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Conversion to Cardiac Surgery During Elective and Urgent Transcatheter Aortic Valve Implantation: A Systematic Review and Meta-Analysis

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ABSTRACT

Transcatheter aortic valve implantation (TAVI) has become an established treatment for severe aortic stenosis. However, the need for unplanned conversion to cardiac surgery (CS) during TAVI remains an infrequent but critical event. It is unclear whether this risk is higher in patients undergoing urgent procedures. We conducted a systematic review and meta-analysis to compare the incidence of unplanned conversion to CS between patients undergoing urgent versus elective TAVI. A systematic search of PubMed, SCOPUS, and Cochrane databases was performed to identify eligible studies. The primary outcome was the rate of unplanned conversion to CS. Secondary outcomes included mortality, device success, vascular complications, device embolization, acute kidney injury (AKI), stroke, permanent pacemaker implantation (PPI), moderate-or-severe paravalvular regurgitation (PVL), need for second valve implantation, bleeding, and duration of hospitalization. Seven studies comprising 71,909 patients were analyzed; 5108 underwent urgent TAVI and 66,801 underwent elective TAVI. No significant difference in conversion to CS was observed between the groups (RR: 0.89; 95% CI: 0.65−1.22). Device success rates were similar (RR: 0.99; 95% CI: 0.97–1.00). Urgent TAVI was associated with prolonged hospitalization (mean difference: 7.75 days; 95% CI: 4.06–11.45) and increased AKI risk (RR: 2.20; 95% CI: 1.53–3.16). Vascular complications, device embolization, stroke, PPI, PVL, second valve implantation, and major bleeding rates were comparable between the groups. Urgent TAVI is not associated with an increased risk of unplanned conversion to surgery. The observed higher AKI rates and longer hospital stay suggest that patient-related factors beyond procedural urgency may contribute to adverse outcomes.

Nikolaos Ktenopoulos and Anastasios Apostolos contributed equally to this work.

1 | Introduction

Aortic stenosis (AS) is the most common valvular heart disease [1], and its incidence is further increasing due to the extended life expectancy [2]. It is characterized by progressive calcification of the aortic valve leaflets, which gradually leads to obstruction of blood flow through the left ventricular outflow tract [3]. As a result, insufficient cardiac output occurs, causing structural changes in the left ventricle, heart failure (HF), decreased exercise tolerance, and eventually death [3]. Furthermore, untreated severe AS can result in catastrophic outcomes, with estimated mortality rates reaching up to 50% at 1 year and up to 80% at 3 years [4].

Since the 1960s, interventional options have continuously evolved. Currently, in addition to surgical aortic valve replacement (SAVR), transcatheter aortic valve implantation (TAVI) has become increasingly popular, being the preferred treatment option for many patients, especially the elderly [5]. TAVI usage has significantly increased, with its indications expanding even to younger, low-surgical-risk patients, as its safety and efficacy have been well-established in several randomized trials (RCTs) [6–12].

According to current European and American guidelines, TAVI should typically be performed electively in stable patients [13, 14]. However, patients with severe aortic stenosis frequently present with acute decompensated HF and hemodynamic deterioration, sometimes progressing to cardiogenic shock [15, 16]. A considerable proportion of these patients are resistant to pharmacological therapies, often undergoing balloon aortic valvuloplasty (BAV) to temporarily improve their hemodynamic status, or as a bridge to TAVI [15, 17, 18].

With the increasing number of patients presenting with acute HF and severe AS, TAVI has recently been performed as a rescue therapy instead of BAV, showing promising outcomes [16]. According to the EuroSCORE II (European System for Cardiac Operative Risk Evaluation), nonelective TAVI can further be classified as urgent, emergent, or salvage procedure [19]. Urgent TAVI is defined when a patient requires an unplanned hospitalization and undergoes TAVI during the same hospital stay due to hemodynamic instability and dependence on inotropic support, with or without mechanical circulatory support. Emergent intervention is defined as the need for TAVI within 24 h, while salvage intervention refers to TAVI performed after return of spontaneous circulation post-cardiopulmonary resuscitation [19]. The rate of urgent/emergent/salvage TAVI in current clinical practice is underestimated, ranging from 10% to 24% [20]. Nevertheless, most data derive from retrospective registries, as patients with cardiogenic shock or hemodynamic instability due to severe AS have generally been excluded from major TAVI RCTs [10, 12].

The aim of this systematic review and meta-analysis is to investigate whether patients undergoing urgent TAVI are at higher risk for unplanned conversion to cardiac surgery (CS).

2 | Materials and Methods

This systematic review and meta-analysis were conducted in accordance with the updated PRISMA 2020 guidelines (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) [21, 22] and the MOOSE checklist (Meta-analyses Of Observational Studies in Epidemiology) (Supporting Information S1: Figure S2A,B) [23]. The protocol and study design were registered at the Open Science Framework (https://osf.io/ku3fz). Institutional Review Board (IRB) approval was not required, as this meta-analysis used previously published study-level data.

A systematic search was conducted in three literature databases, Cochrane Central Register of Controlled Trials, Medline, and Scopus, as recommended by the Cochrane guidelines. Searches were performed from their inception through March 15, 2025. Additionally, manual research was conducted on references of selected studies to identify other potentially eligible studies. Only studies that included the primary endpoint were included in the analysis.

2.1 | Search Strategy

The electronic search included the following terms: "transcatheter aortic valve implantation," "TAVI," "transcatheter aortic valve replacement," "TAVR," "urgent," "emergent," and "elective." No language restrictions were applied. The detailed search strategy used is displayed in the Supporting Information Material.

