Causes of Death Following Transcatheter Aortic Valve Replacement: A Systematic Review and Meta-Analysis

Tian-Yuan Xiong, MD;* Yan-Biao Liao, MD;* Zhen-Gang Zhao, MD; Yuan-Ning Xu, MD; Xin Wei, MD; Zhi-Liang Zuo, MS; Yi-Jian Li, MD; Jia-Yu Cao, MS; Hong Tang, MD; Hasan Jilaihawi, MD; Yuan Feng, MD; Mao Chen, MD, PhD

Background—Transcatheter aortic valve replacement (TAVR) is an effective alternative to surgical aortic valve replacement in patients at high surgical risk. However, there is little published literature on the exact causes of death.

Methods and Results—The PubMed database was systematically searched for studies reporting causes of death within and after 30 days following TAVR. Twenty-eight studies out of 3934 results retrieved were identified. In the overall analysis, 46.4% and 51.6% of deaths were related to noncardiovascular causes within and after the first 30 days, respectively. Within 30 days of TAVR, infection/ sepsis (18.5%), heart failure (14.7%), and multiorgan failure (13.2%) were the top 3 causes of death. Beyond 30 days, infection/sepsis (14.3%), heart failure (14.1%), and sudden death (10.8%) were the most common causes. All possible subgroup analyses were made. No significant differences were seen for proportions of cardiovascular deaths except the comparison between moderate (mean STS score 4 to 8) and high (mean STS score >8) –risk patients after 30 days post-TAVR (56.0% versus 33.5%, *P*=0.005).

Conclusions—Cardiovascular and noncardiovascular causes of death are evenly balanced both in the perioperative period and at long-term follow-up after TAVR. Infection/sepsis and heart failure were the most frequent noncardiovascular and cardiovascular causes of death. This study highlights important areas of clinical focus that could further improve outcomes after TAVR. (***J Am Heart Assoc***. 2015;4:e002096 doi: 10.1161/JAHA.115.002096)

Key Words: aortic stenosis • death • transcatheter valve replacement

For patients deemed inoperable or at high risk for surgical aortic valve replacement (SAVR), transcatheter aortic valve replacement (TAVR) has become a well-established treatment modality and remains a rapidly evolving technique.[1] Although there are cumulative data suggesting comparable or even superior survival and symptomatic outcomes for patients who undergo TAVR versus medical palliation or the conventional SAVR,[2–4] the frequency of mortality, especially late postprocedural mortality, remains high and their causes of death are often vaguely explained.

Although considerable attention has been afforded to procedural refinement and optimization of acute outcomes after TAVR, insufficient postprocedural management may also lead to late events. Thus, it is crucial to formally delineate the causes of death in patients undergoing TAVR with a view to identifying potentially preventable causes. Since a single study may lack the power to provide comprehensive and reliable conclusions,[5,6] a systematic review and meta-analysis of all eligible studies was performed. In this study, we sought to identify and classify the causes of death within and after 30 days postprocedure.

From the Department of Cardiology, West China Hospital, Sichuan University, Chengdu, China (T.-Y.X., Y.-B.L., Z.-G.Z., Y.-N.X., X.W., Z.-L.Z., Y.-J.L., J.-Y.C., H.T., Y.F., M.C.); Cedars–Sinai Heart Institute, Cedars–Sinai Medical Center, Los Angeles, CA (H.J.).
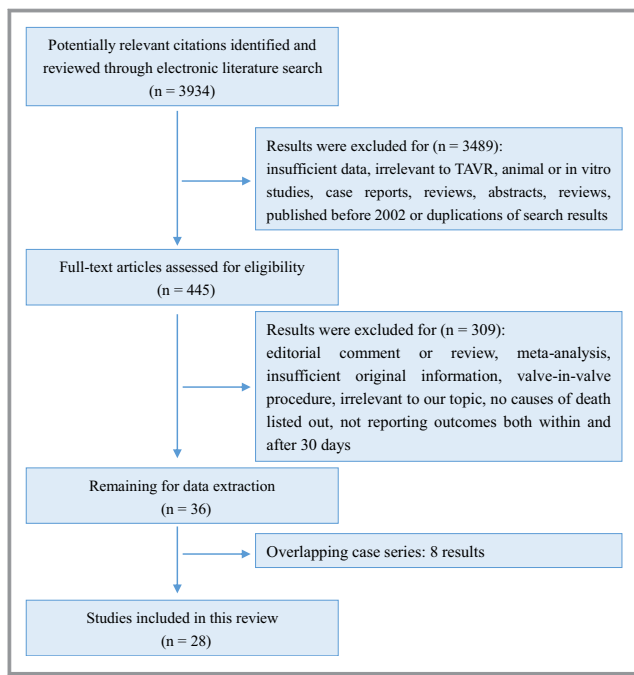
Dr Xiong and Dr Liao have contributed equally to this work.

Dr Jilaihawi, Dr Feng, and Dr Chen have contributed equally to this work.

Accompanying Table S1 and Figures S1 through S4 are available at http://jaha.ahajournals.org/content/4/9/e002096/suppl/DC1

Correspondence to: Yuan Feng, MD, or Mao Chen, MD, PhD, Department of Cardiology, West China Hospital, Sichuan University, 37 Guoxue St, Chengdu 610041, China. E-mail: fynotebook@hotmail.com or hmaochen@foxmail.com

Received April 16, 2015; accepted June 26, 2015.

