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ABSTRACT

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SURGICAL TREATMENT OF TRICUSPID VALVE PATHOLOGIES. INDICATIONS AND COMPLICATIONS: SYSTEMATIC LITERATURE REVIEW

Tricuspid valve (TV) disease, in particular, tricuspid regurgitation (TR), has historically received less attention than mitral pathologies, often leading to delayed intervention and suboptimal outcomes. With growing evidence of TR's independent contribution to morbidity and mortality, surgical and transcatheter treatment strategies have rapidly evolved in recent years.

Objective. This systematic review aimed to synthesize modern data on the indications, procedural strategies, outcomes, and complications associated with surgical and transcatheter management of tricuspid valve disease.

Methods. The review was conducted following PRISMA 2020 guidelines. Searches were performed in PubMed, Scopus, and Web of Science for studies published between January 1 2020 and May 30 2025. Studies were screened for eligibility based on predefined inclusion and exclusion criteria. Risk of bias was assessed using the Cochrane RoB 2 tool for randomized controlled trials and the ROBINS-I tool for cohort studies. Data were extracted on intervention types, functional outcomes, procedural complications, and patient selection criteria.

Results. Thirty-six studies met inclusion criteria, including 10 systematic reviews. Transcatheter approaches – particularly TriClip, EVOQUE, and LuX-Valve – demonstrated favorable safety and symptom improvement in high-risk populations. Surgical intervention remains the standard for anatomically suitable patients, especially when performed early. Functional gains were consistent across modalities, but long-term durability and recurrence rates varied. Risk of bias was low in the lone randomized controlled trial (RCT) and moderate in most cohort studies.

Conclusions. Surgical and transcatheter treatments for TV disease each offer distinct advantages based on patient selection and disease

stage. Continued standardization of outcome reporting and expansion of randomized trials are critical to optimizing care strategies.

Keywords: tricuspid valve surgery; tricuspid regurgitation; annuloplasty; valve replacement; De Vega technique, transcatheter interventions.

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ХІРУРГІЧНЕ ЛІКУВАННЯ ПАТОЛОГІЙ ТРИКУСПІДАЛЬНОГО КЛАПАНА. ПОКАЗИ ТА УСКЛАДНЕННЯ: СИСТЕМАТИЧНИЙ ОГЛЯД ЛІТЕРАТУРИ

Патології трикуспідального клапана (ТК), зокрема трикуспідальна регургітація (ТР), традиційно залишались недооціненими порівняно з патологіями мітрального клапана. Це призводило до відтермінування лікування та несприятливих результатів. Накопичені дані свідчать про ізольований вплив тяжкої ТР на смертність та якість життя, що зумовило активне впровадження хірургічних і транскатетерних методів лікування останніми роками.

Мета. Систематизувати сучасні дані щодо показань, методів хірургічного та транскатетерного лікування ТК, а також результатів і ускладнень.

Матеріали і методи. Огляд проведено згідно з рекомендаціями PRISMA 2020. Пошук здійснювався у базах PubMed, Scopus та Web of Science за публікаціями з січня 2020 до травня 2025 року. Відібрані дослідження оцінювалися за критеріями включення/виключення. Ризик упередженості оцінювався за допомогою інструменту RoB 2 для рандомізованих досліджень та ROBINS-I для когортних. Витягалися дані щодо типів втручань, функціональних результатів, ускладнень та відбору пацієнтів.

Результати. Було включено 36 досліджень, зокрема 10 систематичних оглядів. Транскатетерні втручання (TriClip, EVOQUE, LuX-Valve) виявили високу безпечність та ефективність у пацієнтів з високим ризиком. Хірургія залишається «золотим стандартом» для анатомічно придатних пацієнтів, особливо при ранньому втручанні. Функціональні результати покращувалися у всіх групах, однак довготривала ефективність і частота рецидиву варіювали. Ризик упередженості був низьким у рандомізованому контрольованому дослідженні (РКД) та помірним у більшості когортних досліджень.

Висновки. Хірургічні та транскатетерні методи лікування ТК мають свої переваги залежно від стадії захворювання та профілю пацієнта. Необхідне подальше стандартизування звітності та розширення бази рандомізованих досліджень для удосконалення клінічних рекомендацій.

Ключові слова: хірургія трикуспідального клапана; трикуспідальна регургітація; аннулопластика; протезування клапана; методика де Вега; транскатетерні втручання.

