Cardiac Surgery 2023 Reviewed

Hristo Kirov1 Tulio Caldonazo1 Murat Mukharyamov1 Sultanbek Toshmatov1 Johannes Fischer1 Ulrich Schneider2 Thierry Siemeni1 Torsten Doenst1

1 Department of Cardiothoracic Surgery, Friedrich-Schiller-University of Jena, University Hospital Jena, Jena, Germany
2 Department of Cardiac Surgery, Saarland University Medical Center, Homburg Saar, Germany

Address for correspondence Torsten Doenst, MD, PhD, Department of Cardiothoracic Surgery, Friedrich-Schiller-University of Jena, Am Klinikum 1, 07747 Jena, Germany (e-mail: doenst@med.uni-jena.de).

Abstract

We reviewed the cardiac surgical literature for 2023. PubMed displayed almost 34,000 hits for the search term “cardiac surgery AND 2023.” We used a PRISMA approach for a results-oriented summary. Key manuscripts addressed the mid- and long-term effects of invasive treatment options in patient populations with coronary artery disease (CAD), comparing interventional therapy (percutaneous coronary intervention [PCI]) with surgery (coronary artery bypass graft [CABG]). The literature in 2023 again confirmed the excellent long-term outcomes of CABG compared with PCI in patients with left main stenosis, specifically in anatomically complex chronic CAD, but even in elderly patients, generating further support for an infarct-preventative effect as a prognostic mechanism of CABG. For aortic stenosis, a previous trend of an early advantage for transcatheter (transcatheter aortic valve implantation [TAVI]) and a later advantage for surgical (surgical aortic valve replacement) treatment was also reconfirmed by many studies. Only the Evolut Low Risk trial maintained an early advantage of TAVI over 4 years. In the mitral and tricuspid field, the number of interventional publications increased tremendously. A pattern emerges that clinical benefits are associated with repair quality, making residual regurgitation not irrelevant. While surgery is more invasive, it currently generates the highest repair rates and longest durability. For terminal heart failure treatment, donor pool expansion for transplantation and reducing adverse events in assist device therapy were issues in 2023. Finally, the aortic diameter related to adverse events and technical aspects of surgery dominated in aortic surgery. This article summarizes publications perceived as important by us. It cannot be complete nor free of individual interpretation, but provides up-to-date information for patient-specific decision-making.

Keywords

► aortic valve
► mitral valve surgery
► tricuspid valve
► coronary artery bypass grafting
► CABG
► aorta
► transplantation
► heart

Background and Methods

We here summarize publications selected from a systematic review process. Since the selection will always be biased and affected by individual perception (despite this standardized process), we have again focused on applying a mechanistic perspective wherever possible and also on information most relevant for a proper risk–benefit assessment. We hope the reader appreciates our efforts, which are (as in recent years1–6) strictly adherent to the common principle that everyone is entitled to his or her own opinion, but not to his or her own facts. In other words, readers may not agree with our interpretation of the data, but they can rest assure that the quoted data and associations are accurate.

We used the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-analyses) approach for a systematic literature review. The MEDLINE database was searched using the following search terms combined with
the publication date being between January 1, 2023 and December 12, 2023 for the different chapters of this manuscript: Coronary Artery Bypass Grafting; Aortic Valve; TAVI; Aortic Valve Disease; Mitral Valve Surgery; MitraClip; TEER; Tricuspid Valve; Aortic Aneurysm; Aortic dissection; LVAD; Mechanical Circulatory Support and Heart Transplantation; Clinical Trial. **Supplementary Fig. S1** (available in the online version) shows the PRISMA diagram for the literature review. We selected publications based on their value for indications, decision-making, and patient information, focusing mainly on reliable sources and publications in reputable peer-reviewed journals. Manuscripts with a focus on individual technical details without relevant information for the above-described goals were omitted.

**Introduction**

Treating human disease always requires a risk–benefit assessment. In the cardiac arena, current times are characterized by efforts to reduce periprocedural risks. Many new minimally invasive approaches to address coronary artery and structural heart disease have been tested and presented, suggestive of a pattern that reducing invasiveness may equal reducing risks. Publications in the year 2023 support this perception but also provide information on long-term benefits. It is interesting to note in this context that the risk factor frailty, which practically addresses the difference between chronological and biological age in the elderly, may significantly be reduced with a surgical procedure which is considered high risk because of it. This finding prototypically illustrates the complexity of risk–benefit assessment in the cardiovascular field.

