Systematic Review

The current state of transcatheter aortic valve replacement explant: an updated systematic review

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Background: Despite ever-growing adoption of transcatheter aortic valve replacement (TAVR) in younger healthier patients, a limited number of studies have described post-TAVR valve reinterventions such as surgical explantation known as "TAVR explant".

Methods: We performed a systematic review to characterize the current state of TAVR explant in patients with a failing transcatheter heart valve (THV) using data published by April 30, 2024 in compliance with the PRISMA and MOOSE reporting guidelines. The protocol was registered in PROSPERO (CRD42024529188).

Results: Twenty-eight studies met the eligibility criteria. Almost all studies were non-randomized, observational, and retrospective. The incidence of TAVR explant ranged from 0.2% to 2.8% in patients with a mean age of 67.3–79.0 years, and women representing 25.0–47.1% of cases. The mean time between TAVR implant and explant was 17.0–674.9 days, with most studies reporting a mean time <365 days. Whereas the Society of Thoracic Surgeons-Predicted Risk of Mortality (STS-PROM) score at the time of the TAVR implant ranged between 2.6% and 7.7% (with only one study with score >5%), the STS-PROM score at the time of the TAVR explant ranged between 3.9% and 9.9% (with 17 studies with score >5%). Isolated surgical aortic valve replacement (SAVR) happened in 16.2–100% of cases, aortic root replacement was required in 2.6–41.2%, ascending aortic replacement was performed in 3.2–33.3% of cases. Mitral valve repair/replacement was necessary in 11.8–43.5% and tricuspid valve/repair replacement was done in 2.8–25.0%. Stroke rates were between 0.0% and 20.0% with most studies with rates above 4.0%. The 30-day death rate ranged from 4.8% to 50.0% with most studies with mortality rates higher than 10%. Observed-to-expected mortality ratio was higher than 1.0 in almost all the studies that reported this variable.

Conclusions: TAVR explant remains a rare event, but its clinical impact is non-negligible. Lifetime management strategies should be adopted in younger lower-risk patients when choosing THVs for the index TAVR.

Keywords: Heart valve prosthesis implantation; heart valves; cardiac surgical procedures; cardiovascular surgical procedures

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Introduction

Transcatheter aortic valve replacement (TAVR) is a well-established alternative to surgical aortic valve replacement (SAVR) for patients with severe symptomatic aortic stenosis (1-4). Additionally, the further expansion of TAVR indications includes not only high-risk patients, but also those at intermediate/low risk (based on the results of pivotal trials) and those with bicuspid aortic valves [after approval by the Food and Drug Administration (FDA) despite the exclusion of patients with this specific anatomy from the trials] (5).

With the ever-growing adoption of TAVR in younger healthier patients, significant changes in aortic valve reintervention procedures are expected soon, but a limited number of studies have described post-TAVR valve reinterventions, either TAVR-in-TAVR procedures (6,7) or surgical transcatheter heart valve (THV) explantation ("TAVR explant") (8-17). Of particular concern, are the consistently poor outcomes in patients requiring TAVR explant and this scenario remains underexplored.

In this context, we conducted a systematic review using the existing evidence to characterize the current state of TAVR explant in patients with a failing THV.

Methods

Protocol

This systematic review and meta-analysis followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) reporting guideline (18) and the Meta-Analysis Of Observational Studies in Epidemiology (MOOSE) reporting guideline (19). The protocol was registered in PROSPERO (CRD42024529188).

All observational studies and case series reporting TAVR explant were searched for using a two-level search strategy. First, MEDLINE/PubMed, Embase, Scopus, Web of Science, CCTR/CENTRAL, LILACS, SciELO were searched through April 30, 2024. Second, relevant studies were identified through a manual search of secondary sources including references of initially identified articles, reviews, and commentaries. All references were downloaded for consolidation, elimination of duplicates, and further analyses. The search terms included "failed transcatheter heart valves", "structural valve deterioration", "structural valve degeneration", "endocarditis", "transcatheter aortic valve replacement", "transcatheter aortic valve implantation", "TAVR", "TAVI", "explant", "explantation" and "reoperation". Two independent and blinded authors (X.J., D.A.) reviewed the search results separately to select the studies based on the inclusion and exclusion criteria. Any discrepancies were resolved by discussion and consensus with a third author (M.P.S.). There were no language restrictions.

Studies that met the following criteria were included: the study design was an observational study or a case series, and the study population included adults who underwent TAVR explant for any reason (except for cases with an intraoperative conversion from TAVR to SAVR). The risk of bias in the individual studies was reviewed using the Joanna Briggs Institute Critical Appraisal Checklist (20).

The following information was extracted: authors, year of publication, sample size, frequency of TAVR explant, age, time between TAVR valve implant and explant, Society of Thoracic Surgeons-Predicted Risk of Mortality (STS-PROM), and New York Heart Association (NYHA) class III/IV heart failure at the time of TAVR valve implant and explant, previous cardiac surgery, clinical indications for TAVR explant, type of explanted TAVR valve and implanted surgical valve, concomitantly performed procedures in addition to SAVR, cardiopulmonary bypass (CPB) and aortic cross-clamp times, 30-day mortality, length of intensive care unit (ICU) stay and hospital stay, 30-day readmission, reoperation for bleeding, stroke, renal failure, and new permanent pacemaker implantation (PPI).

Continuous variables are expressed as mean ± standard deviation (SD) or median [interquartile range (IQR)], as appropriate for the data distribution. Categorical variables are expressed as frequency and percentage.

Given the nature of this study, Institutional Research Board approval and patient-informed written consent for publication were not required.