Methods

Study Identification and Selection

A literature search of the PubMed online database was carried out to identify studies that reported the causes of death after TAVR on August 10, 2014 (Figure 1). The search terms were as follows: (percutaneous OR transcatheter OR transfemoral OR transapical OR transsubclavian OR transaortic OR transaxillary) AND (aortic valve) AND (replacement OR implantation). Only articles in English were included. The inclusion criteria

Potentially relevant citations identified and reviewed through electronic literature search (n = 3934)

Results were excluded for (n = 3489): insufficient data, irrelevant to TAVR, animal or in vitro studies, case reports, reviews, abstracts, reviews, published before 2002 or duplications of search results

Full-text articles assessed for eligibility (n = 445)

Results were excluded for (n = 309): editorial comment or review, meta-analysis, insufficient original information, valve-in-valve procedure, irrelevant to our topic, no causes of death listed out, not reporting outcomes both within and after 30 days

Remaining for data extraction (n = 36)

Overlapping case series: 8 results

Studies included in this review (n = 28)

Figure 1. Summary of evidence search and selection. TAVR indicate Transcatheter aortic valve replacement.

were: (1) studies that reported the specific causes of death after TAVR, (2) sufficient data (the number of patients who died because of 1 certain reason and the time interval after TAVR when they died) available, and (3) studies that at least covered both short-term (≤30 days) and long-term (>30 days) death events. Studies were excluded if 1 of the following existed: (1) causes of death were listed vaguely, (2) death events related to valve-in-valve procedures, (3) studies concerning death predictors instead of the actual causes of death, (4) published before 2002, or (5) studies were case reports, reviews, abstracts, guidelines, comments and conference presentations. If more than 1 study was published by the same authors using the same case series or overlapping case series, studies with the largest sample size were included except when different subgroup analysis could be done.

Data Extraction and Quality Assessment

Two main reviewers (T.Y.X and Y.B.L) independently extracted the data and reached a consensus on all items. The following items were extracted from each study if available: first author's name, publication year, study period, region, study design, single or multicenter study, TAVR case number, patients' age, male proportion, New York Heart Association classification, ejection fraction, comorbidities, logistic European System for Cardiac Operative Risk Evaluation (EuroScore), the Society of Thoracic Surgeons (STS) score, chosen valve and access, and follow-up length. When conducting reclassification, cardiac death was defined as any death

directly involving cardiac integrity and function (heart failure, acute myocardial infarction, sudden death/arrhythmia, and tamponade). Vascular complications and bleedings are regarded as procedure-related causes of death, and together with stroke, are grouped into cardiovascular causes of death in our study in accordance with Valve Academic Research Consortium (VARC) consensus document.[7] Before reclassification of causes of death in included studies into different categories, all involved causes were discussed and double-checked by authors to reach the consensus on whether one certain cause of death belongs to a cardiovascular or noncardiovascular group. As for those already grouped into "other cardiovascular" or "other noncardiovascular" in original reports, we can only keep this classification even if certain causes may be separately listed in other studies. Those causes with only few case numbers were also grouped into "other" categories for the sake of clear illustrations.

Study quality was assessed using the Cross-Sectional/ Prevalence Study Quality Assessment Form or Newcastle-Ottawa Quality Assessment Scale (NOS).[8,9]

Statistical Analysis

Results are expressed as counts and percentages for categorical variables. DerSimonian and Laird's random-effects model was used to pool the estimates of proportions of cardiovascular deaths in each duration and subgroup by Comprehensive Meta Analysis Software Version 3. Differences in the proportions of cardiovascular deaths were compared with the χ^2 test by using SPSS software 19.0. Statistical significance was set at $P<0.05$ (2-tailed). Pie charts and bar charts were used to illustrate our results.

Results

Studies Selection and Characteristics

A total of 3934 results were identified after an initial search from the PubMed database. After careful review of abstracts, 3489 results were excluded. After reading full texts of the remaining 445 results, 36 were deemed suitable for data extraction; 8 studies were excluded due to overlapping case series, leaving 28 results for further study[10–37] (Figure 1). Follow-up time ranges from 6 months to (3.8±2) years with acceptable follow-up rate. A summary of included studies is presented in Table 1. Baseline characteristics are provided in Table S1.

Quality Assessment

The quality of eligible cohort studies was assessed using the Newcastle-Ottawa Quality Assessment Scale scale,

Table 1. Summary of Included Studies

Study Information				Procedure Characteristics					Follow-Up	STS Score (%)
Author	Study Period	Region	Design	TAVR (n)	Edwards, n (%)	Medtronic, n (%)	TF, n (%)	TA, n (%)		
Martinez, GJ[10]	2009.6 to 2013.7	Australia	Single center	100	98 (98)	2 (2)	68 (68)	32 (32)	Mean 17 months	—
Stabile, E[11*]	2010.4 to 2011.4	Italy	Single center	60	120 (100)	0	—		6 months	10.4±6.8/9.7±5.1
Omer, S[12]	2011.12 to 2012.12	US	Single center	19	19 (100)	0	19 (100)	0	Mean 8.8±3.9 months	8.8±10.7
Noble, S[13]	2008.8 to 2012.11	Switzerland	Single center	23	1 (4.3)	19 (82.6)	21 (91.3)	—	Mean 408±294 days	8.7±2.9
Walther, T[14]	2009.9 to 2010.8	European	PREVAIL transapical study	150	150 (100)	0	0	150 (100)	1 year	7.5±4.4
Latib, A[15]	2007.11 to 2011.2	Italy	Single center	111	70 (63)	41 (37)	111 (100)	0	1 year	4.57±2.28
Yamamoto, M[16]	2007.12 to 2011.6	Japan	Single center	26	2 (7.7)	24 (92.3)	24 (92.3)	0	6 months	13.4±7.2
Wendler, O[17]	2007.11 to 2009.12	European	SOURCE	1387	1387 (100)	0	0	1387 (100)	2 years	—
Wendler, O[18]	2009.12 to 2011.2	Mixed	Multi centers	120	120 (100)	0	—		—	6.8±4.0
Kempfert, J[19]	2009.11 to 2010.8	Germany	Single center	40	0	0	0	40 (100)	6 months	9.0±4.7
Van Mieghem, NM[20]	2005.11 to 2011.12	Netherlands	Single center	237	12 (5)	222 (94)	228 (96)	3 (1)	Median 13 months	—
Doss, M[21]	2005.1 to 2008.12	Germany	Single center	100	100 (100)	0	0	100 (100)	3.8±2 years	16±3
Ducrocq, G[22†]	2006.10 to 2010.6	France	Single center	201	171 (85)	30 (15)	131 (65)	61 (30)	Mean 7±9 months	—
Ussia, GP[23]	2007.6 to 2008.8	Italy	Italian CoreValve registry	181	0	181 (100)	172 (95)	0	3 years	11.4±9.9
D'Onofrio, A[24]	2008.4 to 2010.11	Italy	I-TA	504	504 (100)	0	0	504 (100)	Mean 9.2±6.5 months	11±4
Bosmans, JM[25]	Until April 2010	Belgium	Belgian TAVR Registry	328	187 (57)	141 (43)	232 (71)	88 (27)	1 year	—
Hernández-Antolín, RA[26]	2007.5 to 2010.4	Spain	Single center	76	50 (66)	26 (34)	76 (100)	0	367±266 days for ES; 172±159 days for MCV	6.34±1.8
Johansson, M[27]	2008.1 to 2009.11	Sweden	Single center	40	40 (100)	0	10 (25)	30 (70)	Mean 10±8 months	—
Lefèvre, T[28]	2007.4 to 2008.1	European	European PARTNER	130	130 (100)	0	61 (47)	69 (53)	1 year	11.6±6.5
Leon, MB[29‡]	2007.5 to 2009.3	Mixed	PARTNER	179	179 (100)	0	179 (100)	0	1 year	11.2±5.8
Drews, T[30]	2008.4 to 2010.1	Germany	Single center	158	198 (100)	0	0	198 (100)	—	21±16.3/29±18.1
Attias, D[31†]	2006.10 to 2009.6	France	Single center	83	72 (87)	11 (13)	83 (100)	0	Median 9 months	15±8
Ye, J[32]	2005.10 to 2009.2	Canada	Single center	71	71 (100)	0	0	71 (100)	3 years	12.1±7.7
Guinot, PG[33†]	2006.10 to 2009.2	France	Single center	90	—		62 (69)	28 (31)	—	15 (11 to 23)
Avanzas, P[34]	2007.12 to 2009.7	Spain	Multi centers	108	0	108 (100)	103 (95)	0	Average 7.6 months	—