**Myocardial Protection and Mortality**

A manuscript that specifically addressed perioperative risk in cardiac surgery in general focused on the status of current techniques for myocardial protection. The development of cardioplegia in addition to cardiopulmonary bypass surgery 50 to 70 years ago made possible the development of cardiac surgery as we know it. The review illustrates that our current cardioplegic solutions are all at least 30 years old, that a relationship between aortic cross clamp-time and mortality still exists, and that clamp time-related mortality risk increases faster in older patients. In addition, the influence of comorbidities (which are more prevalent in today’s patient population) on myocardial protection has not been fully investigated. Thus, there appears to be considerable potential in reducing perioperative risks by individualizing surgical protection and entire treatment strategies, a pattern that applies to all other areas reviewed below.

**Surgical Treatment of Coronary Artery Disease**

**CABG versus PCI**

Recent years have witnessed a heated debate specifically regarding the invasive therapy of left main (LM) disease. In 2023, a joint ESC/EACTS (European Society of Cardiology/European Association for Cardio-Thoracic Surgery) review of the 2018 guideline recommendations on the invasive therapy of LM CAD in patients at low surgical risk and anatomy suitable for percutaneous coronary intervention (PCI) or coronary artery bypass graft (CABG) appeared. The task force reviewed all new data since the 2018 guidelines, including updated aggregated data from the four randomized controlled trials (RCTs), which suggested no statistically significant difference in all-cause mortality at 5 years between CABG and PCI, but significantly less spontaneous myocardial infarction (MI) with CABG. The task force now suggests a Class I A recommendation for CABG and Class IIA recommendation for PCI in LM disease, irrespective of the SYNTAX score, but concluded that both treatment options are clinically reasonable based on available expertise and local operator volumes. They provide a table of clinical conditions that a heart team should use for individual decision-making.

In this context, a meta-analysis assessing CABG and PCI for unprotected LM according to lesion site (ostial/shaft vs. distal, 3 RCTs, 6 adjusted observational) appeared, suggesting that PCI for distal LM lesions was associated with an increased risk of major adverse cardiovascular event (MACE), death, and re-revascularization compared with CABG. Additional evidence in 2023 came from two observational nationwide registry studies comparing outcomes after CABG or PCI in unprotected LM. Such data may provide external validation to RCTs, which are often criticized for their high grades of patient selection. The SWEDEHEART analysis assessed 11,137 patients with significant LM stenosis of which 84% had undergone CABG and 16% PCI between 2005 and 2015. The Canadian study assessed 1,299 PCI and 21,287 CABG patients between 2008 and 2020. Both performed risk adjustments and both showed that CABG was associated with lower mortality and fewer MACCE compared with PCI. Of note, 30-day mortality was not higher with CABG compared with PCI.

The FAME 3 trial (RCT involving patients with 3-vessel coronary artery disease [CAD] not involving the LM in 48 centers worldwide) published its 3-year results. Patients were randomly assigned to receive FFR-guided PCI using zotarolimus drug-eluting stents or CABG. PCI did not meet the noninferiority criteria in the primary outcome analysis, despite its huge noninferiority margin of 1.65. For the 3-year results, the authors now present a new combined endpoint of death, stroke, and MI (excluding the need for revascularization). For this endpoint, the authors describe no difference and report an incidence of 9.2% for CABG versus 12% for PCI. The hazard ratio (HR) was 1.3 [95% confidence interval [CI]: 0.98–1.83] with p = 0.07 (Fig. 1B). The original primary endpoint remained in favor of CABG (incidence of 12.5% for CABG vs. 18.6% for PCI; HR: 1.5 [95% CI: 1.2–2.0] with p = 0.002). A comparison of CABG versus PCI in patients with acute coronary syndrome (ACS) (considered higher surgical risk) undergoing isolated CABG or multi-vessel PCI was published from the U.S. Medicare and Medicaid Services databases.
The authors analyzed 104,127 patients undergoing CABG (n = 51,389) or multi-vessel PCI (n = 52,738). After adjusting for confounders, they showed that CABG (compared with PCI) was associated with lower in-hospital mortality, a significant reduction in risk-adjusted re-admission for MI or heart failure, fewer coronary re-interventions, and improved 3-year survival (Fig. 1C).