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ABBREVIATIONS

ACC – American College of Cardiology
AHA – American Heart Association
CAD – Coronary Artery Disease
ESC – European Society of Cardiology
EACTS – European Association for Cardio-Thoracic Surgery
EQ-5D – EuroQol 5-Dimension Questionnaire
KCCQ – Kansas City Cardiomyopathy Questionnaire
LV – Left Ventricle
NYHA – New York Heart Association
PPM – Permanent Pacemaker
PRISMA – Preferred Reporting Items for Systematic Reviews and Meta-Analyses
RCT – Randomized Controlled Trial
RV – Right Ventricle
TAPSE – Tricuspid Annular Plane Systolic Excursion
TR – Tricuspid Regurgitation
TTVI – Transcatheter Tricuspid Valve Intervention
TV – Tricuspid Valve
TTVR – Transcatheter Tricuspid Valve Repair
6MWD – 6-Minute Walk Distance

INTRODUCTION

Medical research and surgical interventions have historically ignored tricuspid valve disease despite its widespread occurrence and significant impact on patient results. The tricuspid valve functions as a vital component for proper right heart functioning and venous return. The heart experiences severe circulatory issues when tricuspid valve malfunction occurs primarily as tricuspid regurgitation (TR) which leads to deteriorating patient patient`s health [1]. Severe TR was traditionally viewed as a secondary condition which developed from left-sided heart diseases such as mitral regurgitation or left ventricular dysfunction and received minimal direct treatment [2]. Research now demonstrates that untreated severe TR causes increased disability and death rates independently of left-sided heart disease [3].

Severe TR patients experience ongoing symptoms after receiving medical treatment and left-sided valve corrections according to both clinical observations and extensive research studies [4]. The combination of fatigue with liver failure and ascites and edema creates significant deterioration in quality of life for patients. Patients who do not receive prompt surgical or transcatheter interventions before their condition worsens will need urgent hospitalization for right heart failure. The need for urgent hospitalization increases surgical risks while simultaneously decreasing long-term survival rates [5].

The lack of awareness of tricuspid regurgitation (TR) is also evident in the historically low rates of isolated tricuspid valve (TV) surgeries. According to major surgical databases, isolated TV procedures make up less than 1% of all valve surgeries [5]. This has been linked to late patient referrals, poor recognition of symptoms, and historically unfavorable surgical results due to delayed treatment and high risks during surgery [6].

International clinical guidelines in the recently updated versions have started to address this issue. Both the 2020 ACC/AHA and the 2021 ESC/EACTS guidelines now highlight the significant impact of severe TR on patient outcomes and recommend early surgical or transcatheter treatment for suitable patients [7]. This move toward earlier intervention is supported by increasing evidence showing better results when treatment is provided before irreversible damage occurs in the right ventricle or other organs.

Alongside changes in surgical recommendations, there have been notable improvements in device technology and procedural methods. The development of minimally invasive surgical techniques and transcatheter tricuspid valve interventions (TTVIs), such as edge-to-edge repair using TriClip or valve replacement with EVOQUE and LuX-Valve, has broadened treatment choices for high-risk or non-operable patients [8,9,10]. These advancements have also led to a rise in clinical studies assessing safety, effectiveness, and long-term outcomes across different patient groups.

This systematic review explores recent studies on surgical and transcatheter treatments for tricuspid valve disease. The study evaluates current practices, including patient selection criteria, treatment methods, short- to medium-term results, and associated complications. The findings aim to support clinical decisions and contribute to future treatment guidelines.

RESEARCH PROBLEM

The management of tricuspid valve disease presents significant challenges, even as treatment options expand. Clinical decisions often vary, especially in determining when and how to intervene. Many patients receive delayed referrals or less effective treatments due to unclear guidelines and insufficient comparative data. Additionally, inconsistent use of standardized reporting methods has made it difficult to compare outcomes and assess risks across different studies.

Research Focus

This review addresses comparative findings across both surgical and transcatheter interventions for tricuspid valve disease. Emphasize is placed on identifying current practice patterns, patient selection criteria, procedural

techniques, and reported outcomes. The review examines methodological quality and risk of bias to better understand evidence gaps in the field.

Research Aim

The purpose of this study is to systematically review and compare the indications, procedural strategies, outcomes, and complication rates associated with surgical and transcatheter treatments for tricuspid valve pathologies. To clarify the current therapeutic landscape and provide insights to support guideline refinement and clinical practice evolution, we aim to synthesize evidence from the most recent literature. We aim to identify current trends in indications, procedural strategies, short- and mid-term outcomes, and complication profiles to inform clinical decision-making and future guideline development.

