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Editorial

Navigating the Tricuspid Landscape: Evolution of Surgical and Transcatheter Strategies

Michele D'Alonzo[1,*], Antonio Messina[1], Emmanuel Villa[1], Giovanni Troise[1]

[1]Cardiac Surgery Unit, "Fondazione Poliambulanza" Hospital, 25124 Brescia, Italy
*Correspondence: michele.dalonzo@poliambulanza.it (Michele D'Alonzo)
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1. Introduction

For decades, the tricuspid valve (TV) has been regarded as a secondary actor in structural heart disease panorama, often treated as a passive marker rather than a therapeutic target. This perception has progressively shifted. From the "forgotten valve", the TV is now recognized as a pivotal determinant of right heart function and overall cardiac prognosis [1,2,3]. Notwithstanding millions in Europe suffering from clinically relevant tricuspid regurgitation (TR), the number of corrective interventions remains strikingly low.

Moderate-to-severe TR, whether functional or primary, is increasingly recognized as an independent contributor to worse patient outcomes and mortality if left untreated [4,5], starkly contrasting with the well-documented survival benefits of tricuspid valve repair techniques [6]. This editorial discusses why this therapeutic gap persists and argues for a more assertive, timing-sensitive, and strategy-oriented approach to TV disease (Fig. 1).

2. Indications for Intervention

Secondary TR accounts for approximately 90% of cases [7], often in the context of left-sided valve disease, pulmonary hypertension or atrial fibrillation. Primary TR is less common and results from congenital or acquired anatomical involvement of the valve structures.

Current European and American guidelines advocate for proactive management of TR. The 2021 ESC/EACTS guidelines recommend TV repair or replacement during left-sided valve surgery in patients with at least moderate TR and annular dilatation, even in the absence of symptoms [8]. These recommendations have remained essentially unchanged in the 2025 guidelines, although the class of recommendation has been downgraded from IIa to IIb [9]. American guidelines likewise support intervention for isolated primary TR in symptomatic individuals or those with worsening right ventricular function [10]. By contrast, transcatheter interventions have been upgraded, with current guidelines stating that transcatheter tricuspid valve treatment should be considered (IIa) in high-risk patients with symptomatic severe TR.

Yet clinical inertia remains. Rates of concomitant TV repair during mitral surgery vary from 15% to 55%, reflecting divergent interpretations of guideline thresholds, fear of atrioventricular conduction disturbances, and uncertainty around progression risk in mild-to-moderate TR. Still, data suggest that up to 25% of patients with untreated non-severe TR experience progression postoperatively, with poorer survival and quality-of-life metrics [11]. Risk factors for progression include annular dilatation (>40 mm or >21 mm/m^2), pulmonary hypertension, atrial fibrillation, and pacemaker transvalvular leads.

3. Surgical Strategies

The cornerstone of surgical intervention for TR remains the annuloplasty with valve replacement when repair is unfeasible. However, an equally critical decision is the operative environment: should the heart be arrested or allowed to beat?

The arrested heart (AH) technique, employing aortic cross-clamping and cardioplegia, offers the advantage of a static and bloodless field, enabling precision in complex repairs. Conversely, the beating heart (BH) strategy preserves myocardial perfusion, potentially reducing ischemia-related injury and systemic inflammatory response [12]. Nevertheless, BH surgery has limitations: the constant motion and bleeding obscure the surgical field, potentially complicating delicate leaflet or subvalvular interventions.

Baraki et al. [13] observed a higher reoperation rate in BH ($p = 0.039$) and a trend toward reduced late survival (75% for AH vs. 54% for BH at 5 years). On the other hand, Pfannmüller et al. [14] reported 30-day mortality of 11.9% for AH and 6.3% for BH ($p = 0.1$), with a comparable five-year survival. A multicenter Italian study echoed those findings, showing no significant difference in early mortality between AH and BH in isolated TV surgery (6.2% vs. 5.0%; $p = 0.9$), but BH yielded lower rates of acute kidney injury and no recorded neurological complications. Long-term survival and event-free rates were similar, affirming the procedural viability of both techniques [15].