Two other publications assessed the outcomes of CABG versus PCI in patients considered at higher surgical risk, but in chronic coronary syndrome. We conducted a meta-analysis of reconstructed time-to-event data with studies comparing CABG and PCI in octogenarians with LM or multi-vessel disease. CABG was associated with lower late mortality and lower risk of MI and repeat revascularization compared with PCI. A landmark analysis confirmed the survival advantage of CABG over PCI after 21.5 months of follow-up but in this situation it indeed suggested an advantage of PCI over CABG in the first 30-days (and comparable survival from 1 to 21.5 months, Fig. 2A). Another study assessed a cohort of more than 1 million female patients and showed that women experienced higher operative mortality and morbidity compared with men, which had not changed in the past decade. Hannan et al separately compared CABG to PCI with everolimus-eluting stents in women with multi-vessel CAD from the New York State Cardiac Registry (2012–2018). The propensity-score-matched analysis included 15,589 women (60% PCI, 40% CABG). After matching, PCI was associated with a higher 6-year risk of mortality (Fig. 2B), more MI, and repeat revascularization, at similar stroke rates.

Galli et al published a network meta-analysis comparing CABG, PCI, and medical therapy in chronic coronary syndrome. The authors included 18 RCTs in patients without LM disease or reduced left ventricular ejection fraction. They report that physiology-guided PCI and CABG are associated with better outcomes than angiography-guided PCI. Interestingly, CABG was the only treatment associated with a significant reduction in mortality, which was associated with a reduction in MIs. A recent post-hoc analysis of the ISCHEMIA trial also reported the ability of invasive CAD treatment to reduce spontaneous MIs. While the study did not demonstrate a mortality reduction, it found the lowest rates of spontaneous MIs in CABG patients.

Considering the many other comparisons of CABG and PCI in 2023 and those before (which cannot all be mentioned), the same pattern always emerges. All articles illustrating survival advantages or relevant clinical improvements with CABG always show reductions in MI (Fig. 2C) by CABG. We had addressed this observation before with our surgical collateralization hypothesis and later suggested that all prognostic effects associated with invasive treatment of chronic CAD appear to be linked to the prevention of MI. This conclusion finds again support in 2023 and also from the interventional arena. Three trials—BIOVASC, FIRE, and MULTISTARS—report improved clinical outcomes with complete “revascularization” in patients with multi-vessel CAD presenting with ACS and/or ST-elevation myocardial infarction (STEMI; compared with culprit lesion PCI only). While FIRE and MULTISTARS excluded CABG candidates, all demonstrate a significant reduction in MI rates as part of their positive primary endpoint outcome. Finally, a Medicare analysis of patients undergoing PCI in over 1 million patients reports less risk-adjusted mortality and MACE if intravascular imaging was used. Again the outcome improvement correlated with a reduction in MI. Considering the superior ability of CABG over PCI to prevent future MI if the plaque burden in CAD patients is high (with or without STEMI), the need for heart-team-driven individual decision-making in CAD patients becomes clear again. This need is further...
illustrated by an analysis of the New York State’s cardiac registries which showed that ad hoc PCIs occur frequently even among stable patients with multivessel and/or LM disease. Rates of ad hoc PCI are high even among patients with diabetes and low ejection fraction and higher in hospitals without surgery on-site. This finding has initiated a discussion challenging our current practice of shared decision making.
Technical Aspects of CABG
CABG is technically demanding, which was emphasized again in 2023 by several publications. A STS (Society of Thoracic Surgeons) database analysis of almost 1.4 million CABG patients (93,985 re-dos) identified the risk of re-do at the surgeon and not at the center level. The latter authors pooled individual patient data from randomized clinical trials with systematic CABG graft imaging to assess the incidence of graft failure and its association with clinical risk factors. The manuscript illustrates different risk factors affected. The manuscript illustrates different risk factors for graft failure (e.g., age, female sex, smoking). From a mechanistic perspective, graft failure was associated with an increased risk of MI or repeat revascularization and higher rates of death.

Medical Treatment of CABG Patients
Postoperative statin use was associated with less graft failure. However, statin loading before CABG failed to show any benefits in an investigator-initiated, double-blind, and placebo-controlled RCT. Sandner et al additionally illustrated in a review that adding ticagrelor to aspirin for 1 year after CABG is associated with a reduction in the risk of vein graft failure, at the expense of an increased risk of clinically important bleeding.