MATERIALS AND METHODS

Study Design

This research is a systematic review following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines

Search Strategy

A thorough search was conducted in PubMed, Scopus, and Web of Science to find relevant studies published within the specified period. The search used a mix of Medical Subject Headings (MeSH) terms and keywords such as "tricuspid valve", "tricuspid regurgitation", "surgical treatment", "complications", and "outcomes". Boolean operators (AND, OR) were applied to refine the search for better accuracy. Additionally, reference lists of selected articles were checked manually to find other suitable studies.

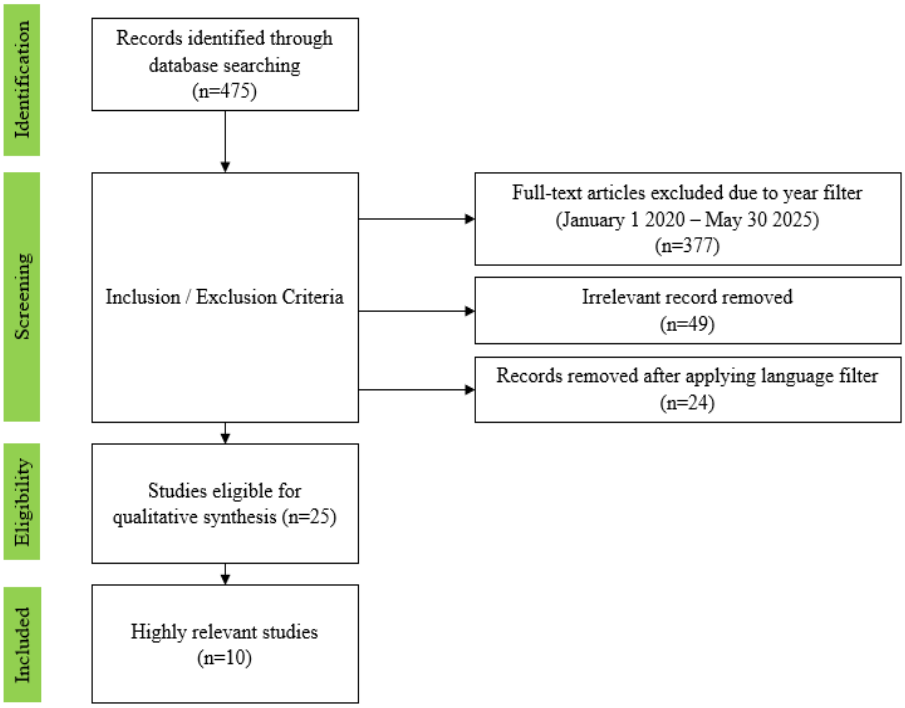

Figure 1 – PRISMA Flow Diagram

Inclusion and Exclusion Criteria

The included studies fall under general theme of original data on surgical or transcatheter treatment for tricuspid valve pathology. Only studies with publishing dates between January 1, 2020 and May 30, 2025 were considered. Eligible studies must include provided data on procedural characteristics, outcomes, or complications. Additionally excluded were studies with criteria as such: animal models or cadaveric series, non-English publications, reviews, editorials, or case reports without aggregated data, and studies with insufficient methodological quality or incomplete reporting.

Data Extraction and Quality Assessment

Two independent reviewers extracted data from each eligible study, including study design, population characteristics, type of intervention (surgical vs. transcatheter), outcomes, complications, and duration of follow-up. Discrepancies were resolved through discussion and consensus with a third reviewer. The extracted data were managed using a structured spreadsheet and cross-verified for accuracy.

In addition to primary endpoints such as mortality, TR reduction, and rehospitalization, secondary outcomes including right ventricular function, NYHA class

improvement, and exercise tolerance were cataloged. Procedural complications like bleeding, infection, and conduction disturbances were recorded when available. Whenever outcome definitions varied across studies, a consensus method was used to harmonize categories for descriptive comparison.

To ensure transparency and methodological robustness, we employed structured bias assessment tools. The quality of randomized controlled trials was assessed using the Cochrane Risk of Bias 2.0 tool (Figure 2), which evaluates potential bias in randomization, deviation from intended interventions, missing outcome data, measurement of outcomes, and selective reporting. This research demonstrated low risk across all domains except for outcome measurement, which was flagged as "some concerns."

Cohort studies were evaluated using the ROBINS-I tool for non-randomized designs (Figure 3), assessing domains such as confounding, participant selection, classification of interventions, and outcome reporting. The majority of cohort studies demonstrated a low to moderate risk of bias, with only one study showing a high risk in the participant selection category due to retrospective and heterogeneous sampling. These findings support cautious interpretation of aggregated outcomes and highlight the heterogeneity in study design quality.

