneity among studies, a random-effects model was used to calculate the pooled effect size. Categorical data were summarized using the Mantel-Haenszel odds ratio (OR) with 95% confidence intervals (CI). Heterogeneity was calculated using the $I^2$ statistic. $I^2$ values of 25%-50% represented low, values of 50%-75% represented medium, and more than 75% represented substantial heterogeneity. A sensitivity analysis was carried out to assess the influence of each study on the pooled effect size. The software “Review Manager” (RevMan, version 5.3; Nordic Cochrane Centre [Cochrane Collaboration], Copenhagen, Denmark; 2014) was used for the meta-analysis. Publication bias was not assessed using funnel plots as there were less than 10 studies in our analysis.

3 RESULTS

The study flowchart is presented in Figure 1. Four studies were excluded after full-text evaluation. In all four studies, MDCT and TEE-based annulus measurements were compared in the same group of patients. A total of six studies met the inclusion criteria. Five studies compared MDCT and 2DTEE for annulus sizing, while one study compared MDCT with 3DTEE-based annulus sizing. The characteristics of the included studies are presented in Table 1. All studies had obtained informed written consent from study participants and were approved by the institutional ethical committee.
Echocardiogram-based and MDCT-based annulus sizing was done at different time intervals in all studies, and data were analyzed retrospectively, except for one trial. Casset et al conducted a prospective randomized trial evaluating the addition of MDCT to TEE and TTE-based annulus measurements on postoperative outcomes. Measurements were recorded in the systolic phase for both groups in all studies. Except for two studies, both MDCT and TEE-based measurements were available to the operator during the procedure. Valves implanted were exclusively Edward SAPIEN or SAPIEN XT in four studies, and Edward Sapien and CoreValve in one study and Edward Sapien and Evolut R in another study. The risk of bias assessment of included studies is presented in Table 2, and the baseline characteristics of the participants of all six studies are shown in Table 3.

Meta-analysis was carried out for five studies comparing outcomes following MDCT and 2DTEE-based annulus measurements. The age of the included patients was >70 years in all studies. Male gender percentage ranged from 44.8% to 63%. The percentage of patients with New York Heart Association (NYHA) score of III/IV were 54.13%-87.5%. Study and control groups were matched on most baseline characteristics in all cohorts. A significantly larger prosthesis was utilized in patients with MDCT-based annulus measurements as compared to those with 2DTEE-based annulus measurements, in four of the five studies.

Pooled analysis of 431 participants in the study group and 509 participants in the control group demonstrated that MDCT-based annular sizing results in significantly lower incidence of more than moderate PVR (OR: 0.31, 95%CI: 0.18-0.54, P = .0001; $I^2$ = 0%) (Figure 2). Details on the incidence of annulus rupture were reported by four studies. Meta-analysis indicated no statistically significant difference in annulus rupture with MDCT or 2DTEE-based annulus sizing (OR: 0.57, 95%CI: 0.12-2.66, P = .91; $I^2$ = 0%) (Figure 3). Data on procedural mortality and 30-day mortality were reported by three studies. Pooled mortality in the MDCT group was 0.86% while in the 2DTEE group was 1.29%, with pooled analysis demonstrating no significant difference (OR: 0.97, 95%CI: 0.19-4.86, P = .97; $I^2$ = 0%) (Figure 4). The incidence of 30-day mortality in patients with MDCT-based annulus sizing (4.16%) and 2DTEE-based sizing (6.30%) was also not significantly different (OR: 0.63, 95%CI: 0.26-1.50, P = .29; $I^2$ = 0%) (Figure 5). On sensitivity analysis, there was no change in significance of the results on exclusion of any study in any of the pooled analysis.
3.1 | MDCT vs 3DTEE

In the retrospective study of Wystub et al., MDCT was used for annulus sizing in 116 patients and 3DTEE was utilized in 111 patients. There was no significant difference in the baseline characteristics of the two groups. Significantly larger valves were used in the MDCT group as compared to the 3DTEE group (Table 3). A significantly higher number of patients in the MDCT group (57.6%) did not have PVR as compared to the TEE group (35.3%; \( P = .016 \)). There was no difference in 30-day mortality between the two groups (3.4% in MDCT group vs 0.9% in 3DTEE group, \( P = .181 \)).