In conclusion, the evidence published in 2023 supports the following conclusions:

- CABG keeps showing a prognostic advantage over PCI or medical therapy when anatomic CAD complexity is high (specifically in LM and multi-vessel CAD).
- This prognostic effect may even exist in patients where CABG is perceived to be at higher risk (e.g., female, STEMI/non-STEMI or elderly patients, above 80 years).
- Prognostic treatment effects of CABG and even PCI, if detected, were always related to reductions in future MIs.
- Graft patency remains crucial for a CABG treatment effect and graft failure is associated with increased rates of MI. They may be optimized by graft selection, surgical skill, and optimal medical therapy.
- The high rates of ad hoc PCI reported in the reviewed evidence led to the suggestion of low guideline adherence in patients with multi-vessel and LM disease.

Surgical Treatment of Valve Disease
Aortic Valve
Aortic Valve Replacement versus Transcatheter Aortic Valve Implantation
The year 2023 saw a growing number of transcatheter aortic valve implantation (TAVI) versus surgical aortic valve replacement (SAVR) comparisons addressing longer follow-ups, specifically in the newer low-risk trials. The Evolut Low Risk trial presented 4-year outcomes. There was no significant difference in mortality (SAVR vs. TAVI: 12.1% vs. 9%, p = 0.07) or stroke rates (2.9% vs. 3.8%, p = 0.32). This is the first trial where an initial advantage in the first 12 months (although not significant for mortality or stroke) was not lost during follow up. The trial was criticized for its high amount of concomitant procedures in the SAVR group (26.3%, with half of them CABG, but also root enlargement, mitral repairs, etc.) and the fact that no information on the type of biological prostheses was provided for the surgical group. In addition, the number of new permanent pacemaker implantation was significantly higher with TAVI (24.6% vs. 9.9%, p < 0.001), but mean gradients were lower with TAVI (9.8 ± 5.5 mm Hg for TAVI vs. 12.1 ± 5.4 mm Hg for SAVR, p < 0.001).

The other low risk trial, PARTNER 3, provided 5-year data of the Sapien 3 valve which was compared with SAVR using a mix of different biological prostheses (63% Magna or Magna Ease, 16% Tricofa, 6% Mosaic, 7% rapid deployment valves, etc.). The trial had randomized 1,000 low-risk patients with severe, symptomatic aortic stenosis. The primary endpoints (combinations of death, stroke, rehospitalization) showed no difference at 5 years. However, survival curves crossed and mortality was numerically lower with SAVR at 5 years (10% vs. 8.2%, HR: 1.23). A landmark analysis of PARTNER 3 also reconfirmed observations from PARTNER II and from a previous individual patient data meta-analysis of six randomized trials at high and intermediate risk. They all demonstrate a short-term advantage for TAVI in the first 12 months, but a significant disadvantage at the 5-year mark.

A meta-analysis of RCTs in “lower” (combining low and intermediate risk) and high-risk patients found an early mortality reduction with TAVR only in “lower” risk patients, which was no longer there during further follow-up. Interestingly, Barili et al meta-analytically assessed the risk of bias in TAVI versus SAVR RCTs. The authors found that there were substantial deviations from the randomly assigned treatment, patients lost to follow-up, concomitant procedures, and systematic selective imbalance in all trials. They point out that all these factors were always in favor of the TAVI outcomes.

Sá et al performed a meta-analysis of reconstructed time-to-event data from both randomized trials and propensity-score matched (PSM) studies evaluating midterm outcomes in low-risk patients. They identified eight studies (3 RCTs, 5 PSM studies) and included 5,444 patients (2,639 underwent TAVI and 2,805 SAVR). TAVI was noninferior to SAVR up to 2 years (HR: 1.08 [95% CI: 0.89–1.31], p = 0.448)
but was associated with a significantly higher risk of all-cause mortality at 8 years of follow-up (HR: 1.22 [95% CI: 1.03–1.43], p = 0.018) (►Fig. 3C).