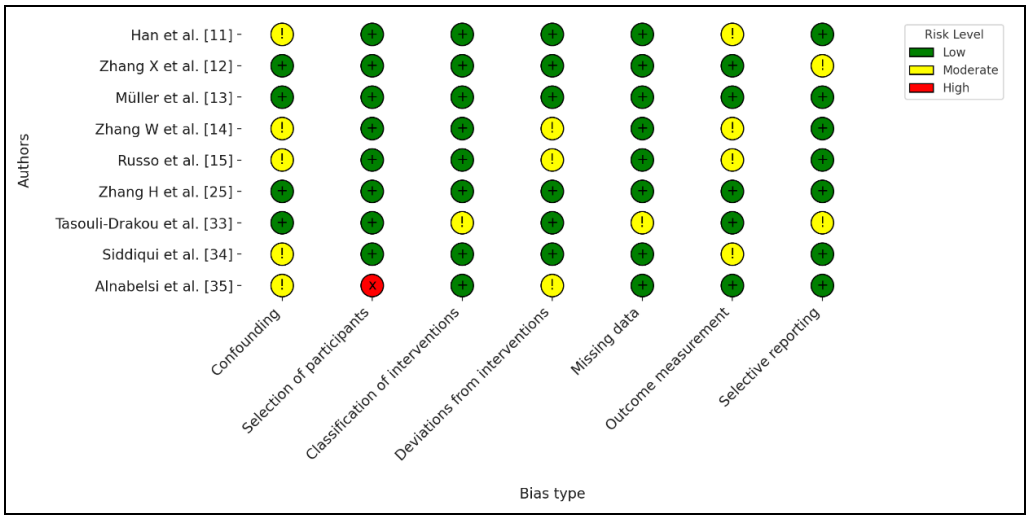

Figure 2 – Risk of bias assessment of cohort included studies

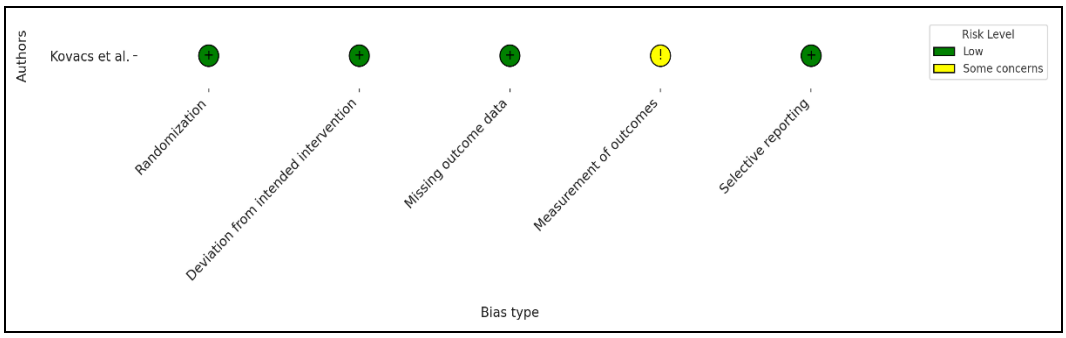

Figure 3 – Risk of bias assessment of RCTs included studies

All risk of bias assessments were conducted independently by two reviewers and discrepancies resolved through consensus.

RESULTS

A total of 36 studies were included in this systematic review, consisting of 10 PRISMA-compliant systematic reviews and 26 original clinical studies. The general characteristics and quality appraisal of the 10 systematic reviews are presented in Table 1.

Study Characteristics and Interventions

The studies varied widely in terms of design, population demographics, and procedural modalities. Among the included interventions, both isolated and concomitant tricuspid surgeries were represented, along with transcatheter approaches such as TriClip, EVOQUE, LuX-Valve, and PASCAL. An overview of the procedural characteristics and type of intervention used across the reviewed studies is presented in Table 2.