Continued

Table 1. Continued

Study Information				Procedure Characteristics						
Author	Study Period	Region	Design	TAVR (n)	Edwards, n (%)	Medtronic, n (%)	TF, n (%)	TA, n (%)	Follow-Up	STS Score (%)
Kapadia, SR[35]	2006.2 to 2007.3	US	Single center	18	—				278±128 days	11.4±7.5
Walther, T[36]	2006.2 to 2008.3	Germany	Single center	25	25 (100)	0	0	25 (100)	Mean 351 days	17 (6 to 43)
Webb, JG[37]	—	Canada	Single center	50	50 (100)	0	50 (100)	0	Median 359 days	—

I-TA indicates Italian registry of transapical aortic valve implantation; MCV indicates Medtronic CoreValve; STS, Society of Thoracic Surgeons; TA-TAVR, transapical TAVR; TAVR, transcatheter aortic valve replacement; TF-TAVR, transfemoral TAVR.

*Randomized by single or double antiplatelet therapy after the procedure.

†These 3 studies shared an overlapping case series. The study by Ducrocq, G et al was used for overall analysis. The study by Attias, D et al was used for TF-TAVR subgroup analysis. The study by Guinot, P et al was used for TA-TAVR subgroup analysis.

‡Inoperable patients were randomly assigned to standard therapy (including balloon aortic valvuloplasty) or TF-TAVR.

while quality of single-arm studies was evaluated by the Cross-Sectional/Prevalence Study Quality. Overall quality of these included studies was good (evaluation forms for each study were not shown).

Time Interval and Causes of Death

Within 30 days, 8.4% (265/3155) of patients died, 46.4% (123/265) of which were deemed noncardiovascular. Noncardiovascular causes accounted for 51.6% (282/546) of 546 deaths after 30 days. As for individual causes, within 30 days, infection/sepsis accounted for 18.5% of deaths, followed by heart failure and multiorgan failure, accounting for 14.7% and 13.2% of deaths, respectively. Beyond 30 days, infection/sepsis each accounted for 14.3% of deaths, followed by heart failure and sudden death as the reported cause of 14.1% and 10.8% of deaths, respectively (Figures 2 through 4). Because of the broad-spectrum character of noncardiovascular causes, detailed modes of "infection/sepsis" and "other noncardiovascular causes" are provided in Table 2 separately from figures for the sake of clear illustrations and better understanding.