Another propensity-matched analysis of the Centers for Medicare and Medicaid data of 6450 patients having isolated SAVR (n = 3,771) or TAVI (n = 2,679) for bicuspid aortic stenosis between 2012 and 2019 showed that TAVI was associated with a similar mortality risk compared with SAVR within the first 6 months but a higher mortality risk between 6 months and 3 years (HR: 2.16, 95% CI: 1.22–3.83).45 Thus, also in 2023, the previously emerging pattern solidified. TAVI may have an early advantage while SAVR outperforms TAVI in terms of survival in the long run. This pattern also seems to apply to redo operations or valve in valve situations,46 although TAVI may be a valid option in well-selected cases.47

In 2023, two conventional surgical registry analyses underscored the good long-term data with SAVR. A registry analysis of all patients with primary, isolated SAVR from the STS database (2011–2019) reported outcomes for 42,586 patients who would have fulfilled the inclusion/exclusion criteria of the PARTNER 3 and the Evolut Low Risk RCTs.48 All-cause mortality at 1, 5, and 8 years was 2.6%, 7.1%, and 12.4%, respectively,48 which is numerically lower than the results of both arms of PARTNER 3 and Evolut Low Risk trials (PARTNER 3 at 5 years: TAVI 10%, and SAVR 8.2%;40 Evolut Low Risk at 3 years: TAVI 6.3% and SAVR 8.3%).49 The same study showed that in patients with predicted risk of mortality <1%, survival after SAVR was even higher with 95% at 8 years.48 Similarly outstanding results were reported by Johnston et al on almost 4,000 isolated SAVRs with STS-predicted risk of mortality <4%,50 with survival rates of 98%, 91%, and 82% at 1, 5, and 9 years.50

### Conventional Aortic Valve Surgery

The classic surgical literature focused on aortic valve reconstruction (valve reimplantation vs. valve remodeling) or replacement with the pulmonary autografts (Ross procedure). Several expert groups report their experience over decades.51–53 They all describe excellent long-term outcomes for valve repair/reimplantation associated with low rates of re-intervention and valve-related complications (VRCs). The only replacement option demonstrating similar long-term outcomes with low rates of re-intervention and VRC appears to be the Ross procedure (in dedicated centers with high expertise). A prominent study by El-Hamamsy

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**Fig. 3** Main outcomes of invasive treatment of the aortic valve in 2023. (A) Landmark analysis of the 5-year outcomes of the PARTNER 3 trial comparing TAVI (with Sapien 3) versus SAVR. From Mack et al. 39 (B) Risk-of-bias assessment for TAVI versus SAVR trials suggesting an uneven deviation from assigned treatment resulting in biases primarily in favor of TAVI. From Barili et al. (licensed under the terms of the CC-BY license) 43 (C) Spline curves illustrating the time-varying hazard ratios for mortality from a meta-analysis of randomized and matched registry studies in low-risk TAVI versus SAVR comparisons. From Sá et al. (licensed under the terms of the CC-BY license) 44 (D) Cumulative incidence of valve thrombosis or valve-related thromboembolism in a trial comparing apixaban with warfarin for anticoagulation after mechanical aortic valve replacement. From Wang et al. 51 SAVR, surgical aortic valve replacement; TAVI, transcatheter aortic valve implantation.
et al. was confirmed by a recent meta-analysis supporting the statements in 2023. Re-intervention appears to be required in approximately 20% of patients at 20 years for either autograft or right ventricular outflow tract issues. If root replacement has to be performed, a meta-analysis of 23 studies in over 11,000 patients suggests that mechanical conduits may outperform biological conduits. Perioperative risk was similar between mechanical and biological conduits, but patients with mechanical solutions had lower mortality after 30 days, which was associated with lower rates of re-intervention. However, previous comparisons between mechanical and biological valves have reported an increased stroke rate after mechanical aortic valve replacement.

Medical Therapy in Valve Surgery

One of the VRCs that may be addressed medically is valve thrombosis. Thrombus formation mainly affects TAVI with up to 40% of valves. Although there appears to be no direct relationship to clinical events, previous evidence suggests that long-term durability may be impaired by leaflet thrombus. The Mayo Clinic reported data on temporary anticoagulation after biological SAVR in over 10,000 patients. They found that guideline-directed anticoagulation was poorly performed and that lack of anticoagulation in the first 3 months after SAVR was associated with more events and more deaths but less bleeding complications.

A prospective, randomized, open-label trial assessed the value of apixaban versus warfarin in patients with On-X mechanical aortic valves. The trial was stopped after 863 participants were enrolled owing to an excess of thromboembolic events in the apixaban group (Fig. 3D).

Finally, a Swedish study assessed medical therapy in patients after aortic valve replacement for regurgitation. Over 2,200 patients underwent the procedure between 2006 and 2017 in Sweden. The authors identified protective effects of renin–angiotensin system (RAS) inhibitors and statins on their combined endpoint of mortality, MI, and stroke.