4 | DISCUSSION

Of the two types of aortic valvular regurgitation, central regurgitation is usually seen in diseased native valves whereas PVR is a complication seen only after TAVR. Since the native valve is still in situ when the prosthesis is placed over the biological tissue, an incomplete seal may remain, thereby resulting in PVR. Despite a technological improvement in devices to provide an efficient seal between the aortic annulus and the implanted prosthesis, the incidence of PVR is as high as 23.8% post TAVR. The PARTNER trial has demonstrated that even mild PVR is associated with an increased risk of late mortality. Similar results have been obtained by other studies wherein more than moderate PVR was found to be a strong predictor of in-hospital death. While redilatation or implantation of valvar-in-valve may be attempted as a corrective measure for PVR, steps for prevention of PVR are necessary for good clinical outcomes.

Complications like PVR after TAVR are usually the result of inappropriate prosthesis size selection. While the annulus can be directly inspected for sizing in surgical aortic valve replacement (SAVR), selecting the prosthesis size is completely dependent on imaging studies in TAVR. Traditionally, 2DTEE was the method of choice for annulus sizing. However, with the introduction of MDCT, dependency on echocardiography for annulus sizing has been reduced in many centers worldwide. The higher spatial resolution of MDCT provides accurate annulus dimensions resulting in more appropriate prosthesis size selection. On the other hand, measurements obtained by 2DTEE are frequently undersized resulting in implantation of a smaller prosthesis. In most of the included studies of this review, a significantly larger prosthesis was selected for implantation in the MDCT group as compared to the TEE group.
Despite MDCT becoming the gold standard imaging for annulus sizing, the requirement of contrast media is a significant limitation especially in patients with severe renal impairment. An estimated 7%-10.5% of TAVR patients have been found to have MDCT contrast-related kidney injury. With around 70% of the TAVR population having preoperative renal disease, TEE may still be an alternative imaging modality for such patients. It may also be useful in individuals with iodine allergy, centers with high patient load or due to economic constraints. In the absence of dynamic information by MDCT, TEE also yields better temporal resolution that aids in tracing calcified nodules and identification of mobile components. In the face of such differences, it is important to analyze the differences in clinical outcomes following MDCT and TEE-based annulus measurements for TAVR.

To date, a total of six studies have compared clinical outcomes following MDCT and TEE-based measurements for TAVR and most of them have utilized 2DTEE in the echocardiography group. The results of our analysis indicate that the use of MDCT for annulus sizing is associated with an estimated 69% decrease in the incidence of more than moderate PVR as compared to 2DTEE-based sizing. The significant difference in the incidence of PVR between the two groups is largely attributed to the underestimation of annulus size by 2DTEE. Dashkevich et al have demonstrated poor correlation between intra-operative annulus measurements and 2DTEE-based dimensions with TEE frequently underestimating the aortic annulus size. Our results failed to demonstrate any difference in the incidence of annulus rupture as well as procedural and 30-day mortality between the two imaging modalities. This could be attributed to the rare occurrence of these events and the limited number of studies with small sample size of the cohorts in our analysis. Further, larger studies may detect differences, if any, for these outcome variables.

To overcome the limitations of 2DTEE, 3DTEE has been introduced as an alternative to MDCT-based annulus sizing. Advances in 3DTEE technology with a multiplanar reconstruction of the aortic root and outflow tract as well as annulus sizing software have improved the efficiency of this imaging modality. In a recent meta-analysis, Rong et al have demonstrated a strong correlation between MDCT-based and 3DTEE-based measurements for TAVR. However, to date, only one study has compared the incidence of complications following MDCT vs 3DTEE-based annulus sizing. Wystub et al, comparing two cohorts of TAVR patients treated at different time intervals, found a reduced incidence of PVR in the MDCT group. Similar to 2DTEE, underestimation of annulus size resulting in smaller prosthesis was described as the probable reason for the difference in PVR.