Results

Study selection and characteristics

After excluding non-eligible studies, 28 studies (8-14,16,17) met the eligibility criteria (21-39) (*Figure 1*). Almost all studies were non-randomized, observational, and retrospective. Table S1 shows the risk of bias in the individual studies using the Joanna Briggs Institute Critical Appraisal Checklist. Most data were obtained from the Michigan experience (13-15,17,28-32), STS Database (9,23,27), EXPLANT-TAVR (21,24,33) and EXPLANTORREDO-TAVR registries (25), the Infectious

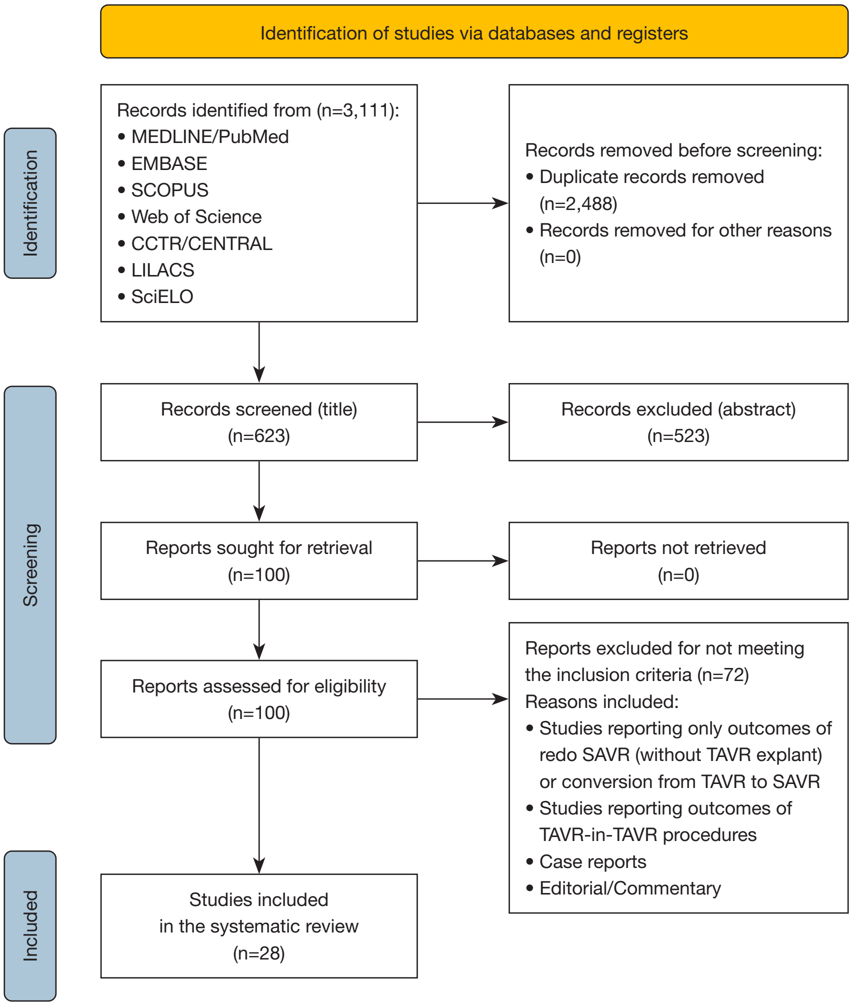

Figure 1 Flow diagram of studies included in data search. SAVR, surgical aortic valve replacement; TAVR, transcatheter aortic valve replacement.

Endocarditis after TAVR International Registry (39), the Nationwide Readmission Database (38), the Centers for Medicare and Medical Services (CMS) (11) and Medtronic-funded studies (22) [pooled data from CoreValve and Evolut R/PRO randomized trials and single-arm studies; the CoreValve US Pivotal Extreme-Risk and High-Risk trials (NCT01240902) and Continued Access Studies (NCT01531374); SURTAVI (Surgical Replacement and Transcatheter Aortic Valve Implantation) randomized trial and Continued Access Studies (NCT01586910); Evolut R US study (NCT02207569); Evolut R US–34R addendum (NCT02746809); Evolut PRO US study (NCT02738853); and Evolut Low Risk randomized trial (NCT02701283)] and other studies.

Patients' baseline characteristics

Table 1 shows the patients' baseline characteristics. Among those studies which reported the incidence of need for TAVR explant, the rate ranged from 0.2% to 2.8%, with most studies reporting incidences <1.0%. Mean age ranged between 67.3 and 79.0 years, with almost all studies showing mean age over 71.0 years. Females represented 25.0–47.1% of cases and the mean time between TAVR implant and explant ranged between 17.0 and 674.9 days, with most studies reporting a mean time <365 days. Whereas the STS-PROM score at the time of the TAVR implant ranged between 2.6% and 7.7% (with only one study with score >5%), the STS-PROM score at the time of the TAVR