Subgroup Analysis by Access

Causes of death by transfemoral TAVR (TF-TAVR)[12,15,26–29,31,37] and transapical TAVR (TA-TAVR)[14, 17, 19, 21, 24, 27, 28, 30, 32, 33, 36] were individually delineated (Figure 5 with absolute numbers). For the TF-TAVR group, 6.6% (39/589) and 17.3% (95/550) of patients died within and beyond 30 days, which were 10.1% (123/1215) and 13.8% (342/2479) for TA-TAVR. In general, multiorgan failure, heart failure, and vascular complications were the 3 leading causes of death for TF-TAVR within 30 days (17.9%, 15.4%, and 15.4%, respectively); beyond 30 days, infection/sepsis, heart failure, and sudden death accounted for 15.8%, 14.7%, and 8.4% of deaths, respectively. Within 30 days of TA-TAVR, infection/sepsis, multiorgan failure, and heart failure accounted for 22.8%, 18.7%, and 13.8% of deaths, while beyond 30 days, heart failure, infection/sepsis, and sudden death accounted for 14.0%, 12.0%, and 9.9% deaths. The pooled estimate of proportions of cardiovascular deaths in the TF-TAVR subgroup were 61.5% (95% CI: 44.4% to 76.2%) within 30 days post-TAVR and 35.7% (95% CI: 23.4% to 50.3%) after 30 days. In the TA-TAVR subgroup, the pooled estimate of proportions of cardiovascular deaths were 44.7% (95% CI: 31.2% to 59.0%) and 39.6% (95% CI: 28.1% to 52.4%), respectively. No significant differences were found between the 2 subgroups in terms of the proportion of cardiovascular deaths (P=0.067 within 30 days; P=0.514 after 30 days) (Figure S1).
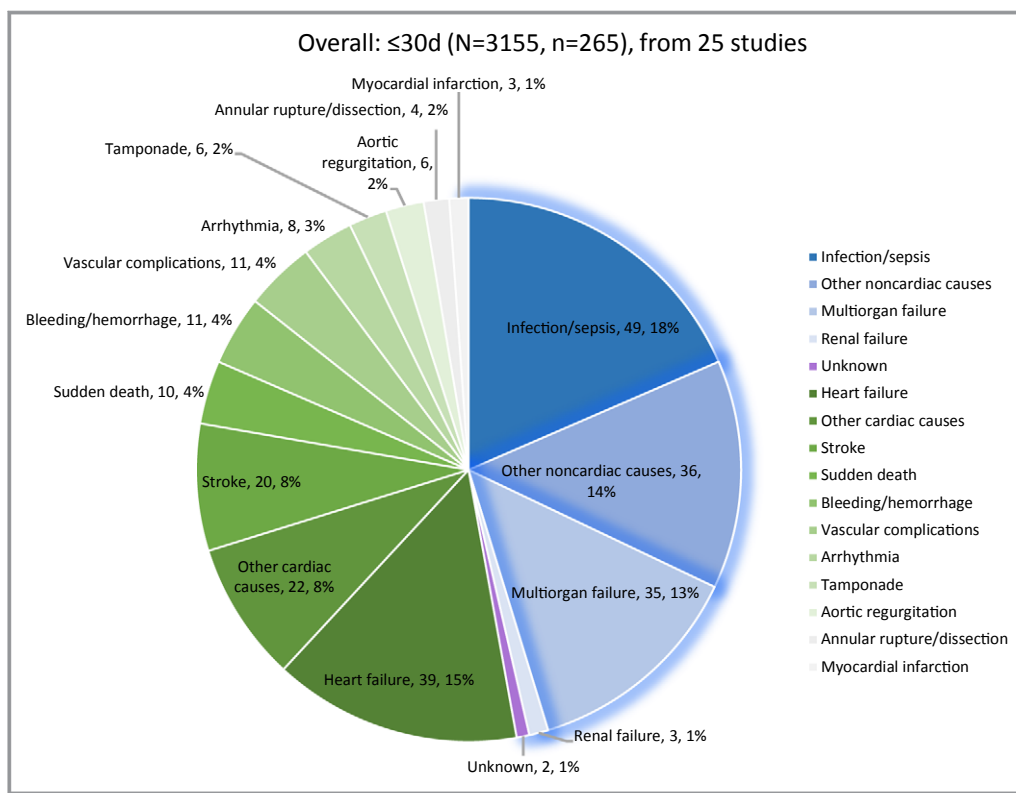
Figure 2. Overall analysis of causes of death within the first 30 days following transcatheter aortic valve replacement.

Subgroup Analysis by Types of Prosthesis

Two most-used valve types, balloon expandable Edwards valve (Edwards Lifesciences, Irvine, CA) and the self-expanding CoreValve system (Medtronic, Inc, Minneapolis, MN), were included in this subgroup analysis (Figure 6 with absolute numbers). Since the CoreValve system cannot be delivered transapically, only TF-TAVR studies were included in this subgroup analysis.[12,23,26,29,31,34,37] For the Edwards SAPIEN Valve group, 6.8% (25/370) and 22.3% (77/345) of patients died within and beyond 30 days, which were 10.7% (35/326) and 10.3% (30/291) for Medtronic CoreValve. Overall, multiorgan failure, vascular complications, and stroke with 20.0%, 16.0%, and 12.0% of deaths were the 3 individual and specific leading causes of death for TAVR using only Edwards SAPIEN Valve within 30 days, while infection/sepsis, heart failure, and renal disease took the lead after 30 days (16.9%, 14.3%, and 6.5% of deaths, respectively). For Medtronic CoreValve, heart failure, vascular complications, infection/sepsis, and aortic regurgitation accounted for 25.7%, 14.3%, 8.6%, and 8.6% of deaths within 30 days, while heart failure was the most common cause after 30 days (10.0% of deaths). The pooled estimates of proportions of cardiovascular deaths in the Edwards SAPIEN Valve subgroup were 66.8% (95% CI: 45.7% to 82.7%) within

30 days post-TAVR and 40.2% (95% CI: 18.7% to 66.2%) after 30 days. In the Medtronic CoreValve subgroup, the pooled estimates of proportions of cardiovascular deaths were 57.5% (95% CI: 36.6% to 76.0%) and 27.6% (95% CI: 14.4% to 46.2%), respectively. No significant differences were found between the 2 subgroups in terms of the proportion of cardiovascular deaths (P=0.394 within 30 days; P=0.189 after 30 days) (Figure S2).