2.2 | Study Selection Procedure

All studies identified by systematic electronic searches were imported into the Rayyan software, and duplicate studies were removed [24]. Additional references from the same study were merged as needed. Titles, abstracts, and keywords of all articles were screened, and irrelevant articles were excluded by two investigators (N.K. and A.A.). Full texts of potentially eligible studies were then assessed, and disagreements were resolved through discussion or consultation with an additional researcher (K.T.).

2.3 | Data Extraction Procedure

A standardized data extraction form was developed to collect study characteristics and key findings from each selected study. This form was validated on three randomly selected studies by three investigators (N.K., A.A., and K.T.). Following validation, two authors independently extracted data from each study (N.K. and A.A.). A third author reviewed the extracted data, resolved discrepancies, and entered data into Review Manager 5 software (Review Manager 2014) (K.T.).

2.4 | Data Items Extracted

The following data were extracted from the included studies [1]: Publication details: authors, publication year, and source [2]. Study characteristics: sample size, inclusion and exclusion criteria [3]. Participant characteristics: demographic data, comorbidities, echocardiographic findings [4]. Procedure-related information: periprocedural characteristics, type of valve implanted, valve size, vascular access site [5]. Outcomes: follow-up results (from hospitalization to 1 year).

2.5 | Risk of Bias Assessment

The risk of bias for cohort studies was assessed using the Risk Of Bias In Non-randomized Studies-of Interventions (ROBINS-I) tool [25], evaluating domains such as confounding, participant selection, intervention classification, deviation from intended interventions, missing data, outcome measurement, and selective reporting. Additionally, the Newcastle−Ottawa Scale (NOS) [26], recommended for observational studies, was employed. Selection, comparability, and outcomes were assessed with four, two, and three points, respectively, with a maximum score of nine points. Scores of 5−6 indicate moderate quality, whereas scores of 7−9 indicate high quality. The quality assessment was performed blindly and independently by two authors (N.K. and A.A.), with disagreements resolved by consultation with a third author (Supporting Information S1: Tables S1 and S2) (K.T.). Potential publication bias was evaluated through funnel plots, plotting sample size against risk ratio (RR) for each endpoint. Additionally, certainty of evidence across all outcomes was assessed using the Grading of Recommendations Assessment, Development, and Evaluation (GRADE) tool, and a summary of findings is provided in the Supporting Information S1: Table S6.

2.6 | Eligibility Criteria and Outcomes

Studies were included in this systematic review and meta-analysis if they fulfilled all of the following criteria [1]: Human studies with two comparative arms [2]. Urgent or emergent TAVI as the intervention arm [3]. Elective TAVI as the comparison arm [4]. Available data regarding conversion to CS. In general, urgent TAVI was defined as per each specific study's criteria. If not otherwise specified, urgent TAVI included both urgent and salvage interventions.

The primary endpoint of this study was the frequency of unplanned conversion to CS. The secondary endpoints included [1]: In-hospital, 30-day, and 1-year all-cause mortality rates [2], in-hospital device success rate (in-hospital) [3], periprocedural vascular complications [4], in-hospital stroke (stroke) [5], in-hospital acute kidney injury (AKI) [6], in-hospital permanent pacemaker implantation (PPI) post-TAVI [7], moderate or severe paravalvular regurgitation (PVL) [8], in-hospital major or life-threatening bleeding complications [9], need for second valve implantation [10], periprocedural device embolization periprocedurally [11], and duration of hospitalization. Each endpoint was defined according to Valve Academic Research Consortium-2 criteria [27].

2.7 | Statistical Analysis

For statistical analyses, RR and corresponding 95% confidence intervals (CI) were calculated using a random-effects model (Mantel−Haenszel). All analyses were conducted at the study level, using RR with 95% CI to estimate the effect of urgent versus elective TAVI. Studies lacking sufficient data for a specific endpoint were excluded from the relevant analysis. Study heterogeneity was assessed using the I^2 statistic ($I^2 = 100\% \times [Q-df]/Q$, where Q represents Cochran's heterogeneity statistic and df represents degrees of freedom). Low, moderate, and high heterogeneity were defined as $I^2 \leq 25\%$, $I^2 \leq 50\%$, and $I^2 > 50\%$, respectively. A $p < 0.05$ was considered statistically significant. Sensitivity analyses using a leave-one-out approach were performed by systematically removing one study at a time to evaluate the effect of each study individually on outcomes. Analysis was conducted using Review Manager software version 5.4 (Cochrane Collaboration).

3 | Results

3.1 | Search Results

The systematic search initially identified 497 records. After removing duplicates, 454 records remained for title and abstract screening, from which 22 were selected for full-text evaluation. Ultimately, seven studies fulfilled the predetermined eligibility criteria and were included in the systematic review and meta-analysis [28–34]. The literature search process is depicted in the PRISMA flow diagram (Supporting Information S1: Figure S1).

3.2 | Study Characteristics

Table 1 summarizes the characteristics of the included studies. All studies, except two, were retrospective. A total of 71,909 patients were included in the analysis: 5108 underwent urgent TAVI, and 66,801 underwent an elective procedure. Two studies were performed in the United States, two in Japan, one in Canada, and the remaining were conducted in European countries (Table 1). All included records were full-text manuscripts, except for one, which was published as an abstract. In the study by Steffen et al., patients with and without cardiogenic shock were grouped together as patients who underwent urgent TAVI and compared to those who underwent elective TAVI [34].