Table 1 Patient characteristics

Study	Study period	TAVR explant (N)	TAVR implant (N)	Age (years), mean ± SD or median [range]	Female sex (%)	Days from implant to explant, mean ± SD or median [range]	STS-PROM at implant (%), mean ± SD or median [range]	STS-PROM at explant (%), mean ± SD or median [range]	Previous cardiac surgery (%)	BEV (%)	SEV (%)
Zaid 2024[a] (21) BEV	2009–2022	202	n/a	73.4±9.2	33.7	381 [162–567]	2.8 [1.9–5.0]	5.1 [2.9–8.9]	31.7	100.0	0.0
Zaid 2024[b] (21) SEV	2009–2022	189	n/a	72.1±10.3	33.9	450 [120–1,155]	3.3 [2.2–5.5]	5.0 [3.0–8.5]	45.7	0.0	100.0
Grubb 2024 (22)	2010–2019	20	5,925	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Bowdish 2024 (23)	2012–2023	2,972	n/a	72 [66–78]	36.4	n/a	n/a	5.9	16.6	37.4	15.7
Zaid 2023[a] (24) Iso	2009–2020	105	n/a	73.4±9.5	31.4	261 [120–852]	2.6 [1.9–4.6]	4.3 [2.8–7.7]	41.0	54.0	51.0
Zaid 2023[b] (24) Conc	2009–2020	94	n/a	72.8±10.3	40.4	387 [105–759]	3.4 [2.4–6.9]	7.7 [3.5–11.5]	22.3	50.0	44.0
Tang 2023 (25)	2009–2022	181	66,760	72.1±9.0	37.0	17.6 [5.0–40.7]	3.1 [2.1–4.9]	3.9 [2.5–6.6]	49.2	39.8	60.2
Rösch 2023 (26)	2016–2019	10	1321	79±4.4	30.0	17±16	n/a	24.64±0.3 EuroScore II	0.0	50.0	20.0
Hawkins 2023[a] (27)	2011–2021	1,126	n/a	74 [67–79]	37.0	n/a	n/a	7.0±7.3 [n=531]	14.9	n/a	n/a
Hawkins 2023[b] (27) ViV	2011–2021	674	n/a	71 [63–76]	36.6	n/a	n/a	n/a	33.2	n/a	n/a
Fukuhara 2023 (28)	2011–2021	374	n/a	73.0 [66.8–78.0]	26.2	n/a	n/a	6.6 [4.1–10.9]	35.6	n/a	n/a
Fukuhara 2023 (29)	2011–2019	20	1,479	71 [62–80]	35.0	474.5 [73–1,168]	3.4 [2.4–6.0]	9.2 [5.6–15.3]	50.0	15.0	85.0
Fukuhara 2023 (30)	2012–2019	34	9,694	72.7±8.9	29.4	292 [73–803]	n/a	7.7 [5.2–13.4]	47.1	32.4	67.6
Fukuhara 2024 (31)	2011–2022	66	2,359	72.0 [63.5–77.0]	27.3	657 [109.5–1,496.5]	3.4 [2.4–5.5]	8.5 [4.1–15.7]	50.0	34.8	62.1
Fukuhara 2023 (32)	2011–2020	37	1,719	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Vitanova 2023 (33)	2009–2020	196	n/a	73.5±9.9	31.1	336 [132–987]	3.2 [2.0–5.8]	5.1 [3.0–9.2]	40.3	53.6	46.4
Ogami 2022 (34)	2013–2021	17	2,100	78.3±5.6	47.1	69 [0–192]	7.7±5.1	11.5±9.5	35.3	64.7	35.3
Yun 2022 (35)	2012–2020	46	n/a	n/a	n/a	n/a	n/a	n/a	n/a	52.2	47.8
Muensterer 2022 (36)	2008–2019	31	2,568	76.3±8.3	25.8	153 [0–679.2]	3.0±1.2	5.9±5.0	16.1	45.5	54.5
Guimaron 2022 (37)	2007–2020	21	1,764	67.3±13	38.1	674.9±803.9	5.7±6.8 EuroScore II	16.4±13.1 EuroScore II	61.9	66.7	33.3
Fukuhara 2022[a] (17) BEV	2016–2019	330	n/a	73.1±10.9	35.5	n/a	n/a	4.7 [3.0–7.4]	48.8	68.3	n/a
Fukuhara 2022[b] (17) SEV	2016–2019	153	n/a	72.2±11.0	43.1	n/a	n/a	6.0 [2.8–10.1]	47.7	n/a	31.7
Malvindi 2021 (16)	n/a	13	n/a	73±7	38.5	365 [150–2280]	n/a	14±9 EuroScore	38.5	84.6	15.4
Fukuhara 2021 (13)	2011–2019	17	1,442	73.0±9.3	35.5	96 [69–438]	3.5 [2.6–4.9]	9.9 [6.2–21.4]	47.1	23.5	76.5
Brescia 2021 (14)	2012–2020	46	9,756	73±8	32.6	139 [3–611]	n/a	8.9 [5.4–18.2]	60.8	26.1	63.0
Bapat 2021 (12)	2009–2020	269	n/a	72.7±10.4	34.9	345 [120–969]	3.2 [2.1–5.8]	5.0 [2.8–8.8]	38.3	50.9	49.1
Ando 2021 (38)	2012–2017	297	73,804	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Nakazato 2020 (10)	2009–2019	4	773	73.5 [65.3–78.8]	25.0	293.5 [195.5–474.8]	4.3 [2.5–6.4]	7.1 [4.7–16.9]	25	100.0	0.0
Jawitz 2020 (9)	2011–2015	123	n/a	77 [67–84]	38.2	75 [21–390]	n/a	n/a	28.5	n/a	n/a
Hirji 2020 (11)	2012–2017	227	132,633	73.7±8.9	35.2	212 [69–398]	10 [9–12] Charlson score	n/a	24.2	n/a	n/a
Regueiro 2019 (39)	n/a	28	6,363	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Mangner 2018 (8)	2008–2017	20	n/a	77.3±5.1	35.0	n/a	n/a	17.2 [9.7–21.6]	n/a	65.0	35.0

Zaid 2024[a], BEV cohort; Zaid 2024[b], SEV cohort; Zaid 2023[a], isolated SAVR cohort; Zaid 2023[b], concomitant + SAVR cohort; Hawkins 2023[a], TAVR-SAVR cohort; Hawkins 2023[b], SAVR-TAVR-SAVR cohort; Fukuhara 2022[a], BEV cohort; Fukuhara 2022[b], SEV cohort. TAVR, transcatheter aortic valve replacement; SD, standard deviation; STS-PROM, Society of Thoracic Surgeons-Predicted Risk of Mortality; BEV, balloon-expandable valve; SEV, self-expanding valve; Iso, isolated; Conc, concomitant; ViV, valve-in-valve; n/a, non-available; SAVR, surgical aortic valve replacement.

explant ranged between 3.9% and 9.9% (with 17 studies with score >5%). We found a high prevalence of previous cardiac surgery (14.9–61.9%). Regarding types of THVs, the prevalence of balloon-expandable valves (BEVs) ranged between 15.0–100% and self-expanding valves (SEVs) ranged from 15.4–100%.