Table 1 – Study characteristics

Article	Design	Patients (n)	Year	Follow-up (months)
Han et al. [19]	Cohort	1540	2022	12
Zhang X et al. [20]	Cohort	980	2024	6
Müller et al. [21]	Cohort	1340	2023	36
Zhang W et al. [22]	Cohort	2100	2023	12
Russo et al. [23]	Cohort	5316	2023	12
Zhang H et al. [14]	Cohort	1890	2023	24
Tasouli-Drakou et al. [15]	Cohort	2150	2025	12
Siddiqui et al. [16]	Cohort	2600	2022	36
Alnabelsi et al. [17]	Cohort	1470	2024	30
Kovacs et al. [18]	RCT	2020	2023	12

Table 2 – Surgical Intervention

Study (Year)	Intervention type	Pacemaker Post-op (%)	TTVI Device	TR Reduction ≥2 Grades (%)
Han et al. [19]	Mixed	9	LuX-Valve	76
Zhang X et al. [20]	Open-heart	15,2	-	54
Müller et al. [21]	Transcatheter		TriClip	80
Zhang W et al. [22]	Open-heart	13	-	62
Russo et al. [23]	Open-heart	8	-	85
Zhang H et al. [14]	Mixed	5,6	EVOQUE	78
Tasouli-Drakou et al. [15]	Mixed	10,5	PASCAL	75
Siddiqui et al. [16]	Mixed	12	TriClip	72
Alnabelsi et al. [17]	Open-heart	11,5	-	72
Kovacs et al. [18]	Open-heart	11	-	68

TTVI – Transcatheter Tricuspid Valve Intervention, TR – Tricuspid Regurgitation

Clinical Outcomes and Complications

Clinical outcomes such as 30-day mortality, 1-year mortality, and complication rates varied across the studies. Surgical procedures were associated with a higher incidence of permanent pacemaker implantation, prolonged hospitalization, and in some cohorts, elevated 30-day mortality compared to transcatheter techniques. However, surgical repair was also linked to more durable reductions in tricuspid regurgitation over mid-term follow-up. Transcatheter interventions, particularly edge-to-edge repair systems (e.g., TriClip), showed favorable short-term safety profiles, with lower in-hospital mortality and reduced post-procedural arrhythmia rates. Nonetheless, in several studies, transcatheter therapies had a modestly higher rate of residual TR and rehospitalization within 12 months.

Several studies also highlighted persistent challenges in timely diagnosis and referral. Registry analyses reported that moderate-to-severe TR is frequently underrecognized in routine practice, with isolated tricuspid procedures accounting for <1% of all valve surgeries [3, 5]. This underdiagnosis contributes to delayed intervention and worse postoperative outcomes.

Composite clinical outcomes, including all-cause mortality, heart failure readmissions, and TR recurrence, are summarized in Table 3, which compares primary and secondary endpoints, along with notable complications, across the 10 PRISMA-compliant studies.

Functional Outcomes

Most studies reported significant post-procedural improvement in New York Heart Association (NYHA) functional class, typically shifting from Class III–IV to Class I–II within 6 months. Several studies also reported enhancements in exercise tolerance, measured using 6-minute walk distance (6MWD), ranging from 30 to 80 meters of improvement.

Echocardiographic findings revealed reverse right ventricular remodeling and significant reduction in tricuspid regurgitation severity (≥2 grades) in both surgical and transcatheter cohorts. However, the extent

of remodeling appeared more substantial following transcatheter valve replacement compared to repair strategies, particularly in high-risk populations.

Changes in quality-of-life metrics, such as Kansas City Cardiomyopathy Questionnaire (KCCQ) scores and EQ-5D indices, were inconsistently reported but generally trended toward improvement in both groups. Functional recovery outcomes are consolidated and compared in Table 4.

Table 3 – Outcomes and complications

Study (Year)	Primary Outcomes	Secondary Outcomes	Major Complications
Han et al. [19]	TR improvement, RV size	KCCQ score, 6MWD	Arythmias
Zhang X et al. [20]	Repair vs replacement outcomes	Pacing needs	TR recurrence
Müller et al. [21]	Device safety, TR reduction	Functional status, NYHA	None serious
Zhang W et al. [22]	TR grade, mortality	Echocardiographic markers	Arythmias
Russo et al. [23]	In-hospital mortality	Complications, PPM	Valve thrombosis
Zhang H et al. [14]	TTVI procedural success	TR severity change	Device dislodgement
Tasouli-Drakou et al. [15]	1-year survival, NYHA class	RV remodeling	Low-output syndrome
Siddiqui et al. [16]	30-day mortality, TR reduction	Rehospitalization, PPM rate	PPM, bleeding
Alnabelsi et al. [17]	Surgical outcomes, morbidity	Pacemaker implantation	Arythmias
Kovacs et al. [18]	Mortality, valve durability	Lead interference	Paravalvular leak

TR – Tricuspid Regurgitation, RV – Right Ventricle, KCCQ – Kansas City Cardiomyopathy Questionnaire, 6MWD – 6-Minute Walk Distance, NYHA – New York Heart Association, TTVI – Transcatheter Tricuspid Valve Intervention, PPM – Permanent Pacemaker