Subgroup Analysis by STS Score

According to mean STS score, studies conducted in patients with a mean STS score between 4 and 8 (regarded as moderate risk) and with mean score larger than 8 (regarded as high risk) were divided into 2 subgroups (Figure 7 with absolute numbers). For moderate-risk patients, 6.8% (31/457) and 10.1% (43/426) died within and beyond 30 days, which were 9.2% (157/1706) and 15.6% (242/1549) for high-risk patients. Multiorgan failure and heart failure accounted for 22.6% and 19.4% of deaths in the moderate-risk group within the first 30 days, while infection/sepsis, heart failure, and multiorgan failure took the lead in the high-risk group (19.7%, 15.3%, and 15.3%, respectively). After 30 days, sudden death, infection/sepsis, and heart failure (23.3%, 18.6%, and 11.6% of deaths) were the top 3 killers for
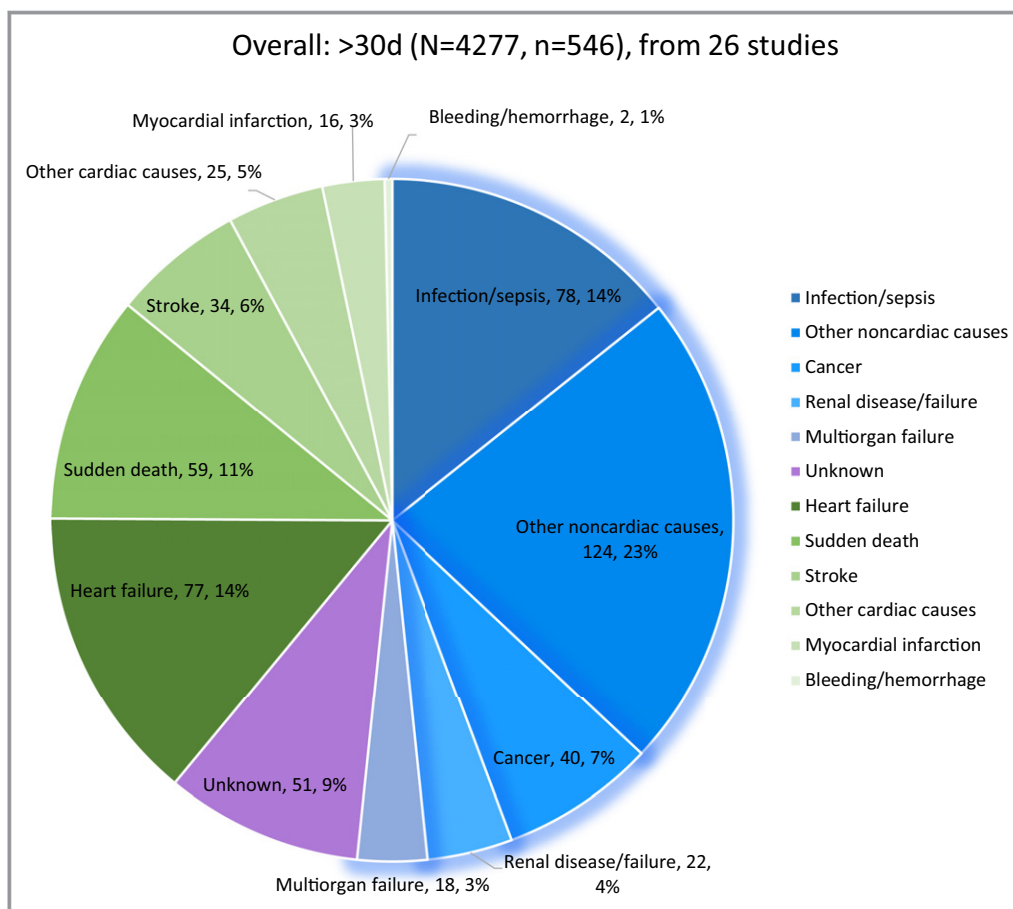
Figure 3. Overall analysis of causes of death after the first 30 days following transcatheter aortic valve replacement (TAVR). Figure 2 and 3 show causes of death post-TAVR per time interval, with total patients included (N), deaths (n), and the blue parts standing for noncardiovascular causes and the green parts for cardiac/procedure-related causes.

moderate-risk patients; on the other hand, infection/sepsis, heart failure, and cancer (19.8%, 15.7%, and 7.9% of deaths) were the 3 leading causes of death for high-risk patients. Comparison for the proportion of cardiovascular deaths saw a significant difference in 2 subgroups after 30 days post-TAVR (moderate risk versus high risk: 55.5% [95% CI: 37.3% to 72.3%] versus 45.6% [95% CI: 32.6% to 59.1%], *P*=0.360, within 30 days; 56.0% [95% CI: 40.6% to 70.4%] versus 33.5% [95% CI: 22.1% to 47.3%], *P*=0.005, after 30 days) (Figure S3).

Comparisons Between TAVR and Other Treatment Choices

Studies that reported causes of death both in patients who underwent TAVR and those who underwent other treatment choices were used for further comparison. In 3 single-center studies that compared outcomes after TAVR and SAVR in a nonrandomized fashion,[15,35,38] TAVR saw a trend of increased proportion of noncardiovascular causes of death

while SAVR had a decreased trend within and after 30 days following the procedure, although the difference is not significant. In cohort B of The Placement of Aortic Transcatheter Valves (PARTNER) trial[29] inoperable patients were randomly assigned to either TAVR or standard therapy (including balloon aortic valvuloplasty). Again, a decreased trend was seen for noncardiovascular causes of death in the traditional treatment group but not in the TAVR group (Figure S4).

Discussion

Aortic stenosis is the most common valvular disease in the world, with a 3-year survival rate less than 30% after symptom onset with medical therapy.[39] Although SAVR is the established therapy for aortic stenosis, over 30% patients are considered at high or prohibitive risk for this procedure[40] and TAVR has evolved as a promising alternative.[41] Certainly, there have been an increasing number of
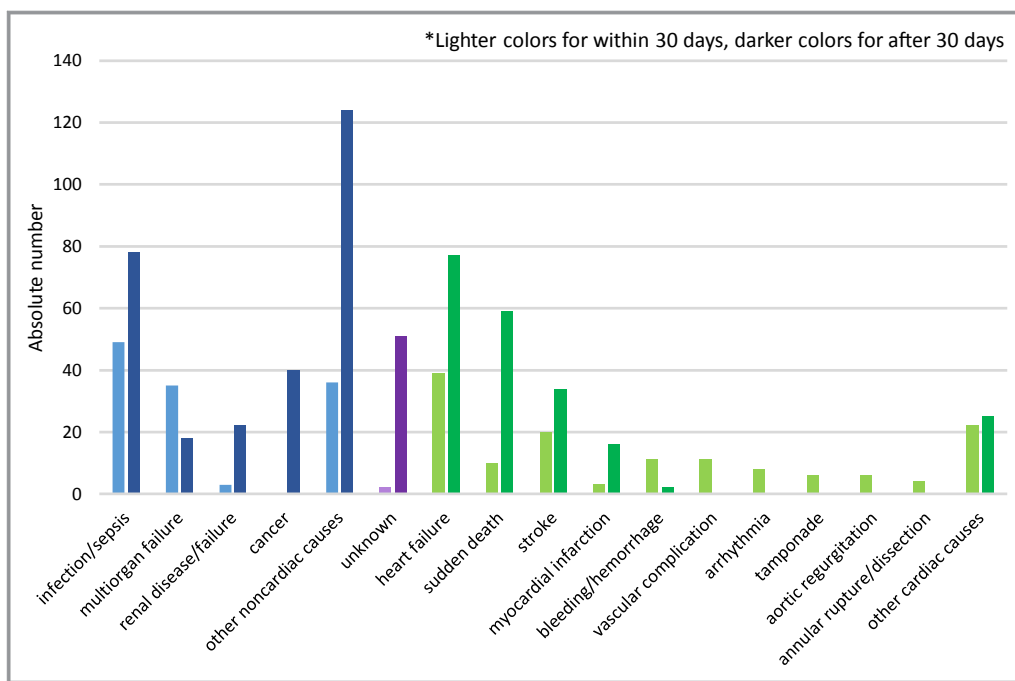
Figure 4. Overall analysis in both durations, within 30 days and after 30 days of the valve procedure.