The results of our review are to be interpreted with the following limitations. Foremost, a limited number of studies with small sample size were available for analysis. Only one study was analyzed for MDCT vs 3DTEE-based annulus sizing. Secondly, only one prospective randomized study has compared MDCT and TEE for annulus sizing. All remaining studies compared cohorts evaluated by either imaging modality at different time intervals. The inherent bias of retrospective observational studies may have skewed the overall
### TABLE 3  Baseline characteristics of patients in studies comparing MDCT and TEE-based annular sizing

| Author/Year       | Hayashida et al\(^{19}\) | Jilaihawi et al\(^{23}\) | Binder et al\(^{21}\) | Hansson et al\(^{22}\) | Casset et al\(^{20}\) | Wystub et al\(^{24}\) |
|-------------------|---------------------------|---------------------------|------------------------|------------------------|------------------------|------------------------|
| Sample size       | 175                       | 175                       | 96                     | 133                    | 58                     | 25                     | 116                    |
| Age (y)           | 83.2 ± 6.4                | 83.3 ± 6.4                | 82.4 ± 10.2            | 82 ± 8                 | 82.6 ± 6               | 83.2 ± 7.8             | 80 ± 6                 |
| Male (%)          | 52                        | 49.7                      | 45                     | 57                     | 44.8                   | 48                     | 42.2                   |
| BMI, kg/m\(^2\)   | 26.0 ± 4.2                | 25.6 ± 4.5                | -                      | 27 ± 6                 | 25.9 ± 5               | 26.1 ± 4.2             | 28 ± 5.7               |
| NYHA class III/IV (%) | 82.6                  | 84                        | -                      | 54.13                  | 77.6                   | 84                     | 71.9                   |
| Diabetes (%)      | 22.3                      | 23.4                      | 32.5                   | 32                     | 27.6                   | 24                     | 40                     |
| Hypertension (%)  | 70.9                      | 69.7                      | 92.5                   | 84                     | 86.2                   | 64                     | -                      |
| COPD (%)          | 25.7                      | 34.3                      | 50                     | 38                     | 20.7                   | 13.1                   | 32.7                   |
| CAD or PCI (%)    | 54.9                      | 62.3                      | 30                     | 30                     | 36.2                   | 52                     | 51.3                   |
| Previous MI (%)   | 7.4                       | 14.9                      | -                      | 21                     | 29.3                   | 20                     | -                      |
| PVD (%)           | 29.7                      | 30.3                      | -                      | 20                     | 20                     | 12                     | 4                      |
| Logistic EuroScore| 20.1 ± 10.4               | 24.4 ± 11.5               | 7.5 ± 14.5             | -                      | 18.9 ± 12.6            | 19.5 ± 11.1            | 15.7 ± 11.1            |
| LVEF (%)          | -                         | -                         | 61.5 ± 11.8            | 53 ± 14                | 53.8 ± 14.1            | 51.8 ± 10.9            |
| Aortic valve area (cm\(^2\)) | 0.64 ± 0.13            | 0.62 ± 0.16               | -                      | 0.7 ± 0.2              | 0.67 ± 0.19            | 0.7 ± 0.2              |
| Mean aortic gradient (mm Hg) | 48.3 ± 16.5          | 47.0 ± 16.5               | 44.5 ± NR              | 42 ± 18                | 46.2 ± 19.1            | 50.3 ± 13.4            |
| Transfemoral route (%) | 54.28±                 | 58.28                     | 87.5                   | 87.5                   | 82.3                   | 82.3                   |
| Transapical route (%) | 21.14*                 | 31.42                     | 12.5                   | 12.5                   | 17.7                   | 17.7                   |
| Annulus diameter (mm) | NR                    | NR                        | 23.2 ± 2.1             | 22.6 ± 2.2             | 22.5 ± 3               | 21.7 ± 2.3             |
| Mean prosthesis size | 23 mm: 26%             | 26 mm: 60.7%              | 23 mm: 46.3%           | 23 mm: 57.5%           | 23 mm: 15.5%           | 23 mm: 45%             |
|                   | 26 mm: 37.5%             | 26 mm: 57.5%              | 26 mm: 42.5%           | 26 mm: 51.7%           | 26 mm: 55%             | 26 mm: 55%             |
|                   | 29 mm: 13.3%             | 29 mm: 22%                | 26 mm: 1.5%            | 29 mm: 32.7%           | 29 mm: 0%              | 29 mm: 0%              |
|                   | 2.5%                     | 2.5%                      | 26 mm: 30.8%           | 26 mm: 51.1%           | 26 mm: 44.8%           | 26 mm: 25.7%           |
|                   | 29 mm: 16.5%             | 29 mm: 16.5%              | 26 mm: 1.5%            | 29 mm: 32.7%           | 29 mm: 0%              | 29 mm: 0.9%            |