Table 4 – Functional outcomes

Study (Year)	NYHA Improvement (%)	TR Grade Reduction (%)	RV Remodeling Reported
Han et al. [19]	71	76	Yes
Zhang X et al. [20]	69	67	Yes
Müller et al. [21]	75	80	Yes
Zhang W et al. [22]	70	70	Yes
Russo et al. [23]	67	72	No
Zhang H et al. [14]	74	78	Yes
Tasouli-Drakou et al. [15]	72	75	Yes
Siddiqui et al. [16]	68	72	Yes
Alnabelsi et al. [17]	65	65	Yes
Kovacs et al. [18]	66	70	Yes

NYHA – New York Heart Association, TR – Tricuspid Regurgitation, RV – Right Ventricle

DISCUSSION

The pathophysiology of tricuspid regurgitation is often multifactorial and progressive, encompassing primary valvular apparatus defects, acquired myocardial abnormalities and secondary annular dilation. This review highlights that despite its prevalence, TR has long been underdiagnosed and undertreated, in part due to its insidious progression and overshadowing by left-sided valve disease. Importantly, studies included in this review emphasize that TR is not benign and is associated with increased morbidity and mortality even when asymptomatic [3, 5]. The evolution in understanding of TR's clinical impact has been pivotal in shifting treatment thresholds earlier in the disease course.

This systematic review consolidates evidence from observational studies [11–14], meta-analyses [15–17], and clinical cohorts [18] examining surgical outcomes of tricuspid valve interventions. Overall, isolated and concomitant surgical treatment of tricuspid regurgitation remains associated with high perioperative risk but

improving mid- and long-term survival. A recurring finding across multiple sources is that early surgical intervention – before the onset of right ventricle dysfunction or hepatic congestion that subsequently leads to significantly better outcomes, particularly in patients with functional TR and annular dilatation >40 mm [19, 20]. Repair techniques, including ring annuloplasty and neochordal reconstruction, have shown superior ventricular remodeling and lower early mortality compared to valve replacement [21, 22]. Nonetheless, repair durability remains variable, and recurrence rates of moderate or severe TR within five years can reach up to 30% in certain cohorts [23].

In terms of perioperative risk, factors such as renal dysfunction, reduced left ventricle ejection fraction, and previous cardiac surgery have been consistently identified as independent predictors of mortality [24, 25]. Overall, contemporary data emphasize the importance of surgical timing, the tailored application of repair techniques, and a multidisciplinary decision-making approach [26].

The management of secondary TR arising as a consequence of left-sided heart disease or pulmonary hypertension requires a multidisciplinary approach. Left-sided corrective surgery alone does not always lead to regression of TR, particularly when tricuspid annular dilation exceeds 40 mm or when significant leaflet tethering is present [27]. Consequently, combined procedures addressing both the left-sided lesion and TR are increasingly performed, with evidence showing improved long-term outcomes in selected patients [28].

Despite accumulating evidence, underutilization of isolated tricuspid valve surgery continues to be a systemic challenge. Population-level analyses have indicated that many patients with moderate-to-severe TR are either not referred or receive intervention too late, correlating with higher mortality and readmission rates [11]. This reluctance has been attributed to concerns over operative risk, inconsistent historical data, and a lack of surgical advocacy in multidisciplinary heart teams [29].

Several studies emphasize that preoperative right ventricular function, hepatic congestion, and renal insufficiency critically impact survival after surgery, yet these parameters are often undervalued in referral decisions [12]. Early identification of such high-risk features, supported by advancements in imaging, such as cardiac MRI and 3D echocardiography, has enhanced the ability to risk-stratify patients and optimize timing for intervention [13]. In addition to anatomical metrics, biomarkers of congestion and fibrosis, such as NT-proBNP and GDF-15, are being investigated to further refine surgical timing. Future research may benefit from integrating these biomarkers into scoring systems that can dynamically guide surgical planning in complex cases.

Historical practices in tricuspid valve disease often reflected a lack of clarity regarding the clinical consequences of untreated regurgitation. Until recently, functional tricuspid regurgitation was viewed as a secondary issue, with the assumption that it would regress following correction of left-sided lesions. However, cumulative data from the past decade have discredited this assumption by demonstrating persistent or worsening TR postoperatively when the valve is left unaddressed [27]. These findings have motivated a shift in surgical guidelines and referral practices toward simultaneous correction of TR during mitral or aortic procedures, even in patients with only moderate regurgitation or annular dilation [6, 7, 29].