3.3 | Patient Characteristics

Table 2 and Supporting Information S1: S3 display the baseline patient characteristics. The mean age exceeded 80 years in all studies except one, where age data were not reported. Although female patients typically are underrepresented in TAVI studies, women comprised a significant proportion (overall, 56.41%) of the cohort. Preprocedural echocardiographic findings are presented in Supporting Information S1: Table S4. There were no significant differences in the parameters of AS severity; however, there was a higher proportion of patients with moderate or severe mitral regurgitation in the urgent TAVI group. Data regarding general anesthesia, transfemoral access, implantation of self-expanding or balloon-expandable valves, and valve-in-valve (ViV) procedures are summarized in Table 3. The definitions for urgent TAVI for each study are presented in Supporting Information S1: Table S5.

TABLE 1 | Studies' characteristics.

First author	Year of publication	Study design	Country	Study sample
Enta [29]	2020	Prospective	Japan	1613
Ichibori [30]	2019	Retrospective	USA	474
Kabahizi [31]	2021	Retrospective	Great Britain	1157
Kitahara [32]	2022	Retrospective	Japan	25,495
Kolte [33]	2018	Retrospective	USA	40,042
Alnasser [28]	2014	Prospective	Canada	702
Steffen [34]	2022	Retrospective	Germany	2798

Abbreviation: USA, United States of America.

3.4 | Primary Endpoint

Seven studies with a total of 71,909 patients were analyzed (Central Illustration 1). Among them, 5108 patients underwent urgent TAVI, and 66,801 underwent elective TAVI. Conversion to unplanned CS during TAVI did not differ significantly between the two groups (RR: 0.89, 95% CI: 0.65−1.22, $I^2 = 0\%$) (Figure 1). Data regarding conversion to unplanned CS were available for all included studies, as it was a mandatory criterion for study inclusion.

3.5 | Secondary Endpoints

Data on in-hospital mortality were available from all seven studies (71,909 patients). Urgent TAVI was associated with a 2.45-fold increased risk of in-hospital mortality compared to elective TAVI (RR: 2.45, 95% CI: 1.69−3.54, $I^2 = 38\%$) (Figure 1). Similarly, mortality at 30 days and 1 year was higher in the urgent TAVI group (RR: 3.46, 95% CI: 1.93−6.21, $I^2 = 92\%$; and RR: 1.54, 95% CI: 1.01−2.34, $I^2 = 95\%$, respectively) (Figures 1 and 2). Additionally, no significant differences were observed regarding successful valve implantation between the groups (RR: 0.99, 95% CI: 0.97−1.00, $I^2 = 66\%$) (Figure 3). Patients undergoing urgent TAVI had a significantly longer hospitalization by approximately 8 days (mean difference: 7.75, 95% CI: 4.06−11.45, $I^2 = 99\%$) (Figure 4). The overall incidence of periprocedural vascular complications and device embolization was low, but slightly higher in urgent TAVI patients (RR: 1.52, 95% CI: 0.72−3.22, $I^2 = 81\%$; and RR: 1.45, 95% CI: 0.68−3.06, $I^2 = 14\%$) (Supporting Information S1: Figures S3 and S4). Patients undergoing urgent TAVI had a higher risk of developing AKI during hospitalization postprocedurally (RR: 2.20, 95% CI: 1.53−3.16, $I^2 = 55\%$) (Supporting Information S1: Figure S5). Rates of in-hospital stroke (RR: 1.06, 95% CI: 0.84−1.34, $I^2 = 35\%$) (Supporting Information S1: Figure S6) and PPI (RR: 1.01, 95% CI: 0.93−1.11, $I^2 = 0\%$) (Supporting Information S1: Figure S7) were comparable between urgent and elective TAVI. Additionally, rates of moderate-to-severe postprocedural PVL (RR: 1.24, 95% CI: 0.90−1.72, $I^2 = 47\%$), the need for second valve implantation (RR: 1.26, 95% CI: 0.69−2.28, $I^2 = 0\%$), and major or life-threatening bleeding during hospitalization (RR: 1.16, 95% CI: 0.78−1.72, $I^2 = 77\%$) did not differ significantly between the two groups (Supporting Information S1: Figures S8, S9, and S10).

3.6 | Risk of Bias Assessment

Two tools were used for risk-of-bias assessment: ROBINS-I and the NOS. According to ROBINS-I, all included studies exhibited a high risk of bias primarily due to confounding bias. A study rated as high-risk in at least one domain was classified as overall high-risk, which was expected due to the inherent selection bias associated with the urgent nature of the intervention and its effect on outcomes, especially mortality. However, the risk of bias in other domains was mostly low or moderate. According to the NOS, all seven studies were classified as high quality based on criteria related to selection, comparability, and outcome assessment (Supporting Information S1: Tables S1 and S2). Funnel plots were used to evaluate publication bias. Finally, according to the GRADE assessment, the certainty of evidence was rated as moderate for the primary endpoint and low to very low for most secondary outcomes, mainly due to inconsistency and imprecision among observational data (Supporting Information S1: Table S6).

4 | Discussion

To the best of our knowledge, our systematic review and meta-analysis is the first to compare conversion to unplanned CS rates between patients undergoing urgent versus elective TAVI. The key findings of our analysis are the following (Central Illustration 1):

I. No difference in conversion rates to unplanned CS was observed between urgent and elective TAVI.
II. In-hospital, 30-day, and 1-year mortality were significantly higher in the urgent TAVI group.
III. The length of hospital stay was approximately 8 days longer in patients undergoing urgent procedures.
IV. Rates of periprocedural vascular complications, device embolization, and AKI during hospitalization after TAVI were increased in the urgent procedures.