Abbreviations: BMI = body mass index; CAD = coronary artery disease; COPD = chronic obstructive pulmonary disease; 2D = two-dimensional; 3D = three-dimensional; LVEF = left ventricular ejection fraction; MDCT = multidetector computed tomography; MI = myocardial infarction; NR = not reported; NYHA = New York Heart Association; PCI = percutaneous coronary intervention; PVD = peripheral vascular disease; TEE = transesophageal echocardiography.

Data presented as number, percentage, or Mean ± Standard Deviation.

*Significant difference in prosthesis size between MDCT and TEE groups.
results. Thirdly, there was significant variation between studies in terms of differences in types of prosthesis used, prosthesis size, method of evaluation for postoperative PVR (TEE and TTE), etc. Fourthly, prosthesis sizing was not singularly dependent on MDCT or TEE in most of the studies, but was influenced by operator preferences, anatomical factors, and other imaging studies as well. Lastly, we could not analyze all postoperative outcomes like the incidence of vascular complications and pacemaker implantation, due to the paucity of data. Long-term mortality data were also not available from the included studies for a pooled analysis.

This is the first systematic review and meta-analysis evaluating outcomes after MDCT vs TEE-based annulus sizing for TAVR. After the pooling of data of more than 800 patients, our results indicate that the use of MDCT against 2DTEE is associated with a
significantly reduced incidence of more than moderate PVR after TAVR. However, there seems to be no difference in annulus rupture, procedural, and 30-day mortality with either imaging modality. Further studies are required to provide evidence on postoperative outcomes following MDCT or 3DTEE-based annulus sizing.