A key advantage of the beating-heart approach lies in the ability to immediately detect conduction disturbances when operating near the atrioventricular conduction system. Excessive suture depth or inadvertent injury becomes evident in real time through rhythm alterations, allowing

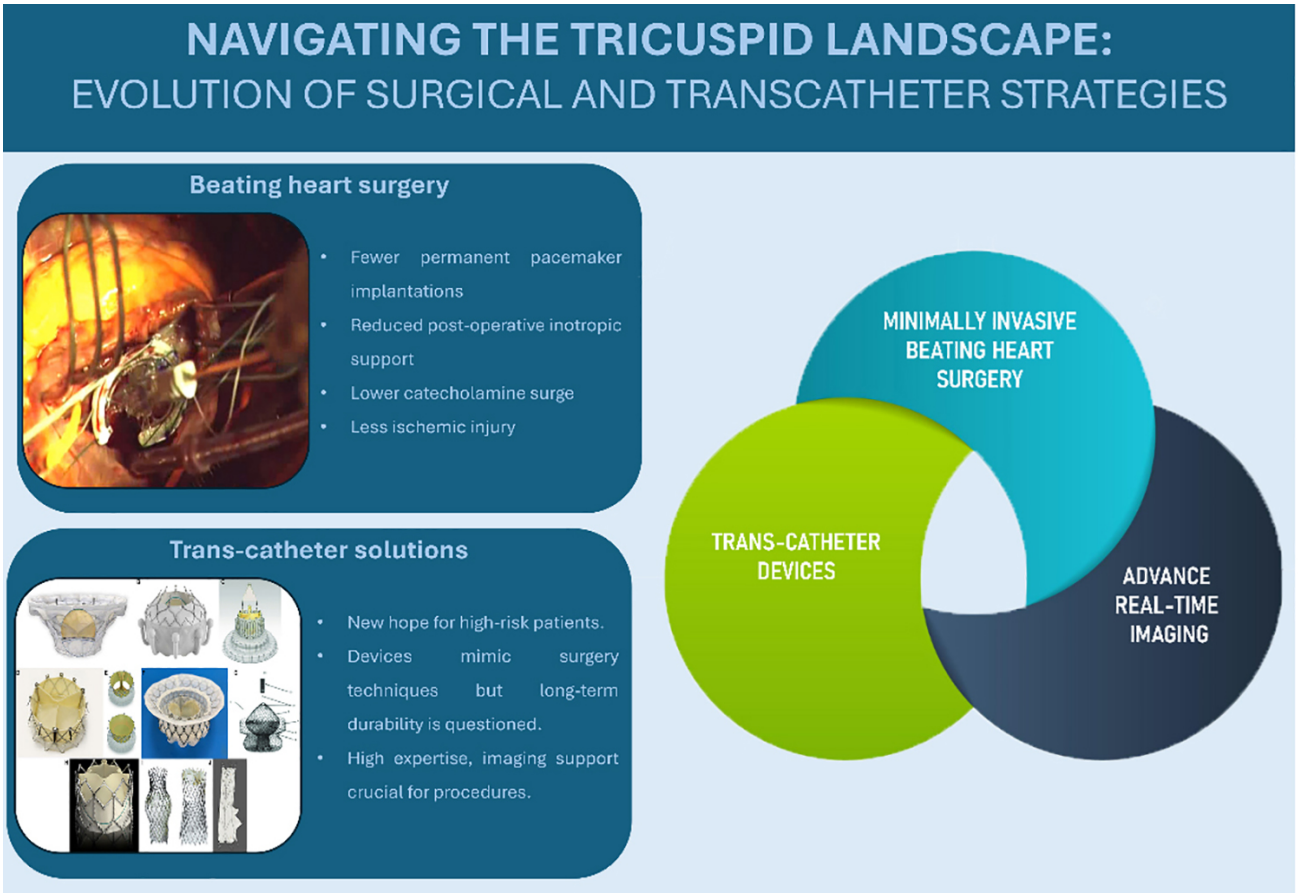

Fig. 1. Evolution of surgical and transcatheter strategies in tricuspid valve disease.

prompt correction by repositioning sutures before permanent damage occurs. This intraoperative feedback is inherently lost during AH surgery and likely contributes to the lower rates of permanent pacemaker implantation consistently reported with beating-heart tricuspid procedures, as also observed by Hasde et al. [16] evaluated 208 patients were evaluated after TV repair in combination with left-sided surgery. BH showed a favorable profile: fewer permanent pacemaker implantations (3% vs. 13%) and reduced postoperative inotropic support [16].