large multicenter studies and numerous single-center small studies trying to identify mortality after TAVR. However, when managing a postprocedural patient, predicted mortality alone is far from enough. A delineation of the causes of death after TAVR is fundamental to the optimization of acute and late outcomes. The present study afforded important insights in this regard.

We saw noncardiovascular causes of death as important modes of death, particularly beyond 30 days: infection/sepsis, heart failure, and multiorgan failure were the top 3 individual and specific causes of death within the first 30 days and infection/sepsis, heart failure, and sudden death beyond 30 days, leaving infection/sepsis and heart failure being the biggest killers in noncardiovascular and

Table 2. Detailed Modes of Noncardiovascular Deaths in Overall Analysis

| Category	Time Interval	
	≤30 Days	>30 Days
Infection/sepsis		Pneumonia
		Urologic infection
Other noncardiovascular causes	Acute adrenal insufficiency	Peripheral vascular disease
	Gastrointestinal event	Intestinal ileus
	Psychosis	Trauma
	Acute liver failure	Cachexia
	Ischemic bowel	Cirrhosis
		Frailty/natural causes
		Abdominal aortic aneurysm
		Accident
		Bone fracture
		Hypercapnic encephalopathy
		Acute pancreatitis
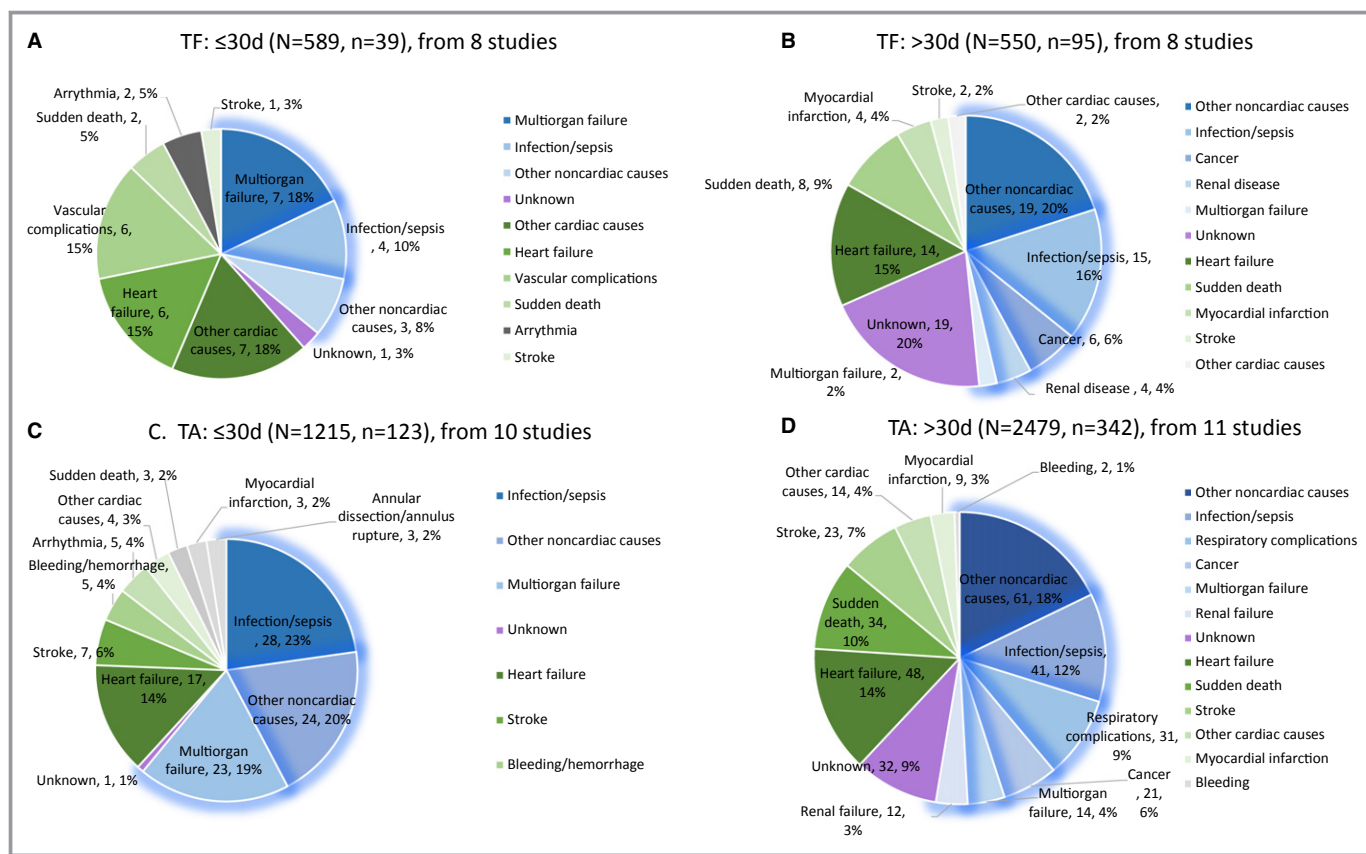
Figure 5. Subgroup analysis by access. TA indicates transapical; TF, transfemoral.