Indications for TAVR explant

Table 2 shows the indications for TAVR explant. The major indications were failed implantation (2.9–35.9%), paravalvular leak (PVL) (7.7–71.4%), endocarditis (5.9–100.0%) or structural valve deterioration (3.2–64.0%).

Procedural characteristics

Table 3 shows the procedural characteristics for TAVR explant. Isolated SAVR was performed in 16.2–100% of cases. Aortic root replacement was required in 2.6–41.2%, and ascending aortic replacement was performed in 3.2–33.3% of cases. Mitral valve repair/replacement was necessary in 11.8–43.5% and tricuspid valve/repair replacement was done in 2.8–25.0%. Coronary artery bypass graft (CABG) surgery was performed in 5.9–33.3%. Regarding types of surgical valves implanted after TAVR explant, most valves were bioprosthetic (74.5–100.0%). Mean CPB and aortic cross times ranged between 107.0–228.5 and 80.6–168.0 minutes, respectively.

Procedural outcomes

Table 4 shows the procedural outcomes after TAVR explant. The 30-day death rate ranged from 4.8% to 50.0% with most studies with mortality rates higher than 10%. Observed-to-expected mortality ratio was higher than 1.0 in almost all the studies that reported this variable. Stroke rates were between 0.0% and 20.0% with most studies with rates above 4.0%. Reoperation for bleeding/cardiac tamponade varied from 0.0% to 13.8% and renal failure ranged between 8.0% and 53.3%. New PPI rates ranged between 6.1% and 18.4% and 30-day readmission rates ranged from 5.9% and 36.7%.

Discussion

Summary of evidence

This is the largest systematic review describing characteristics and outcomes of TAVR explant in patients with failing THVs. The most important findings in the present study are the following (*Figure 2*):

(I) The overall frequency of TAVR explant is low, with most cases occurring within the first year after the index TAVR;
(II) The main indications for TAVR explant are failed implantation, PVL, endocarditis, and structural valve deterioration;
(III) STS-PROM score was higher at the time of TAVR explant than at the time of the prior TAVR implant, with a high prevalence of previous cardiac surgery (for example, as in *Figure 3*, showing a TAVR explant in a patient who had undergone valve-in-valve TAVR after a previous SAVR);
(IV) Both BEV and SEV lead to TAVR explants;
(V) There are significant rates of aortic root replacement, ascending aortic replacement, and mitral valve repair/replacement at the time of TAVR explants;
(VI) The 30-day death rates are usually higher than 10.0% with observed-to-expected mortality ratio higher than 1.0 in almost all the reports;
(VII) Stroke rates are non-negligible;
(VIII) New PPI rates are high;
(IX) Patients are frequently readmitted after discharge at 30 days.

Comments

Although a marked increase in TAVR case volume has been observed, the incidence of TAVR explant seems to be low. However, this observation warrants caution for various reasons. These TAVR explants were mostly early failures, with most cases occurring within the first year after the index TAVR, while we know from the medical literature (40) that early valve failure of surgical bioprostheses is uncommon within the first five years.

Early failures can be caused by (I) accelerated pannus formation which leads to bioprosthetic valvular dysfunction, obstruction through subvalvular extension of pannus, and regurgitation when pannus encroachment restricts leaflets (41-43); (II) structural valve deterioration secondary to rapid calcification [which can be accelerated by concomitant prosthesis-patient mismatch (44)] and leaflet tear or perforation (45). PVL, which is seldom seen in surgical bioprosthetic valves, is also one of the most common causes of failure warranting TAVR explant (46). Additionally, endocarditis after TAVR has been described as a cause of

Table 2 Indications for TAVR explant

Study	Paravalvular leak/aortic regurgitation (%)	Structural valve deterioration (%)	Failed implantation (%)	Endocarditis (%)
Zaid 2024[a] (21) BEV	11.9	21.8	n/a	55.4
Zaid 2024[b] (21) SEV	21.2	30.2	n/a	36.0
Grubb 2024 (22)	n/a	n/a	n/a	n/a
Bowdish 2024 (23)	n/a	64.0	n/a	36.0
Zaid 2023[a] (24) Iso	15.2	21.9	2.9	48.6
Zaid 2023[b] (24) Conc	25.5	17.0	4.3	41.5
Tang 2023 (25)	28.7	51.9	5.0	n/a
Rösch 2023 (26)	n/a	n/a	n/a	100.0
Hawkins 2023[a] (27)	n/a	n/a	n/a	n/a
Hawkins 2023[b] (27) ViV	n/a	n/a	n/a	n/a
Fukuhara 2023 (28)	n/a	n/a	n/a	100.0
Fukuhara 2023 (29)	25.0	40.0	10.0	10.0
Fukuhara 2023 (30)	50.0	n/a	17.6	11.8
Fukuhara 2024 (31)	28.8	n/a	n/a	18.2
Fukuhara 2023 (32)	n/a	n/a	n/a	n/a
Vitanova 2023 (33)	17.3	21.4	4.1	42.9
Ogami 2022 (34)	17.5	11.8	23.5	23.5
Yun 2022 (35)	n/a	n/a	n/a	n/a
Muensterer 2022 (36)	32.3	3.2	6.5	51.6
Guimaron 2022 (37)	71.4	28.6	23.8	14.3
Fukuhara 2022[a] (17) BEV	14.8	6.1	27.6	23.9
Fukuhara 2022[b] (17) SEV	18.9	5.2	35.9	13.1
Malvindi 2021 (16)	7.7	30.8	15.4	46.2
Fukuhara 2021 (13)	41.2	23.5	23.6	5.9
Brescia 2021 (14)	28.3	10.9	34.8	13.0
Bapat 2021 (12)	16.7	15.2	3.3	43.1
Ando 2021 (38)	n/a	n/a	n/a	n/a
Nakazato 2020 (10)	25.0	50.0	n/a	25.0
Jawitz 2020 (9)	15.5	11.4	12.1	9.8
Hirji 2020 (11)	n/a	n/a	n/a	20.7
Regueiro 2019 (39)	n/a	n/a	n/a	100.0
Mangner 2018 (8)	n/a	n/a	n/a	100.0