Mitral Valve

Although current guidelines recommend transcatheter approaches to the mitral and the tricuspid valve only in patients who are no candidates for surgery, the number of publications addressing the impact of transcatheter options alone continuously increases. This was also the case in 2023.

The randomized COAPT trial reported its 5-year outcomes comparing transcatheter edge-to-edge repair (TEER) for severe functional mitral regurgitation to guideline-directed medical therapy alone. The lower rate of hospitalizations for heart failure and lower all-cause mortality with TEER remained, with those patients having the least degrees of mitral regurgitation doing best. Since there was no surgical arm in this trial, a direct comparison of TEER and surgery is still missing, but results of the MATTERHORN trial (NCT02371512) are on the horizon. For structural (degenerative) MR, two trials are currently active in comparing TEER and surgical repair (the Abbott sponsored REPAIR-MR-trial [NCT04198870] and the CTSN-sponsored PRIMARY-trial [NCT05051033]). In the meantime, significant fractions of structural MR patients are already treated with TEER in the absence of randomized evidence. Makkar et al. reported on 20,000 patients who received TEER for structural MR. The study concludes that TEER is safe (mortality 2.7%, O/E ratio 0.6) with high procedural success, which is in most TEER studies defined as moderate or less MR after the procedure. The authors report severe MR at discharge in 11% of patients. However, only half of all patients left the hospital with a surgically acceptable result (i.e., MR ≤ 1), although chances for MR ≤ 1 increased over time (Fig. 4A).

An important observation in this context is the finding that the lowest 1-year mortality was observed in patients who had both residual MR ≤ 1 and mean mitral gradients of 5 mm Hg or less (11.4%) versus those with an unsuccessful procedure (26.7%).

This relationship between repair success and 1-year mortality (and rehospitalizations) was also found by others in 2023, for instance in the Prospective German Multicenter...
Registries (MITRA-PRO). Bisco et al suggested sustained mitral regurgitation reduction to be key to survival improvement even in patients 80 to 89 years of age. Watt et al finally report the same findings in surgical patients with severe functional MR. Reductions of postoperative MR grade resulted in an incrementally lower risk of death or reoperation during follow-up. Considering this relationship, it appears only logical to ask for a successful and durable elimination of MR. A meta-analysis that reviewed six studies comparing PASCAL or MitraClip TEER devices quantified the real-world outcomes after TEER in 1,581 patients. Residual MR ≤1 at discharge was present in 73.1% and 63.8% for PASCAL and MitraClip, respectively. These values decreased at midterm follow-up to 71.3% and 56.2%, respectively. These outcomes together with data from Fig. 4A suggest that more than one-third of patients after current interventional therapy sustain at least moderate MR after the procedure. Also in 2023, Badhwar et al reported that surgery can generate repair rates for structural MR of over 95% of cases at very low surgical risk (<1%) and an editorial emphasized the role of surgery as gold standard for patients with structural MR.

One of the greatest arguments mentioned against surgery is always the need for median sternotomy, which set in motion significant activity to develop minimally invasive access to the heart for all procedures. The mini-mitral trial was a multicenter RCT comparing 166 mini-thoracotomy with 164 sternotomy patients undergoing isolated mitral valve repair performed by expert mitral valve surgeons in the United Kingdom. The primary outcome was physical functioning and associated return to usual activities measured by change from baseline in the SF-36 version 2 physical functioning scale 12 weeks after the index surgery, assessed by an independent researcher blinded to the intervention. While there was an advantage for the minimally invasive approach after 6 weeks, the primary outcome was not different at 12 weeks. Considering the above mentioned relationship of repair quality and survival, it may be worth noting that rates and quality of valve repair in the mini-mitral trial were high at 1 year in both groups (Fig. 4B).

While the mini-mitral trial did not further specify the technical details of the repair, we performed a meta-analysis of reconstructed time-to-event data comparing the resect and respect approaches for posterior prolapse mitral valve repair. We found no difference in long-term mortality, MR recurrence, or reoperation between the two techniques after adjusting for patient risk factors.

Tricuspid Valve
The current guidelines state that tricuspid valve interventions are underused and often initiated too late. Surgical treatment (preferably repair) is indeed recommended as first-line therapy in patients with severe tricuspid regurgitation (TR) even if symptoms are low or absent (see guidelines for details). Interventional treatment is only recommended for inoperable patients. Despite this, a sudden increase of TR cases during the last years has been observed. Reviewing the literature in 2023, the same impression to that for the mitral valve emerges, as interventional results are increasingly reported with sole comparisons to medical therapy.