cardiovascular causes of death, respectively. This is in line with prior works in this area.[17,20] Although TAVR is minimally invasive, patients usually have predisposing factors for infection including age; poor pulmonary, renal, and immune function; diabetes; and need for ventilation and central venous access and monitoring.[42] Also, as high-efficiency particulate air-filtered laminar airflow is absent in most catheterization labs, this may increase the risk for procedure-related infection.[43] Thus, the use of broad-spectrum antibiotics for prophylaxis beforehand merits further investigation. It is accepted that aortic stenosis leads to an adaptive hypertrophic response of the myocardium, which allows for maintenance of cardiac output but may lead to progressive myocardial failure. Monrad et al[44] identified the remodeling of left ventricular volume, mass, and shape as a process that may proceed up to almost a decade after correction of the valvular abnormality. Thus, the long-standing left ventricular hypertrophy, increased myocardial oxygen demand, and increased left ventricular end-diastolic pressure may play an important role in cardiac deaths seen.

Previous studies demonstrated that after an early phase of high risk of cardiovascular deaths, risk of cardiovascular death was substantially reduced in patients receiving SAVR.[45] Non-valve-related cardiac failure and malignancy were reported as

the most common certified cardiac and noncardiac causes of death in octogenarians involved in the UK Heart Valve Registry.[46] In our following comparison between TAVR and SAVR or standard therapy, decreased trends were seen for noncardiovascular causes of death within and after 30 days following SAVR and standard therapy, the proportion of which increased following TAVR. Yet, because of current selection criteria, patients undergoing TAVR tend to have more comorbidities and may end up dying from those noncardiovascular comorbidities. Nonetheless, TAVR still proves itself to be a reliable alternative with similar mortality and mode of death even when the referred patients are deemed to be at high risk.

In the following subgroup analyses, no significant differences were seen for proportions of cardiovascular deaths except the comparison between moderate and high-risk patients after 30 days post-TAVR. Bearing different performing characteristics and risk potentials, TF and TA as access choices at least showed evenly distributed modes of death, which may be helpful when stratifying patients to certain treatment options, as was the case for Edwards SAPIEN Valve and Medtronic CoreValve as valve choices. On the other hand, in current practice, patient selection is often based on the evaluation of surgical risk. STS score or the EuroSCORE I/II are now frequently used for risk stratifica-
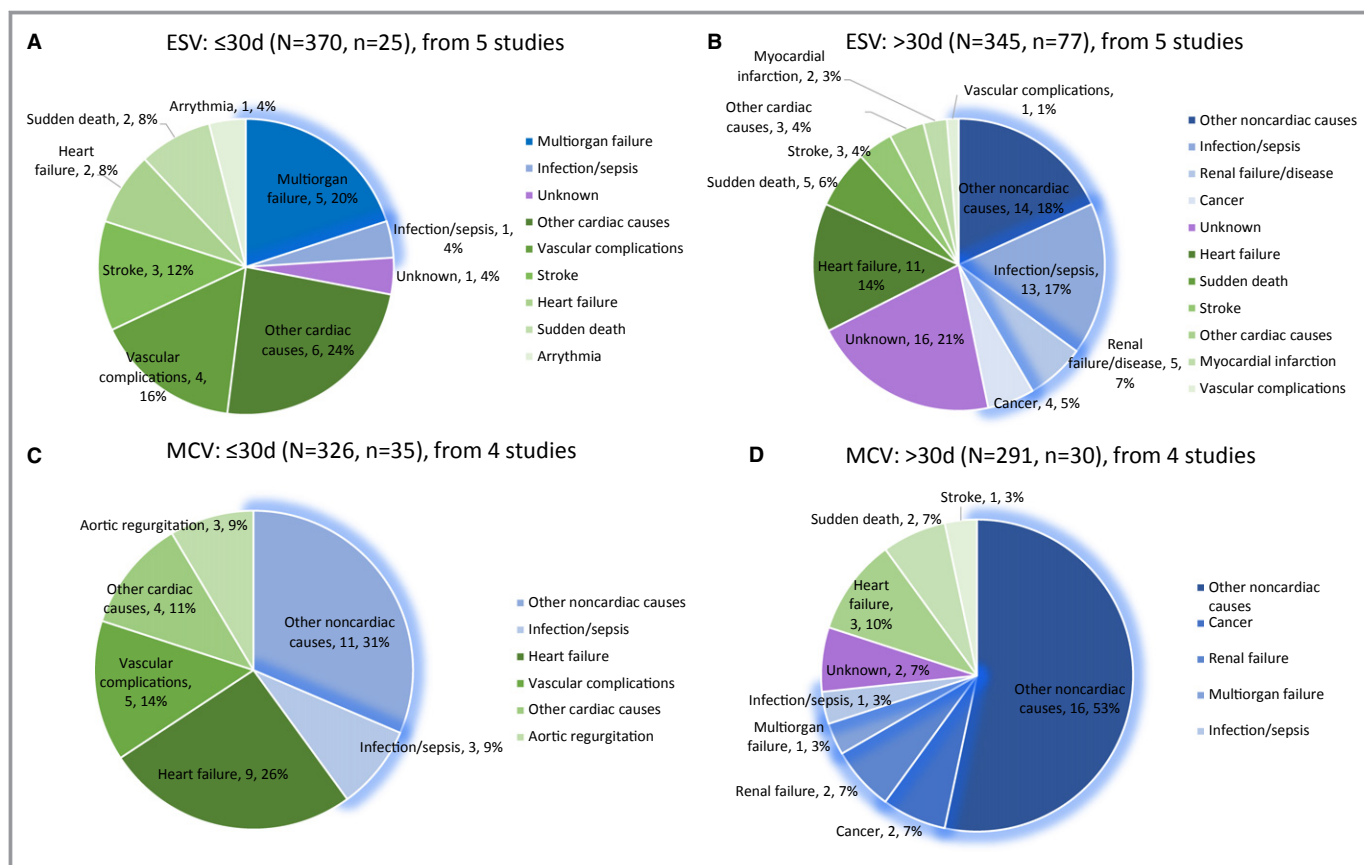
Figure 6. Subgroup analysis by types of prosthesis. ESV indicates Edwards SAPIEN valve; MCV, Medtronic CoreValve.