Values may add to over 100% as some patients had more than 1 indication for TAVR explant. Zaid 2024[a], BEV cohort; Zaid 2024[b], SEV cohort; Zaid 2023[a], isolated SAVR cohort; Zaid 2023[b], concomitant + SAVR cohort; Hawkins 2023[a], TAVR-SAVR cohort; Hawkins 2023[b], SAVR-TAVR-SAVR cohort; Fukuhara 2022[a], BEV cohort; Fukuhara 2022[b], SEV cohort. TAVR, transcatheter aortic valve replacement; BEV, balloon-expandable valve; SEV, self-expanding valve; Iso, isolated; Conc, concomitant; ViV, valve-in-valve; n/a, non-available; SAVR, surgical aortic valve replacement.

Table 3 Procedural characteristics

Study	Isolated SAVR (%)	Aortic root replacement (%)	Ascending aortic replacement (%)	Mitral valve repair/ replacement (%)	Tricuspid valve repair/ replacement (%)	CABG (%)	Bioprosthetic valve implanted (%)	Mechanical valve implanted (%)	CPB time, min, mean ± SD or median [range]	Aortic cross-clamp time, min, mean ± SD or median [range]
Zaid 2024[a] (21) BEV	42.1	7.4	4.5	20.8	5.5	16.3	85.1	14.9	129 [103–174]	95 [73–127]
Zaid 2024[b] (21) SEV	42.3	15.3	5.3	24.3	11.6	12.2	85.7	14.3	141 [100–194]	97 [68–153]
Grubb 2024 (22)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Bowdish 2024 (23)	37.1	13.4	9.4	23.2	7.3	17.7	n/a	n/a	153 [112–214]	113 [81–156]
Zaid 2023[a] (24) Iso	100.0	n/a	n/a	n/a	n/a	n/a	80.0	20.0	113.6±46.8	80.6±36.2
Zaid 2023[b] (24) Conc	0.0	n/a	n/a	22.6	8.5	11.6	84.0	16.0	165.5±73.1	123.0±62.4
Tang 2023 (25)	44.2	10.5	6.1	20.4	2.8	17.7	86.2	13.8	146 [106–202]	104 [73–149]
Rösch 2023 (26)	50.0	0.0	0.0	40.0	0.0	10.0	100.0	0.0	119±45	85±26
Hawkins 2023[a] (27)	n/a	16.4	10.4	25.2	8.0	17.3	n/a	n/a	107 [120–223]	107 [77–149]
Hawkins 2023[b] (27) ViV	n/a	19.9	15.6	21.1	7.6	16.6	n/a	n/a	152 [114–214]	113 [83–150]
Fukuhara 2023 (28)	n/a	n/a	n/a	28.9	9.6	13.9	81.8	3.5	148 [110–206]	113 [80–155]
Fukuhara 2023 (29)	35.0	30.0	10.0	35.0	25.0	20.0	80.0	20.0	202 [152–250]	168 [120–199]
Fukuhara 2023 (30)	32.4	17.6	n/a	29.4	17.6	20.6	91.1	8.9	215±100	167±79
Fukuhara 2024 (31)	18.2	22.7	10.6	27.3	16.7	10.6	n/a	n/a	182 [132–236]	137 [92–190]
Fukuhara 2023 (32)	16.2	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Vitanova 2023 (33)	62.2	14.3	9.2	n/a	n/a	14.8	84.7	15.3	133.9±59.4	96.2±46.2
Ogami 2022 (34)	52.9	41.2	0.0	11.8	5.9	23.5	100.0	0.0	158.5±87.8	103.1±51.3
Yun 2022 (35)	n/a	37.0	33.3	43.5	23.9	33.3	n/a	n/a	n/a	n/a
Muensterer 2022 (36)	74.2	0.0	3.2	19.4	6.5	6.5	96.8	3.2	125±47	84±33
Guimaron 2022 (37)	38.1	n/a	n/a	n/a	n/a	19.0	85.7	9.5	130.2±55.1	93.3±47.2
Fukuhara 2022[a] (17) BEV	37.0	23.9	8.5	22.7	5.5	15.5	74.5	10.6	168±79	119±56
Fukuhara 2022[b] (17) SEV	37.9	18.9	22.2	20.3	10.5	14.4	78.4	6.5	175±88	119±53
Malvindi 2021 (16)	30.8	15.4	15.4	38.5	0.0	15.4	n/a	n/a	n/a	n/a
Fukuhara 2021 (13)	64.7	11.8	11.8	23.5	17.6	5.9	94.1	5.9	184 [138–246]	137 [91–188]
Brescia 2021 (14)	34.8	15.2	32.6	21.7	13.0	15.2	82.6	6.5	165 [131–235]	121 [95–174]
Bapat 2021 (12)	45.4	2.6	7.1	17.5	4.8	13.4	84.0	16.0	150.9±72.4	109.4±57.0
Ando 2021 (38)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Nakazato 2020 (10)	25.0	0.0	0.0	25.0	25.0	50.0	100.0	0.0	228.5 [209.8–261.5]	136.5 [133.8–141.8]
Jawitz 2020 (9)	n/a	n/a	n/a	2.4	n/a	5.7	n/a	n/a	146 [117–198]	102 [74–132]
Hirji 2020 (11)	87.2	n/a	n/a	n/a	n/a	8.4	79.3	20.7	n/a	n/a
Regueiro 2019 (39)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Mangner 2018 (8)	30.0	10.0	15.0	n/a	n/a	15.0	n/a	n/a	n/a	n/a