No differences were observed between urgent and elective TAVI regarding successful valve implantation, the need for a second valve implantation, moderate-to-severe post-procedural PVL, major or life-threatening bleeding, stroke, and the frequency of PPI post-TAVI.

TABLE 2 | Patients' characteristics.

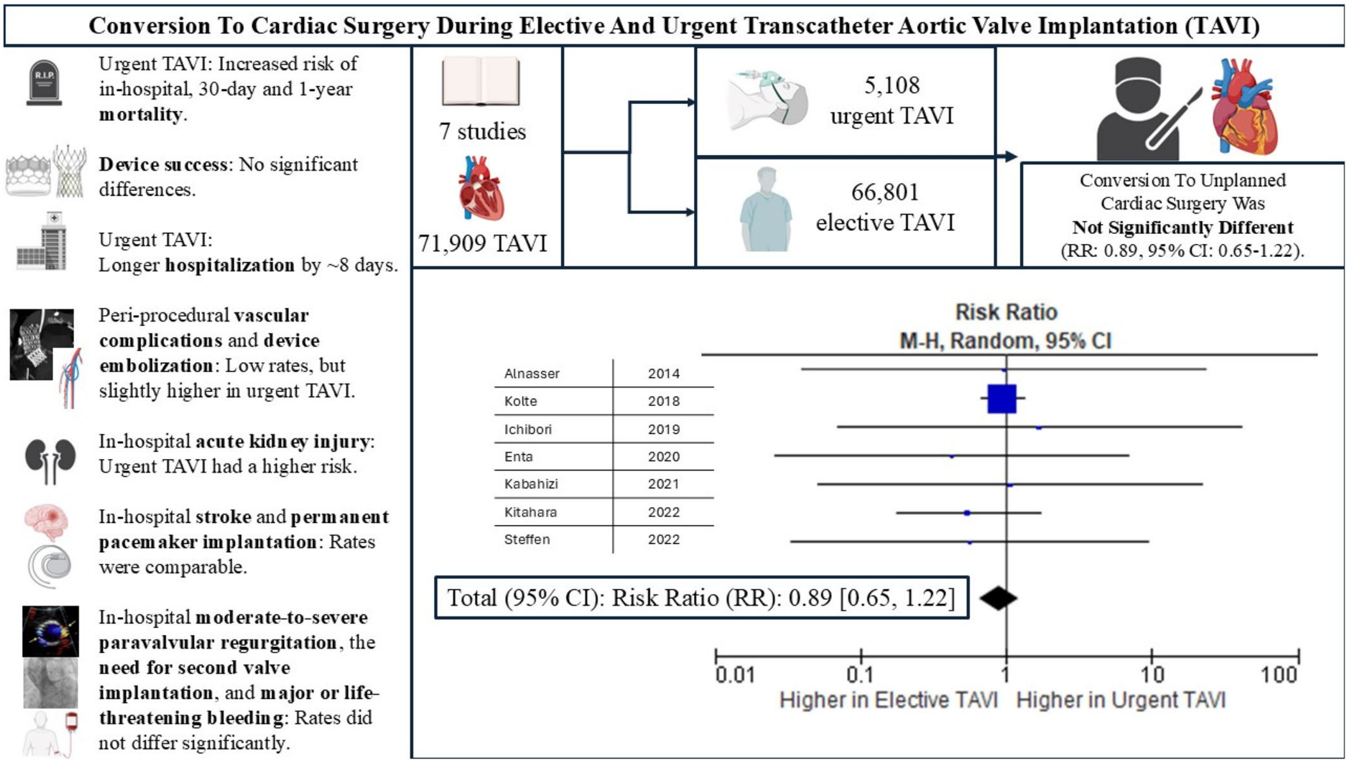
First author	*N* of patients		Mean age, years		Female (*N*)		Hypertension (*N*)		Dyslipidemia (*N*)		Type 2 diabetes mellitus (*N*)		Smoking (*N*)		CKD (*N*)	
	Elective	Urgent	Elective	Urgent	Elective	Urgent	Elective	Urgent	Elective	Urgent	Elective	Urgent	Elective	Urgent	Elective	Urgent
Kabahizi	975	182	82 ± 2.1	80.1 ± 7	455	77	N/A	N/A	N/A	N/A	176	40	N/A	N/A	121	34
Kitahara	24,917	578	N/A	N/A	17,047	402	19,738	436	12,140	264	6607	160	N/A	N/A	N/A	N/A
Enta	1526	87	84.3 ± 5	84.9 ± 7	1075	61	1203	65	648	40	401	29	37	7	N/A	N/A
Kolte	36,090	3952	83.3 ± 7.41	83.3 ± 7.41	17,474	1902	32,477	3608	N/A	N/A	12,690	1557	1672	231	3177	631
Ichibori	396	78	81.6 ± 8.5	80.8 ± 9.6	188	38	N/A	N/A	N/A	N/A	160	35	17	6	12	8
Alnasser	152	52	83 ± 7	85.75 ± 5.19	73	31	132	42	97	32	42	15	N/A	N/A	5	3
Steffen	2745	179	81.37 ± 6.16	81.34 ± 7.98	1371	70	2344	159	1123	110	773	73	523	43	1236	137

Abbreviations: CKD, chronic kidney disease; N/A, not available.

TABLE 3 | Periprocedural characteristics of the patients.