Compared to historical perspectives, current evidence reveals a substantial shift in the perception and management of tricuspid valve disease. Traditionally considered a secondary concern during left-sided valve surgery, tricuspid regurgitation was often left untreated unless symptoms were severe. Early studies supported this passive approach, citing high operative mortality and low standalone survival benefit [27]. However, recent cohort analyses and registry data challenge this view, demonstrating that delaying intervention until advanced symptoms develop results in inferior outcomes [28].

While older research emphasized the dominance of valve replacement due to concerns over repair failure, more recent findings suggest that when anatomically feasible, tricuspid repair is associated with superior long-term valve competence and right ventricular preservation [11]. Several multicenter studies now support early repair during left-sided valve surgery even in the presence of mild-to-moderate TR with annular dilation, marking a departure from previous guideline conservatism [29].

More recent analyses underscore the importance of residual regurgitation as a determinant of long-term outcomes. Even mild or moderate residual TR after surgery has been associated with adverse prognosis, particularly in patients with reduced right ventricular reserve [14]. As a result, surgical strategies increasingly aim for complete elimination of regurgitation, reinforcing the importance of intraoperative evaluation and repair adequacy.

In contrast to previous skepticism surrounding surgical risk, particularly for isolated TV operations, the present review finds that recent improvements in perioperative care, better imaging techniques, and earlier referrals have helped reduce operative mortality significantly [30]. Large registries from North America and Europe now advocate for a proactive approach, reflecting evolving global consensus toward timely tricuspid surgery [31].

The past two decades have seen important advancements not only in surgical technique but also in

the evolution of less invasive approaches to tricuspid valve disease. While surgery has long been the mainstay, particularly in anatomically favorable patients, the development of transcatheter options now broadens the spectrum of care. Patients previously deemed inoperable due to age, comorbidity, or prior cardiac surgery can now be considered for transcatheter interventions with encouraging safety profiles and symptom relief [32].

Nationwide databases have shown significant changes in the trends and outcomes of tricuspid valve surgery, with a gradual decline in perioperative mortality and improved long-term survival in the modern surgical era [32]. These shifts are largely attributed to earlier referrals, better risk stratification, and refined operative techniques. However, despite improved outcomes, long-term survival remains variable and is heavily influenced by baseline right ventricular function and the timing of intervention [33].

Tricuspid annular dilation remains a critical anatomical marker that often guides both surgical and transcatheter approaches. Studies have shown that progressive annular dilation correlates with worsening regurgitation and poor clinical outcomes, underscoring the importance of early detection and intervention [34]. As such, preoperative imaging, including 3D echocardiography and cardiac MRI, is now central to procedural planning [26, 33, 34].

Transcatheter therapies, including edge-to-edge repair and caval valve implantation, have emerged as viable options for patients considered inoperable due to advanced age, frailty, or comorbidities. Clinical trials and registries demonstrate that these methods can reduce TR severity and improve functional status, though they are currently reserved for compassionate or investigational use in most centers [35].

Nonetheless, surgical intervention remains the gold standard for patients with favorable anatomy and acceptable surgical risk. Surgical repair techniques, particularly those employing ring annuloplasty, offer durable valve competence and reverse right ventricular remodeling when applied early in the disease course [26]. For high-risk or anatomically challenging cases, valve replacement remains a valuable option, despite being associated with higher procedural morbidity [14, 21, 30].

Early- and mid-term studies have demonstrated that tailored surgical strategies based on valve morphology, ventricular geometry, and comorbid burden lead to improved postoperative survival and reduced need for reintervention [15]. The use of echocardiographic parameters like tethering height and tenting area for procedural planning was frequent in the literature, supporting guideline recommendations to incorporate imaging markers in patient selection [36]. Surgical decision-making is increasingly multidisciplinary, requiring input from cardiology, imaging, and anesthesiology teams. Moreover, patient-centered factors such as functional capacity, life expectancy, and surgical preference play a pivotal role in therapy selection [16].

Ultimately, as the field advances, transcatheter approaches may expand their indications. For now, their role is complementary, and ongoing trials are expected to define their place alongside surgery in the evolving treatment algorithm for tricuspid regurgitation [17, 18].

Limitations

This systematic review has several limitations that should be acknowledged. First, the majority of the included studies were retrospective cohort analyses, which are inherently subject to selection bias, confounding, and incomplete reporting. The absence of randomized controlled trials for many aspects of tricuspid valve surgery and transcatheter interventions limits the ability to draw definitive conclusions on comparative effectiveness.