Zaid 2024[a], BEV cohort; Zaid 2024[b], SEV cohort; Zaid 2023[a], isolated SAVR cohort; Zaid 2023[b], concomitant + SAVR cohort; Hawkins 2023[a], TAVR-SAVR cohort; Hawkins 2023[b], SAVR-TAVR-SAVR cohort; Fukuhara 2022[a], BEV cohort; Fukuhara 2022[b], SEV cohort. SAVR, surgical aortic valve replacement; CABG, coronary bypass graft surgery; CPB, cardiopulmonary bypass; SD, standard deviation; BEV, balloon-expandable valve; SEV, self-expanding valve; Iso, isolated; Conc, concomitant; ViV, valve-in-valve; n/a, non-available; TAVR, transcatheter aortic valve replacement.

Table 4 Postoperative outcomes after TAVR explant

Study	30-day mortality (%)	Reoperation for bleeding/cardiac tamponade (%)	Stroke (%)	Renal failure (%)	New permanent pacemaker implantation (%)	Length of ICU stay, days, mean ± SD or median [range]	Length of hospital stay, days, mean ± SD or median [range]	30-day readmission (%)	Observed-to-expected mortality ratio
Zaid 2024[a] (21) BEV	15.1	n/a	3.6	n/a	18.4	3.1 [1.6–7.0]	12 [8–21]	13.9	n/a
Zaid 2024[b] (21) SEV	17.3	n/a	6.0	n/a	17.5	3.0 [1.3–6.7]	13 [8–19]	8.9	n/a
Grubb 2024 (22)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Bowdish 2024 (23)	14.1	9.6	4.6	11.0	14.6	n/a	9 [7–15]	n/a	1.42
Zaid 2023[a] (24) Iso	9.9	n/a	5.7	n/a	12.4	3.0 [1.0–6.0]	13 [8–19.5]	11.3	n/a
Zaid 2023[b] (24) Conc	16.6	n/a	4.3	n/a	17.0	3.7 [1.9–7.7]	11 [7–17]	14.7	n/a
Tang 2023 (25)	11.6	n/a	2.3	n/a	17.8	3.0 [1.4–6.3]	11 [7–17]	14.4	3.49
Rösch 2023 (26)	10.0	n/a	n/a	40.0	n/a	14±16	27±25	n/a	0.41
Hawkins 2023[a] (27)	17.3	9.1	5.2	12.3	n/a	4.0 [2.0–7.0]	9 [7–15]	17.0	n/a
Hawkins 2023[b] (27) ViV	12.0	8.6	2.7	11.1	n/a	3.2 [1.9–6.6]	9 [6–14]	15.0	n/a
Fukuhara 2023 (28)	13.6	5.9	4.5	11.7	12.8	4.0 [2.1–7.6]	11 [8–16]	14.4	2.2
Fukuhara 2023 (29)	15.0	5.0	0.0	30.0	7.0	8.5 [3.6–11.0]	11 [8–18]	n/a	1.63
Fukuhara 2023 (30)	14.7	11.8	0.0	30.0	7.7	5.0 [1.9–8.2]	10.0 [7.5–17.0]	27.6	1.8
Fukuhara 2024 (31)	9.1	4.5	4.5	38.6	11.4	n/a	12.5 [7.8–19.3]	36.7	1.07
Fukuhara 2023 (32)	0.0	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Vitanova 2023 (33)	9.6	n/a	6.6	8.0	15.9	3.0 [1.2–6.3]	12 [8–19]	13.5	2.25
Ogami 2022 (34)	41.2	0.0	5.9	n/a	11.8	2.9±2.9	9.9±12.7	5.9	3.58
Yun 2022 (35)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Muensterer 2022 (36)	25.8	n/a	n/a	n/a	n/a	12±13	25±14	n/a	4.37
Guimaron 2022 (37)	4.8	0.0	9.5	23.8	9.5	n/a	16.6±19.5	n/a	n/a
Fukuhara 2022[a] (17) BEV	17.9	5.8	4.5	12.1	16.0	3.9 [2.0–7.3]	13 [7–20]	12.7	2.0
Fukuhara 2022[b] (17) SEV	19.6	9.2	7.2	16.3	17.0	4.8 [2.5–8.5]	14 [8–19]	11.8	2.3
Malvindi 2021 (16)	15.4	0.0	0.0	23.1	7.7	4 [2–18]	14 [5–42]	n/a	n/a
Fukuhara 2021 (13)	11.8	0.0	0.0	53.3	27.2	5.0 [3.2–11.9]	13 [9–18]	n/a	1.19
Brescia 2021 (14)	32.6	10.9	4.3	22.5	6.1	4.7 [2.0–8.7]	11 [9–17]	27.0	n/a
Bapat 2021 (12)	13.1	n/a	5.9	8.2	18.4	6.2±7.9	16.1±13.3	13.7	2.51
Ando 2021 (38)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Nakazato 2020 (10)	25.0	0.0	0.0	0.0	0.0	n/a	n/a	n/a	n/a
Jawitz 2020 (9)	17.1	13.8	3.3	10.4	14.6	n/a	n/a	n/a	n/a
Hirji 2020 (11)	13.2	n/a	5.7	n/a	n/a	5 [1–10]	11 [8–16]	n/a	n/a
Regueiro 2019 (39)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Mangner 2018 (8)	50.0	n/a	20.0	45.0	n/a	n/a	n/a	n/a	n/a