ORCID
Xiangin He https://orcid.org/0000-0003-1000-5879

REFERENCES
1. Nielsen HHM, Egeblad H, Andersen HR, et al. Aortic regurgitation after transcatheter aortic valve implantation of the Edwards SAPIEN tm valve. *Scand Cardiovasc J*. 2013;47(1):36–41.
2. Généreux P, Head SJ, Van Mieghem NM, et al. Clinical outcomes after transcatheter aortic valve replacement using valve academic research consortium definitions: a weighted meta-analysis of 3,519 patients from 16 studies. *J Am Coll Cardiol*. 2012;59(25):2317–2326.
3. Tamburino C, Capodanno D, Ramondo A, et al. Incidence and predictors of early and late mortality after transcatheter aortic valve implantation in 663 patients with severe aortic stenosis. *Circulation*. 2011;123(3):299–308.
4. Messika-Zeitoun D, Serfaty J-M, Brochet E, et al. Multimodal assessment of the aortic annulus diameter: implications for transcatheter aortic valve implantation. *J Am Coll Cardiol*. 2010;55(3):186–194.
5. Blanke P, Reinöhl J, Schlensak C, et al. Prosthesis oversizing in balloon-expandable transcatheter aortic valve implantation is associated with contained rupture of the aortic root. *Circ Cardiovasc Interv*. 2012;5(4):540–548.
6. Moss RR, Ivens E, Pasupati S, et al. Role of echocardiography in percutaneous aortic valve implantation. *JACC Cardiovasc Imaging*. 2008;1(1):15–24.
7. Schultz CJ, Moelker AD, Tzikas A, et al. Cardiac CT: necessary for precise sizing for transcatheter aortic valve implantation. *EuroIntervention*. 2010;6(Suppl G):G6–G13.
8. Kretzschmar D, Lauten A, Goebel B, et al. Optimal prosthesis sizing in transcatheter aortic valve implantation by exclusive use of three-dimensional transoesophageal echocardiography. *Clin Physiol Funct Imaging*. 2016;36(2):99–105.
9. Delgado V, Ng ACT, van de Veire NR, et al. Transcatheter aortic valve implantation: role of multi-detector row computed tomography to evaluate prosthesis positioning and deployment in relation to valve function. *Eur Heart J*. 2010;31(9):1114–1123.
10. Mylotte D, Dorfmeister M, Elhmidi Y, et al. Erroneous measurement of the aortic annular diameter using 2-dimensional echocardiography resulting in inappropriate CoreValve size selection: a retrospective comparison with multislice computed tomography. *JACC Cardiovasc Interv*. 2014;7(6):652–661.
11. Qingsong Z, Hamed I, Salemi A, et al. Three-dimensional echocardiography for transcatheter aortic valve replacement sizing: a systematic review and meta-analysis. *J Am Heart Assoc*. 2019;8(19):e015463.
12. Willson AB, Webb JG, Freeman M, et al. Computed tomography-based sizing recommendations for transcatheter aortic valve replacement with balloon-expandable valves: comparison with tr ansesophageal echocardiography and rationale for implementation in a prospective trial. *J Cardiovasc Comput Tomogr*. 2012;6(6):406–414.
13. Jabbour A, Ismail TF, Moat N, et al. Multimodality imaging in transcatheter aortic valve implantation and post-procedural aortic regurgitation. *J Am Coll Cardiol*. 2011;58(21):2165–2173.
14. Moher D, Liberati A, Tetzlaff J, Altman DG, PRISMA Group. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. *PLoS Med*. 2009;6(7):e1000097.
15. Higgins J, Green S. *Cochrane Handbook for Systemic Reviews of Interventions*. Version 5. The Cochrane Collaboration, 2011. Available online at: https://handbook-5-1.cochrane.org. Accessed August 15, 2019.
16. Kim SY, Park JE, Lee YJ, et al. Testing a tool for assessing the risk of bias for nonrandomized studies showed moderate reliability and promising validity. *J Clin Epidemiol*. 2013;66(4):408–414.
17. Higgins J, Altman D, Sterne J. *Cochrane Statistical Methods Group and the Cochrane Bias Methods Group. Chapter 8: Assessing risk of bias in included studies. In: Cochrane Handbook for Systemic Reviews of Interventions*. Version 5.1. The Cochrane Collaboration; 2011. Available online at: https://handbook-5-1.cochrane.org. Accessed June 1, 2019.
18. Hammerstingl C, Schueler R, Weber M, et al. Three-dimensional imaging of the aortic valve geometry for prosthesis sizing prior to transcatheter aortic valve replacement. *Int J Cardiol*. 2014;174(3):844–849.
19. Hayashi K, Bouvier E, Lefèvre T, et al. Impact of CT-guided valve sizing on post-procedural aortic regurgitation in transcatheter aortic valve implantation. *EuroIntervention*. 2012;8(5):546–555.
20. Casset C, Jankowski A, Bertrand B, et al. Evaluation of imaging strategy to optimize and improve outcome of transcatheter aortic valve implantation. *Am J Cardiol*. 2017;120(9):1633–1638.
21. Binder RK, Webb JG, Willson AB, et al. The impact of integration of a multidetector computed tomography annulus area sizing algorithm on outcomes of transcatheter aortic valve replacement: a prospective, multicenter, controlled trial. *J Am Coll Cardiol*. 2013;62(5):431–438.
22. Hansson NC, Thuesen L, Hjortdal VE, et al. Three-dimensional multidetector computed tomography versus conventional 2-dimensional transesophageal echocardiography for annular sizing in transcatheter aortic valve replacement: influence on postprocedural paravalvular aortic regurgitation. *Catheter Cardiovasc Interv*. 2013;82(6):977–986.
23. Jilaihawi H, Kashif M, Fontana G, et al. Cross-sectional computed tomographic assessment improves accuracy of aortic annular sizing for transcatheter aortic valve replacement and reduces the incidence of paravalvular aortic regurgitation. *J Am Coll Cardiol*. 2012;59(14):1275–1286.
24. Wystub N, Báz L, Möbius-Winkler S, et al. Aortic annulus measurement with computed tomography angiography reduces aortic regurgitation after transfemoral aortic valve replacement compared to 3-D echocardiography: a single-centre experience. *Clin Res Cardiol*. 2019;108(11):1266-1275.
25. Lerakis S, Hayek SS, Douglas PS. Paravalvular aortic leak after transcatheter aortic valve replacement: current knowledge. *Circulation*. 2013;127(3):397–407.
26. Goel S, Pasam RT, Wats K, et al. Transcatheter aortic valve replacement versus surgical aortic valve replacement in low-surgical-risk patients: an updated meta-analysis. *Catheter Cardiovasc Interv*. 2019;20(10):838–842.
27. Kodali SK, Williams MR, Smith CR, et al. Two-year outcomes after transcatheter or surgical aortic-valve replacement. *N Engl J Med*. 2012;366(18):1686–1695.
28. Abdel-Wahab M, Zahn R, Horack M, et al. Aortic regurgitation after transcatheter aortic valve implantation: incidence and early outcome. Results from the German transcatheter aortic valve interventions registry. *Heart*. 2011;97(11):899–906.
29. Napodano M, Gasparetto V, Tarantini G, et al. Performance of valve-in-valve for severe para-prosthetic leaks due to inadequate transcatheter aortic valve implantation. *Catheter Cardiovasc Interv*. 2011;78(7):996–1003.
30. Dashkevich A, Blanke P, Siepe M, et al. Preoperative assessment of aortic annulus dimensions: comparison of noninvasive and intraoperative measurement. *Ann Thorac Surg*. 2011;91(3):709–714.
31. Bloomfield GS, Gillam LD, Hahn RT, et al. A practical guide to multimodality imaging of transcatheter aortic valve replacement. *JACC Cardiovasc Imaging*. 2012;5(4):441–455.