First author	General anesthesia (*N*)		ViV Procedure (*N*)		Trans-femoral access (*N*)		Non-trans-femoral access (*N*)		Balloon-expandable valve (*N*)		Self-expandable valve (*N*)	
	Elective	Urgent	Elective	Urgent	Elective	Urgent	Elective	Urgent	Elective	Urgent	Elective	Urgent
Kabahizi	N/A	N/A	53	16	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Kitahara	19,876	467	810	15	22,107	525	2810	53	18,762	415	6155	163
Enta	N/A	N/A	N/A	N/A	1241	72	285	15	1387	82	139	5
Kolte	30,691	3387	1863	382	28,414	2980	7676	972	26,784	2984	8897	931
Ichibori	4	1	N/A	N/A	N/A	N/A	N/A	N/A	171	44	225	34
Alnasser	N/A	N/A	8	3	82	39	70	13	148	49	4	3
Steffen	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Abbreviations: N/A, not available; ViV, valve-in-valve.



CENTRAL ILLUSTRATION 1 | Our meta-analysis demonstrates a low but impactful risk of unplanned cardiac surgery during TAVI, with no difference between elective and urgent procedures. These results reinforce the need for immediate surgical backup and optimized team preparedness to improve patient safety. [Color figure can be viewed at wileyonlinelibrary.com]

Recent studies continue to underscore the critical, albeit rare, role of unplanned CS during TAVI. Eggebrecht et al.'s [35] landmark meta-analysis of over 9200 patients reported a 1.1% incidence of unplanned CS, predominantly due to valve embolization, annular rupture, and aortic dissection, with a striking 30-day mortality rate exceeding 67% among those requiring conversion. Similarly, Marin-Cuartas et al. [36] described an unplanned CS rate of 1.1% in a large contemporary series, with higher mortality in high-risk patients. In this nationwide analysis, the researchers reinforced these findings by identifying conversion as an independent predictor of in-hospital mortality. An analysis from our nationwide, prospective registry encompassing TAVI procedures performed in Greece from February 2013 to October 2022 showed that only 12 (0.003%) out of 3611 patients having undergone TAVI required unplanned conversion to CS. Although the incidence of conversion to surgery was lower in the Greek registry, the mortality rate was high; 50% died during 1-year follow-up [37]. These studies consistently illustrate that, while rare, unplanned surgical conversion is a life-saving measure associated with high procedural risk and adverse outcomes.

Our meta-analysis not only corroborated the low overall incidence of conversion to CS but also offered an important new perspective: unlike prior assumptions, we observed no significant difference in conversion rates between elective and urgent TAVI procedures [16, 31, 38]. This finding contrasts with the prevailing notion that procedural urgency may predispose to higher intraprocedural complications requiring surgical bailout. The absence of a significant difference in our analysis may reflect the evolution of standardized protocols, patient selection strategies, and procedural planning irrespective of procedural urgency. This insight is clinically relevant, as it suggests that the risk of unplanned conversion is inherent to the TAVI procedure itself and not necessarily driven by procedural urgency, thereby emphasizing the universal need for institutional preparedness across all TAVI cases.

It is important to acknowledge that definitions of procedural urgency vary across registries; while this study adopted the EuroSCORE II classification—where "emergent" refers to intervention within 24 h—the STS definition designates "emergent" as surgery performed as soon as possible. Moreover, the classification of "urgent" is often center-specific and may be influenced by logistical factors such as operating room availability or institutional capacity, rather than strictly by clinical necessity.

Further supporting this concept, Nasso et al. [39] demonstrated that the availability of a dedicated rescue team during TAVI significantly improved survival following unplanned surgical conversion, reducing 30-day mortality to 27%, which is markedly lower than historical data. These observations, together with our findings, reinforce the critical importance of conducting TAVI procedures in well-equipped centers with immediate surgical backup and established rescue protocols, regardless of procedural urgency. The implementation of structured heart team strategies, seamless surgical readiness, and rapid response systems should be prioritized to ensure that patients undergoing both elective and urgent TAVI benefit from the highest safety standards and optimized outcomes.