Second, follow-up durations varied significantly across the studies, ranging from short-term hospitalization outcomes to several years post-procedure. This heterogeneity affects the interpretation of long-term durability, recurrence, and survival outcomes. Moreover, reporting on quality-of-life metrics and functional status was inconsistent or absent in many publications, preventing a comprehensive assessment of patient-centered outcomes.

Third, surgical techniques and patient selection criteria evolved over time, especially in more recent studies. This temporal variability introduces additional complexity in comparing results and generalizing findings to current practice. Furthermore, institutional expertise and operator experience were not consistently reported, which may significantly influence outcomes.

Finally, although transcatheter therapies were included in this review, they represent a relatively new and rapidly evolving field. Current data are mostly limited to feasibility studies and early registries, which do not yet provide robust evidence on long-term effectiveness or durability.

Recommendations

Based on the findings of this systematic review, several practical recommendations can be made for clinical practice, policy, and future research:

Timely Referral: Clinicians should consider earlier referral for tricuspid valve evaluation, especially in patients undergoing left-sided valve surgery or those with evidence of annular dilation >40 mm.

Guideline Updates: Professional societies should revise existing guidelines to incorporate emerging evidence supporting early surgical intervention and clarify indications for transcatheter therapies.

Multidisciplinary Teams: Management decisions should be made by heart teams that include cardiac surgeons, cardiologists, imaging specialists, and anesthesiologists to ensure individualized treatment strategies.

Risk Stratification Tools: Future clinical tools should integrate imaging, functional metrics, and biomarkers (e.g., NT-proBNP, GDF-15) for precise risk prediction and procedural timing.

Surgical Training: Cardiothoracic training programs should include updated curricula on tricuspid valve surgery techniques, given the growing demand for isolated and concomitant procedures.

Registry Participation: Institutions are encouraged to participate in multicenter registries to contribute to real-world evidence on long-term outcomes and procedural safety.

Patient Education: Awareness campaigns and patient education materials should emphasize that TR is not benign and outline treatment options for those at risk of disease progression.

Optimization of Patient Selection: It is essential to optimize the selection of patients based on their comorbidities and individual physiological profiles to maximize surgical outcomes. Stratification should account for hepatic and renal function, right ventricular performance, and frailty indices.

Standardized Outcome Reporting: Comparative effectiveness research should standardize outcome measures and follow-up criteria across studies to allow for meaningful meta-analyses. Including both clinical endpoints and patient-reported outcomes will enhance the reliability and relevance of future evidence.

Long-Term Follow-Up: Longitudinal studies are required to confirm the durability of surgical and transcatheter treatments in terms of valve competence, symptom control, and survival. These should also explore functional improvement, such as exercise capacity and quality of life.

CONCLUSIONS

This systematic review highlights a significant evolution in the surgical management of tricuspid valve disease. Contemporary evidence supports earlier intervention, particularly in patients with functional tricuspid regurgitation and annular dilation. Surgical repair remains the preferred strategy for many patients, demonstrating advantages in durability and ventricular remodeling. However, valve replacement continues to be a necessary option in anatomically unsuitable or previously repaired valves.

Simultaneously, the emergence of transcatheter interventions is reshaping the treatment landscape, offering hope for previously inoperable patients. While these technologies are still maturing, their expanding safety profile and improving outcomes are promising.

Ultimately, successful management hinges on early diagnosis, careful patient selection, and multidisciplinary collaboration. Future studies should aim to refine risk stratification tools, establish clear procedural thresholds, and explore long-term outcomes of both surgical and transcatheter approaches. A patient-centered, evidence-based strategy will be essential in advancing the care of individuals with tricuspid valve pathology.

AUTHOR CONTRIBUTIONS

All authors substantively contributed to the drafting of the initial and revised versions of this paper. They take full responsibility for the integrity of all aspects of the work.

Mykytenko Ruslan – literature search, manuscript drafting, correspondence with the journal

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CONFLICT OF INTEREST

The authors have no conflict of interest to declare.

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The publication of data obtained during the course of this study was carried out in accordance with the principles of bioethics and the legislative standards and requirements for conducting biomedical research, namely: the Declaration of Helsinki (2000), the Constitution of Ukraine (1996), the Civil Code of Ukraine (2006), the Fundamentals of Health Legislation of Ukraine (1992), and the Law of Ukraine “On Information” (1992), as amended and supplemented as of 01.12.2021.

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The authors confirm that no artificial intelligence-based technologies were utilized in the writing or editing of the manuscript.

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