Zaid 2024[a], BEV cohort; Zaid 2024[b], SEV cohort; Zaid 2023[a], isolated SAVR cohort; Zaid 2023[b], concomitant + SAVR cohort; Hawkins 2023[a], TAVR-SAVR cohort; Hawkins 2023[b], SAVR-TAVR-SAVR cohort; Fukuhara 2022[a], BEV cohort; Fukuhara 2022[b], SEV cohort. TAVR, transcatheter aortic valve replacement; ICU, intensive care unit; SD, standard deviation; BEV, balloon-expandable valve; SEV, self-expanding valve; Iso, isolated; Conc, concomitant; ViV, valve-in-valve; n/a, non-available; SAVR, surgical aortic valve replacement.

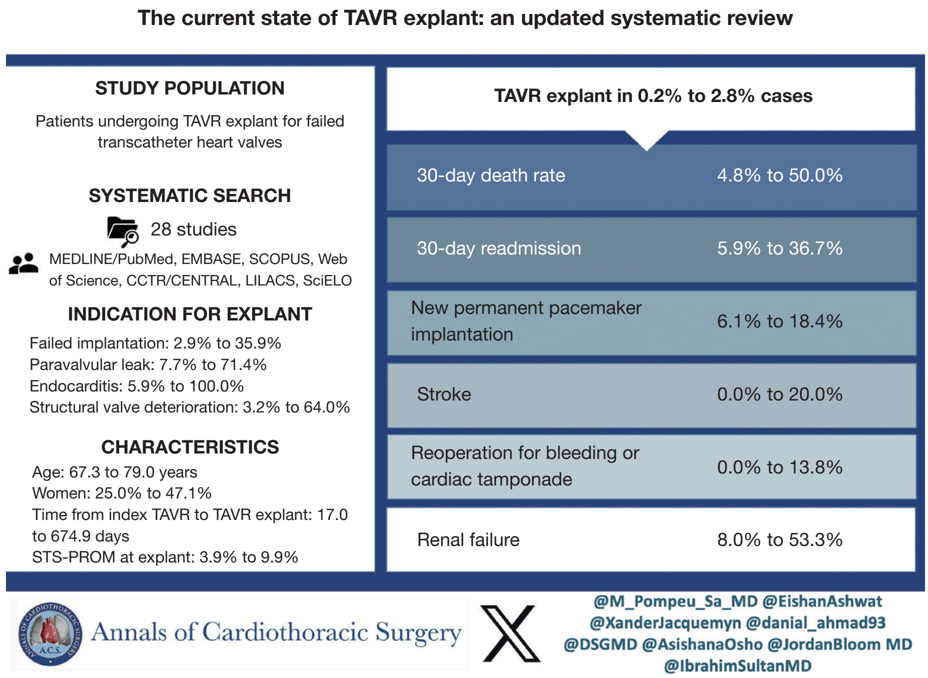

Figure 2 Graphical abstract. TAVR, transcatheter aortic valve replacement; STS-PROM, Society of Thoracic Surgeons-Predicted Risk of Mortality.