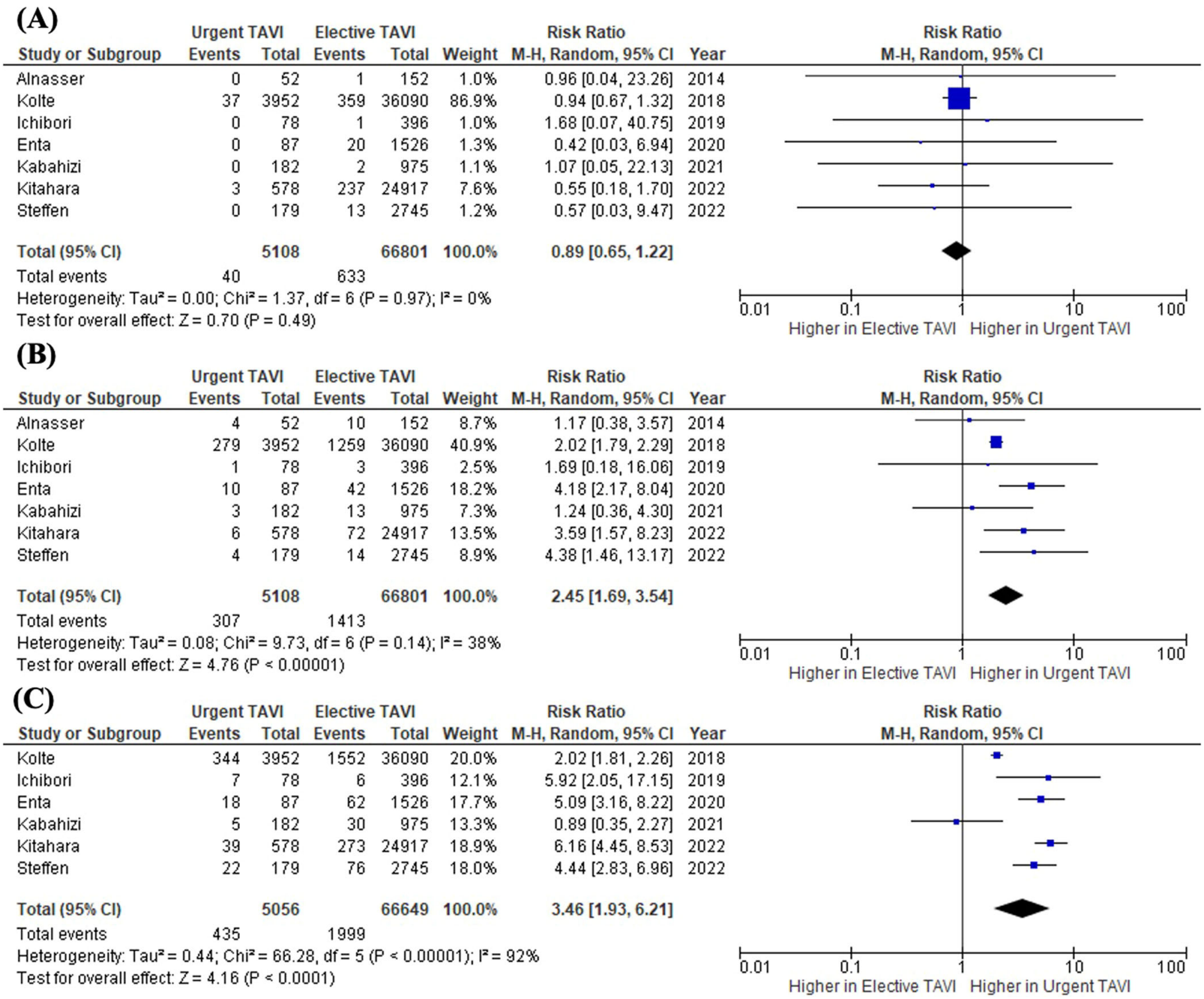


FIGURE 1 | Conversion to cardiac surgery and in-hospital mortality outcomes. (A) Risk ratio (RR) for conversion to unplanned cardiac surgery during transcatheter aortic valve implantation (TAVI) in urgent versus elective procedures (B) for in-hospital mortality following urgent versus elective TAVI, and (C) for 30-day mortality comparing urgent to elective TAVI. [Color figure can be viewed at wileyonlinelibrary.com]

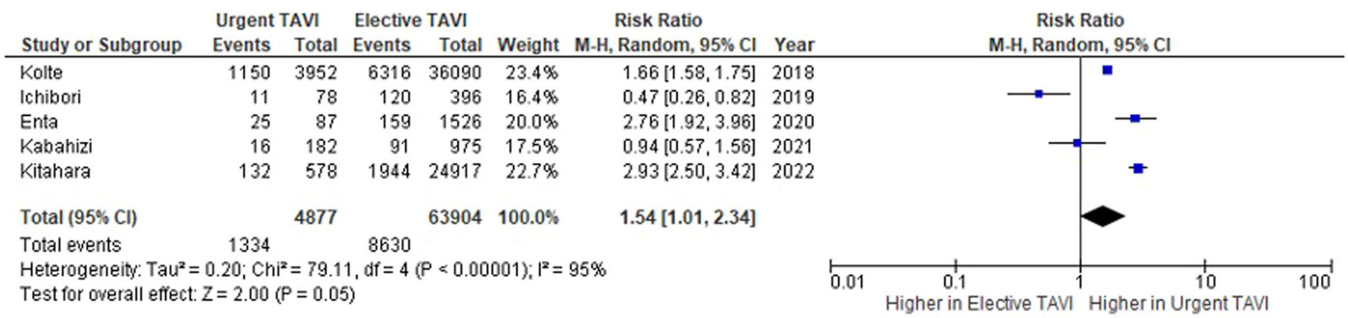


FIGURE 2 | 1-year mortality. [Color figure can be viewed at wileyonlinelibrary.com]

Furthermore, this systematic review and meta-analysis confirmed findings from the majority of individual studies, indicating higher in-hospital, 30-day, and 1-year mortality rates for patients undergoing urgent TAVI [30–33]. These results could be attributed to a more adverse clinical profile and increased incidences of AKI and vascular complications in the urgent TAVI group.