tion. Hemmann et al[47] have identified STS score as the strongest predictor of long-term survival following TAVR. Thus, we used the mean value of each study's STS score as a risk stratification indicator. The finding of a higher proportion of cardiovascular deaths in moderate-risk patients after 30 days may be explained by the increasing deaths from more comorbidities in high-risk patients. There are certain limitations that need to be stressed. First, because of the huge variation of the number of causes of death, we have made some grouping such as putting accidental death and bone fracture into the "noncardiovascular causes" category. Also, although the VARC-2 criteria were used, further distinguishing of some possible procedure-related deaths was difficult because the lack of original information could cause overestimation of the proportion of noncardiovascular deaths, especially within 30 days after TAVR. Thus, this reclassification may inevitably lead to some bias. Second, heterogeneity should not be forgotten since our study did include large multicenter registries and also single-center studies with relatively small samples. Moreover, heterogeneity from different inclusion criteria in different centers also exists. Third, our results were related to time; however, for those results in the period after 30 days following TAVR, the death toll will be altered if follow-up time changes. Thus, there is a limitation for our included studies without a uniform time to end follow-up. Fourth, we did not exclude studies whose sample size was small. Considering the learning curve, heterogeneity in performing skills does exist across different centers.

Conclusions

The presented data provide important insights into the causes of early and late deaths after TAVR. Many of these causes are potentially preventable and merit specific attention to areas including infection prophylaxis and heart failure optimization. We believe that bearing all the most possible adverse events in mind and with the assistance of future technological advances, cardiologists will further improve patients' outcomes after TAVR.
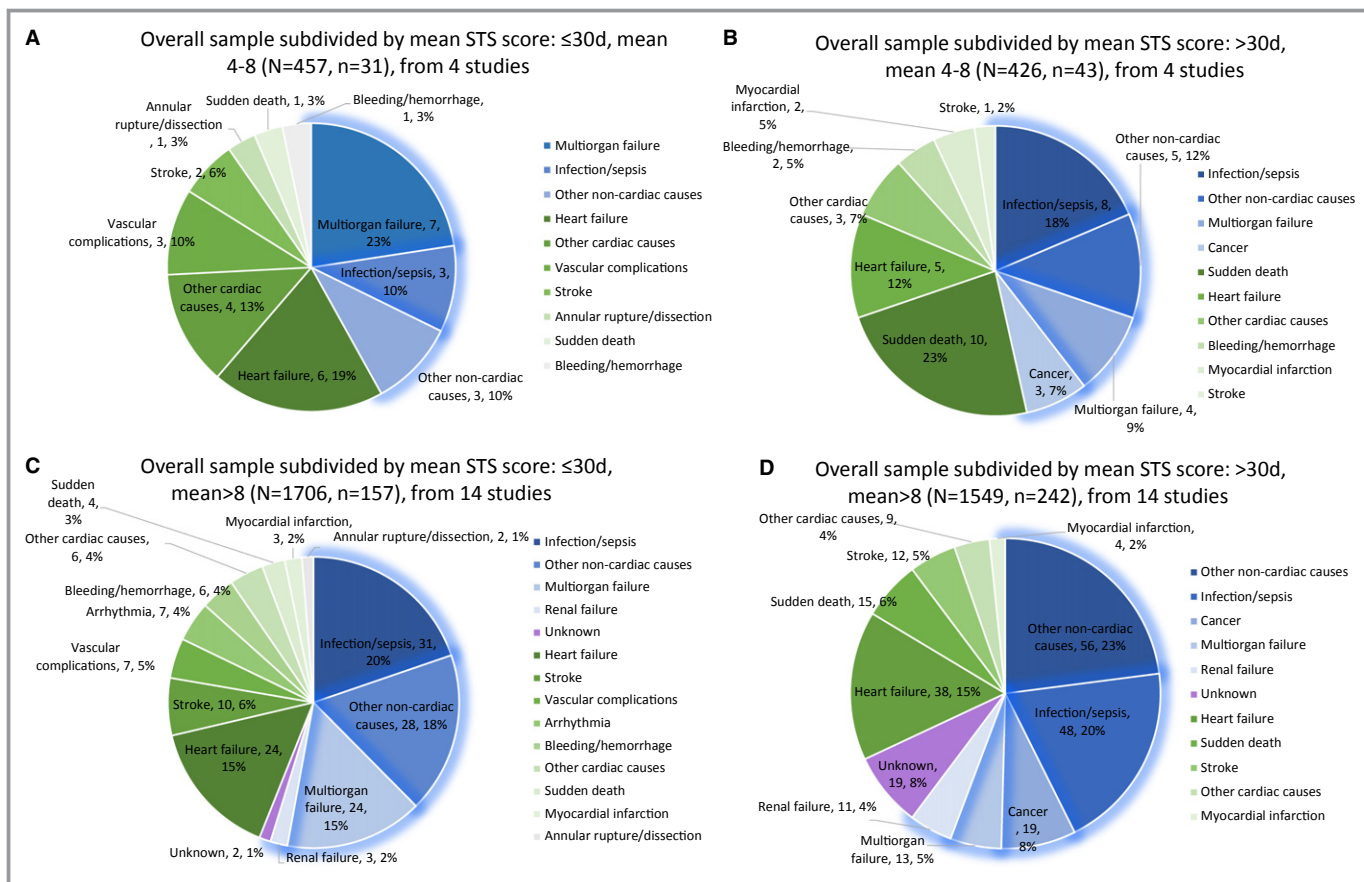
Sources of Funding

Figure 7. Subgroup analysis by mean Society of Thoracic Surgeons (STS) score.

Disclosures

Jilaihawi declares that he is a consultant for Edwards Lifesciences, St. Jude Medical, and Venus Medtech. The other authors declare no competing interests.

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ORIGINAL RESEARCH

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