32. van Mourik MS, van Kesteren F, Planken RN, et al. Short versus conventional hydration for prevention of kidney injury during pre-TAVI computed tomography angiography. *Netherlands Heart J*. 2018;26(9):425–432.

33. Hansen JW, Foy A, Yadav P, et al. Death and dialysis after transcatheter aortic valve replacement: an analysis of the STS/ACC TVT registry. *JACC Cardiovasc Interv*. 2017;10(20):2064–2075.

34. Thourani VH, Forcillo J, Beohar N, et al. Impact of preoperative chronic kidney disease in 2,531 high-risk and inoperable patients undergoing transcatheter aortic valve replacement in the PARTNER Trial. *Ann Thorac Surg*. 2016;102(4):1172–1180.

35. Khalique OK, Hamid NB, White JM, et al. Impact of methodologic differences in three-dimensional echocardiographic measurements of the aortic annulus compared with computed tomographic angiography before transcatheter aortic valve replacement. *J Am Soc Echocardiogr*. 2017;30(4):414–421.

**SUPPORTING INFORMATION**

Additional supporting information may be found online in the Supporting Information section.

Table S1. Search protocol and PubMed results.

**How to cite this article:** Tang G, Lv Q, He X. Comparison of postoperative outcomes following multidetector computed tomography based vs transesophageal echocardiography based annulus sizing for transcatheter aortic valve replacement: A systematic review and meta-analysis. *Echocardiography*. 2020;37:1617–1626. [https://doi.org/10.1111/echo.14684](https://doi.org/10.1111/echo.14684)