When comparing urgent versus elective TAVI, patient selection bias must be considered. Patients undergoing TAVI are

FIGURE 3 | Device success. [Color figure can be viewed at wileyonlinelibrary.com]

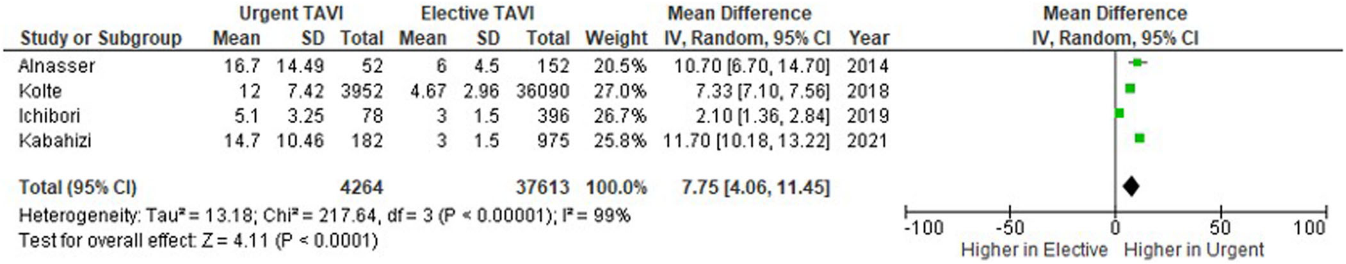


FIGURE 4 | Length of hospitalization. [Color figure can be viewed at wileyonlinelibrary.com]

generally high-risk, with various comorbidities such as HF, prior coronary interventions, and higher surgical risk, all associated with worse short- and long-term outcomes [38]. Notably, patients in the urgent TAVI group may not have been scheduled for elective TAVI earlier due to high or prohibitive surgical risks or a poor prognosis. However, hospitalization for acute HF might have changed the therapeutic plan, leading to urgent TAVI as a rescue intervention.

Higher mortality rates observed could be associated with the increased incidence of AKI. Renal failure and dialysis requirement are well-known risk factors linked to worse outcomes in patients undergoing CS or TAVI. Several factors may explain why patients undergoing urgent TAVI have more than twice the risk of developing AKI [16]. First, acute cardiac decompensation frequently leads to cardio-renal syndrome due to kidney hypoperfusion, substantially increasing morbidity and mortality. Second, urgent TAVI patients usually undergo necessary preprocedural evaluations, including contrast-enhanced computed tomography (CT) imaging, potentially worsening renal function. Therefore, strategies such as low-contrast CT imaging or contrast-free TAVI procedures should be considered to prevent AKI in urgent TAVI cases. Lastly, the urgent context limits the ability to apply AKI preventive measures, such as timely medication adjustments, hydration protocols, and routine monitoring of renal function [31].

Moreover, urgent TAVI was associated with an increased rate of periprocedural vascular complications. Vascular complications during TAVI significantly impact patient outcomes. Sherwood et al. analyzed data from 34,893 patients undergoing TAVI in the US STS/ACC TVT registry [40], demonstrating vascular complications as an independent predictor of mortality at both 30 days and 1 year. These results were consistent with subsequent studies. The higher rate of complications observed in urgent TAVI likely reflects a more complicated clinical profile, including complex vascular anatomy and extensive cardiovascular disease [41, 42].

Current literature demonstrates comparable valve implantation success and similar rates of moderate-to-severe postprocedural PVL between urgent and elective TAVI [20, 29–34, 42, 43], consistent with our meta-analysis. Additionally, echocardiographic parameters of AS severity did not differ significantly between the two groups in the included studies, suggesting that increased mortality in urgent cases is unlikely due to technical issues such as patient-prosthesis mismatch (PPM), PVL, or valve dysfunction [44].

Compared with conservative treatment alone, invasive strategies (SAVR, BAV, or TAVI) provide improved clinical outcomes in patients with AS experiencing acute HF. A 5-year follow-up study showed lower mortality and hospitalization rates for HF with SAVR compared to conservative management. Additionally, urgent TAVI is associated with better clinical outcomes compared to emergent BAV as a bridge to TAVI. BAV should only be considered a rescue procedure when anatomical constraints prevent TAVI, as it does not fully address severe AS and offers limited reduction in acute HF adverse events, compared to medical management [16, 20, 29].

Given the progressive nature of AS and the poor outcomes associated with urgent TAVI compared to elective procedures, particularly regarding mortality, this meta-analysis underscores the importance of timely intervention. Current AS staging may inadequately reflect the extent of cardiac remodeling, and a revised system accounting for cardiac damage beyond symptomatology and stenosis severity may be warranted. Early elective TAVI is associated with improved outcomes, and this concept has recently been supported by randomized clinical trials. The EARLY TAVR trial (NCT03042104) demonstrated that in asymptomatic patients with severe AS, early TAVI significantly reduced the composite endpoint of death, stroke, or unplanned cardiovascular hospitalization compared to clinical surveillance (26.8% vs. 45.3%; hazard ratio, 0.50; $p < 0.001$) over a median follow-up of 3.8 years, without an increase in procedural adverse events [45]. Conversely, the TAVR UNLOAD trial (NCT02661451) evaluated patients with moderate AS and heart failure with reduced ejection fraction (HFrEF) and showed that while TAVI did not significantly improve the primary hierarchical composite endpoint compared to surveillance, it was associated with a meaningful improvement in health status and quality of life at 1 year [46]. Consequently, these findings support early intervention in selected patient populations and suggest a potential role for preemptive TAVI in improving symptoms and quality of life, even before progression to severe AS. These data should be carefully considered by healthcare systems, particularly in countries where procedural delays persist due to resource limitations or systemic pressures, as timely elective TAVI may reduce the risk of decompensation, prolonged hospitalization, and poor outcomes inherent to urgent procedures [20, 29–34]. Future studies using artificial intelligence and deep learning methods might predict earlier and accurately patients under higher risk for developing acute HF due to aortic stenosis, so as to intervene earlier [47].