4. Techniques of Tricuspid Valve Repair

Successful TV repair requires mastery of several distinct techniques, each tailored to the anatomical substrate and pathophysiological context. Suture annuloplasty, pioneered by Kay et al. [17] and De Vega [18], offers simplicity and speed: even with many variations of these techniques being developed, these two remain the most well-known, studied, and frequently performed. However, concerns about their long-term durability persist, especially when dealing with severe annular dilatation or functional tricuspid regurgitation. Ring annuloplasty, introduced by Carpentier, employs rigid or semi-rigid rings to restore the native geometry of the annulus. Lastly, the clover technique, derived from Alfieri's mitral repair strategy, stitches leaflet centers to create a tricuspid trifoliation, supplemented by ring annuloplasty. A recent study examining 258 patients who underwent tricuspid edge-to-edge repair found no statistically significant differences in surgical outcomes between the double-orifice and clover repair techniques [19].

TV replacement, often with bioprosthetic devices, is reserved for structurally compromised valves (e.g., endocarditis, carcinoid, congenital dysplasia) or failed repairs. A systematic review and meta-analysis of 27 studies involving 10,478 patients found TV repair to be associated with more favorable long-term mortality outcomes compared to replacement. While early mortality was similar across surgical approaches, late mortality was significantly higher for both bioprosthetic and mechanical TV replacements compared to TV repair [20].

While robotic mitral valve surgery has become increasingly common over the past decade, particularly in Japan and the United States, robotically assisted TV surgery remains rare. This is true whether it is performed alongside mitral valve repair or as the main procedure. The main reasons for this are its technical complexity and the extended times needed for cross-clamping and cardiopulmonary bypass [21]. Notably, the freedom rate from recurrent moderate TR following their robotic tricuspid annuloplasty was

98% at one year. This rate is comparable to outcomes seen with tricuspid repair performed through median sternotomy, suggesting satisfactory short-term results for this robotic approach [22].

5. Transcatheter Solutions

Transcatheter therapies have become a real game changer, especially for high-risk patients and those who have already had surgery and are managing multiple health issues. However, it is worth noting that these innovative devices often draw their inspiration from traditional surgical techniques.

For instance, devices like the Millipede Ring (Boston Scientific, Marlborough, MA) and Cardioband (Edwards Lifesciences, Irvine, CA) system are designed to mimic the well-established ring annuloplasty technique. Similarly, the Trialign (Mitralign, Inc, Tewksbury, MA) is based conceptually on the suture-bicuspidization technique with interesting results. However, the inherent connection to surgical methods naturally leads to questions about the long-term durability of these newer transcatheter TV repair devices compared to surgical strategies [23,24,25].

Transcatheter edge-to-edge repair (T-TEER) using the TriClip (Abbott, Santa Clara, CA) has shown consistent procedural success. In the TRILUMINATE trial, patients experienced significant improvements in NYHA class and TR severity, with acceptable safety profiles [26]. Despite early promise, these devices face limitations: complex valve geometry, inadequate leaflet grasping in some cases, and uncertain long-term durability.

6. Conclusive Messages

The therapeutic neglect of TV disease is no longer tenable. Evidence increasingly supports early and deliberate intervention, particularly when left-sided surgery presents an opportune moment. Both BH and AH strategies offer viable outcomes, though BH may confer advantages in preserving organ function, reducing pacing requirements, and shortening recovery times.

Surgical expertise and patient-specific anatomical and functional parameters must drive decision-making. Furthermore, the rapid evolution of transcatheter technologies necessitates the collaboration of interventional cardiologists, imaging specialists, and surgeons into cohesive heart teams. The tricuspid valve may no longer be forgotten, but it is far from fully understood.

Intraoperative view highlighting the clinical advantages of this approach, including lower rates of permanent pacemaker implantation, reduced postoperative inotropic support, and minimized myocardial ischemic injury compared to traditional AH techniques. Transcatheter solutions represent devices for tricuspid repair and replacement. These offer a vital alternative for high-risk patients, though long-term durability is still being evaluated. Success relies on high procedural expertise and dedicated imaging support: Venn diagram illustrating the convergence of minimally invasive surgery, transcatheter innovation, and advanced real-time imaging. This intersection defines the modern “Heart Team” approach necessary to optimize patient outcomes.

Abbreviations

TV, tricuspid valve; TR, tricuspid regurgitation; BH, beating heart; AH, arrested heart; PPM, permanent pacemaker.

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