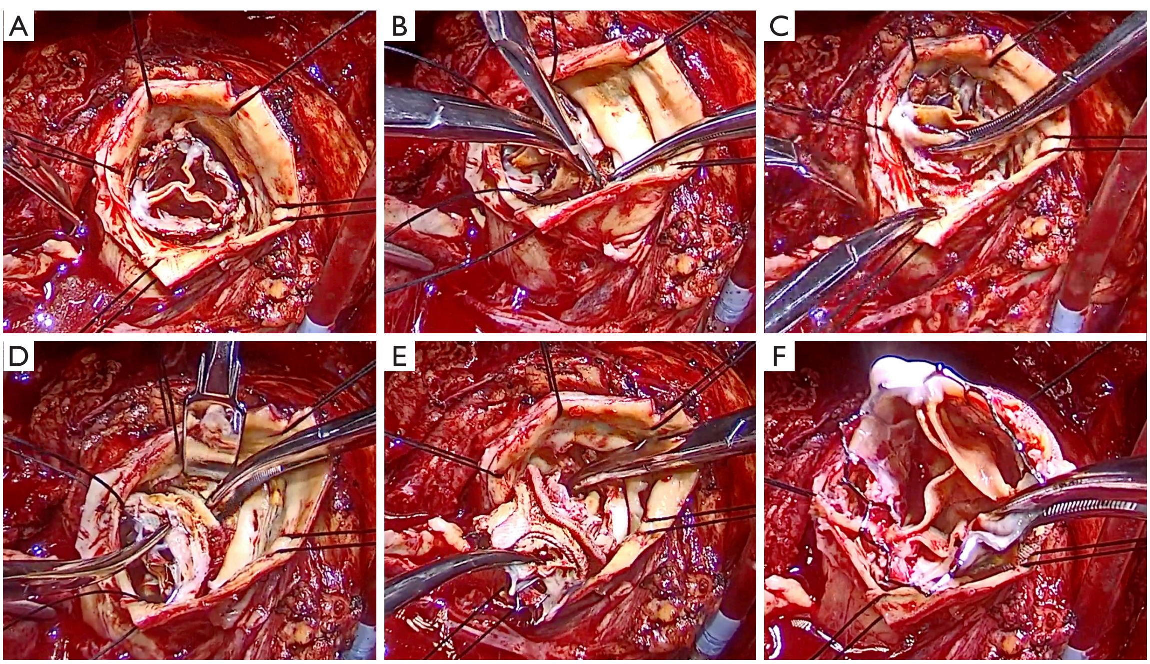

Figure 3 TAVR explant of a balloon-expandable transcatheter heart valve in a patient who underwent previously valve-in-valve TAVR. (A) Exposure of balloon-expandable THV in a failed bioprosthetic valve; (B-E) simultaneous explantation of THV and surgical valve from the aortic annulus; (F) complete removal of both valves from the aortic annulus; this surgical procedure was performed by Dr. Jordan P. Bloom (co-author) at the Massachusetts General Hospital, Harvard Medical School. TAVR, transcatheter aortic valve replacement; THV, transcatheter heart valve.

failures (8,26,28,39).

Although the incidence of complications [such as PVL, patient-prosthesis mismatch (PPM), and new PPI after TAVR] are to be reduced with refinements in implantation techniques (47,48) and new-generation THVs, the number of TAVR explant procedures will probably increase owing to late failures in younger lower-risk patients who will likely outlive the THVs.

Concomitant procedures were commonly performed at the time of TAVR explants, which warrants a deeper discussion. This might be explained by the presence or worsening of untreated cardiac diseases at the time of the index TAVR, completely new cardiac lesions absent at the time of the index TAVR, and the need for unplanned procedures during the TAVR explant (the latter possibly being the reason why we observed high rates of aortic root replacements and ascending aortic replacement). Coronary artery disease (49) and mitral/tricuspid valve diseases (50) are highly prevalent in patients undergoing TAVR. Considering these aspects, more careful selection of patients for the index TAVR may be warranted in terms of lifetime management (51) of aortic valve diseases. A question to be answered in the future would be whether there would be any difference in terms of risk and complexity of TAVR explants between different types of THVs (BEVs *vs.* SEVs). Fukuhara *et al.* (17) identified a total of 483 patients with documented explanted THV, consisting of 68% BEV patients and 32% SEV patients. During TAVR-explant, 63% of patients required other simultaneous procedures, including aortic repair (27%), mitral procedures (22%), CABG (15%), and tricuspid procedures (7%). Patients with SEVs underwent more frequent ascending aortic replacement (22% *vs.* 9%; P<0.001) than those with BEVs, whereas the aortic root replacement rate was similar (19% *vs.* 24%; P=0.22). The overall 30-day mortality was 18% without differences in mortality or other major complications between the groups. Of the 157 patients with isolated SAVR and available STS-PROM score, the observed-to-expected mortality ratio was 2.2.

The observed 30-day death rates were considerably high (more than 10% in most studies). Compared with reported rates for redo SAVR outside the context of TAVR explants, these rates exceed the overall rate of 5.0% reported in studies with information about redo SAVR for failed surgical bioprosthetic valves (52,53). These increased death rates are also expressed in the observed-to-expected mortality ratios >1.0 in almost all the studies and this is even more noticeable if we consider the fact that the STS-PROM score at the time of the TAVR explant was above 5% in most studies, which means that the observed mortality associated with TAVR explants is much higher than the STS-PROM score was able to predict. However, we should bear in mind that Bowdish *et al.* (23) showed recently that the existing STS-PROM risk models performed poorly in the setting of TAVR explants, which pointed to the necessity of creation of a new risk calculator specifically for TAVR explants. Indeed, the STS used recent national data from the STS Adult Cardiac Surgery Database between 2012 and 2023 to analyze outcomes of SAVR after previous TAVR (54). The analysis of 5,457 patients reported an average growth rate in cardiac surgery after prior TAVR of 150% per year overall and this was much higher since low-risk TAVR approval in 2019. Outcomes were worse with increasing surgical urgency, older age, dialysis dependence, and multiple reoperations. These real-world outcomes underly the updated SAVR after TAVR risk models in the new risk calculator (55), which provides essential data to inform heart team decisions, particularly if TAVR is to be considered for younger age and low-risk patients who may not have been studied in the low-risk trials.

Limitations

This study has several limitations. First, most studies are of retrospective observational nature with varying sample sizes, which reduces the certainty of evidence.

Second, several studies did not report important variables, and certain clinical characteristics were based solely on just a few studies, thus, the interpretation of these results warrants caution.

Third, important factors such as surgical access, anthropometric characteristics, and pharmacological treatments were not consistently recorded and could not be reliably investigated.

Fourth, although we had established initially in our protocol the adoption of a meta-analytical approach to pool the data, we decided to limit ourselves to the systematic review due to the clear existence of overlapping samples in the studies with potential cohort duplications from the same database or different data sources, inter-database duplications, such as between the data belonging to the Michigan experience (13-15,17,28-32), STS Database (9,23,27), EXPLANT-TAVR (21,24,33) and EXPLANTORREDO-TAVR registries (25), and the Nationwide Readmission Database (38) along with the CMS (11).

Conclusions

We described the clinical/procedural characteristics, indications, and outcomes of TAVR explant. Although the rates of TAVR explant remain low, concurrent procedure rates were high at the time of TAVR explant, and the immediate mortality and morbidity are considerable. In this context, it is of paramount importance to focus not only on the periprocedural outcomes following the index TAVR procedures, but also on longer-term aspects. Our systematic review might be used to appropriately select candidates for TAVR, especially those younger lower-risk patients who would probably outlive the THVs implanted at the index TAVR and for whom lifetime management strategies should be adopted.

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Footnote

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