In some cases, procedural heterogeneity was observed across the included studies, particularly regarding anesthesia type, access route, and intra-procedural management. This variability likely contributed to the differences in outcomes between elective and urgent TAVI. Notably, Ichibori et al. demonstrated that adopting a minimalist strategy, using local anesthesia or conscious sedation and streamlined transfemoral access, even in urgent settings, was associated with procedural success and short-term outcomes comparable to those of elective cases. These findings suggest that simplification of the procedures and avoidance of unnecessary invasiveness can mitigate periprocedural risk in hemodynamically unstable patients. The influence of operator experience and institutional expertise may therefore partly explain the variability in conversion rates and early mortality observed among studies.

In addition to procedural diversity, significant clinical heterogeneity existed within urgent TAVI cohorts. Steffen et al. recently analyzed critically ill patients undergoing emergency TAVI and found markedly higher 90-day mortality among those presenting with cardiogenic shock compared with decompensated but stabilized patients. Predictors of adverse outcome included hypotension, the need for mechanical ventilation, and renal replacement therapy, underscoring the prognostic importance of adequate preprocedural stabilization. These data highlight that the spectrum of "urgent" TAVI encompasses patients with widely varying hemodynamic profiles and comorbidities. Consequently, interpretation of the pooled meta-analytic results should be made with caution, and individualized assessment and optimization before valve implantation remain essential for improving outcomes in this high-risk population.

4.1 | Limitations

Our systematic review and meta-analysis have several limitations. First, this was a pre-specified study-level meta-analysis, and patient-level analyses were not applied. Furthermore, substantial heterogeneity was observed in some analyses, primarily due to variations in definitions of acute HF and cardiogenic shock across the studies [16]. To address this, we performed analyses using a random-effects model, considered as the most appropriate based on current evidence. Missing data on several patient characteristics limited our ability to perform meta-regression analyses, representing another potential limitation. It should be noted that two large-scale registry studies—one from the STS/ACC TVT registry and another from the Japanese TAVI registry—contributed approximately 98% of the total patient population. Notably, the STS/ACC TVT registry reported a more than twofold increase in the need for unplanned CS and a significantly higher 30-day mortality (HR = 4.75) following urgent or emergent TAVI, particularly in cases requiring periprocedural cardiopulmonary bypass, which may suggest procedural heterogeneity in defining surgical conversion. Although outcomes were reported according to VARC-2 criteria, variations in the adoption or interpretation of these definitions across included studies may have introduced heterogeneity in reported endpoints. In particular, inconsistencies in the definitions of successful valve implantation, in-hospital AKI, and stroke could affect the comparability of these outcomes. Where individual studies did not specify definitions, this should be acknowledged as a source of potential bias. Additionally, the risk of bias assessed with the ROBINS-I tool was considered high across all studies, potentially affecting the overall quality of our meta-analysis. However, it's important to note that this was mainly due to confounding bias inherent in the non-randomized design and the urgent nature of interventions, particularly impacting outcomes such as mortality. Nevertheless, this bias assessment was not confirmed by the NOS, which rated the majority of included studies as high quality [25, 26, 48, 49]. A detailed analysis of prognostic factors such as valve type, access route, or other procedural characteristics could not be performed because these variables were inconsistently reported across the included studies. Consequently, potential associations between these factors and the need for conversion to CS remain uncertain. Finally, considerable heterogeneity among the included studies—particularly in definitions of urgency, baseline comorbidities, and procedural strategies—may have influenced the pooled outcomes; therefore, these results should be interpreted with caution when applied to clinical decision-making.

5 | Conclusions

Our systematic review and meta-analysis demonstrate that patients undergoing urgent TAVI don't seem to be at increased risk of conversion to unplanned CS compared to elective procedures and have similar rates of successful valve implantation. However, urgent TAVI is associated with higher in-hospital, 30-day, and 1-year mortality, likely due to increased incidences of AKI and vascular complications. Rates of PPI and stroke did not differ between the two cohorts. Our findings highlight the importance of timely elective intervention in stable patients with severe AS to prevent hospitalizations due to acute HF and improve patient outcomes. Further studies are warranted to further validate our results.

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Ethics Statement

This study is a systematic review and meta-analysis and did not involve direct research with human participants or animals. Therefore, ethical approval was not required.

Consent

The authors have nothing to report.

Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

All data generated or analyzed during this study are included in this published article and its supplementary material files.

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Supporting Information

Additional supporting information can be found online in the Supporting Information section.
PRISMA_2020_checklist. **Table S1:** Evaluation of observational studies with the Newcastle-Ottawa Scale. **Table S2**: Risk of Bias Assessment using the Risk Of Bias In Non-randomized Studies - of Interventions (ROBINS-I) tool. **Table S3**: Patients' characteristics. **Table S4**: Echocardiographic and clinical characteristics of the patients. **Table S5**: Urgent Transcatheter Aortic Valve Replacement (TAVR) definition. **Table S6**: Grading of Recommendations Assessment, Development, and Evaluation (GRADE) assessment. **Figure S1**: PRISMA 2020 flow diagram for new systematic reviews including searches of databases and registers only. **Figure S2**: MOOSE (Meta-analyses Of Observational Studies in Epidemiology) Checklist (A+B). **Figure S3**: Peri-procedural vascular complications. **Figure S4**: Device embolization. **Figure S5**: In-hospital acute kidney injury. **Figure S6**: In-hospital stroke. **Figure S7**: In-hospital permanent pacemaker implantation. **Figure S8**: Moderate-to-severe post-procedural paravalvular regurgitation. **Figure S9**: Need for second valve implantation. **Figure S10**: Major or life-threatening bleeding during hospitalization.