For instance, the TRILUMINATE trial compared medical therapy with transcatheter tricuspid valve edge-to-edge repair in patients with isolated moderate to high surgical risk and severe TR. The trial reported an improvement in quality of life in the interventional arm, which correlated with a significant reduction of TR grade. However, there was no difference in any of the clinically quantifiable parameters (outcomes of the 6-minute walk test even decreased), and mild residual regurgitation was only achieved in half of the patients.

Dreyfus et al used their TRI-Score to assess outcomes from a multi-center registry of 2,413 patients with isolated TR. They found an improvement in survival associated with successful reduction in TR in patients with mild and moderate risk. However, if repair success was absent with the intervention or if the score reflected the highest risk, long-term mortality was unaffected. Fig. 5 illustrates that surgical risk at low TRI-Score was equal to interventional risk (panels C and D), but 2-year outcome was better. Periprocedural mortality risk increased most in the surgical group with increasing TRI-Score ( Fig. 5C), suggesting that increased invasive risk consumes potential long-term benefits specifically at the highest risk group. The community often considers isolated tricuspid surgery a high-risk procedure. We addressed this potentially erroneous conclusion by illustrating the influence of an immortal time bias on surgical outcomes. If patients die after a diagnosis has been made and while waiting for surgery, this mortality is not considered in surgical outcomes (hence, immortal time bias). This bias may decrease the surgical effect if medical therapy is the comparator. However, in case of tricuspid surgery (and other conditions), waiting for surgery increases operative risk, which may offset the immortal time bias, suggesting earlier surgery in these cases.

The main findings in 2023 for classic valve surgery are:

• The evidence for the treatment of aortic valve stenosis confirms the outstanding long-term results for conventional surgery. Only the Evolut Low Risk trial preserved an early TAVI advantage over time. These facts are not reflected in the guidelines.
• The best long-term outcomes (normalization of life expectancy) can be achieved with valve repairs or the Ross procedure, when these techniques are feasible.
• When treating mitral regurgitation or TR, a durable, high-quality repair is associated with the best long-term outcomes. This applies to both surgical and interventional techniques.
• The quality and durability of a repair is surgically higher than interventionally, but surgical risk may be higher.

Surgery for Terminal Heart Failure
For the surgical treatment of heart failure, important publications in 2023 assessed the possibilities of expanding the donor pool and the role of mechanical circulatory support.

A randomized, noninferiority trial compared results of transplanting hearts from brain-death donors (BDDs) with traditional cold storage with those from circulatory-death
donors (CDDs) that were resuscitated and preserved in a mobile extracorporeal perfusion and preservation system (Organ Care System Heart, TransMedics). The primary end point was risk-adjusted survival at 6 months. A total of 166 transplant recipients were included in the as-treated primary analysis (80 CDDs and 86 BDDs). CDD was non-inferior to BDD (94% vs. 90% 6-month survival).

After the first xenotransplantation with genetically modified pig hearts in 2022, the results of two transplantations using gene-edited pig hearts transplanted into brain-dead human recipients were published in 2023. Both xenografts demonstrated excellent cardiac function after early after transplantation and continued to function for the duration of the observation. Cardiac function in one of the hearts declined postoperatively, attributed to a size mismatch. There was no evidence of cellular or antibody-mediated rejection, as assessed using histology, flow cytometry, and a cytotoxic crossmatch assay. Importantly, there was no evidence of zoonotic transmission from the donor pigs to the human recipients. The second person to receive a transplanted pig heart lived for 6 weeks, but beyond press releases, there was no scientific publication in 2023.

Another approach to address the problem of growing patient numbers with terminal heart failure and organ shortage is reducing the need for transplantation by improving the exploitation of classic therapeutic option. The team in Bad Oeynhausen prominently published the CASTLE HTx trial, in which 194 terminal heart failure patients with symptomatic atrial fibrillation referred for heart transplantation were randomized to either catheter ablation or control. They reported a significant reduction in the primary endpoint of death, left ventricular assist device (LVAD) implantation, or urgent heart transplantation after 18 months in the ablation group (HR: 0.24, CI: 0.11–0.52).

Finally, in 628 LVAD patients, a randomized study of aspirin (100 mg/d) versus placebo in addition to vitamin K antagonists was conducted in 51 centers from 9 countries. Aspirin avoidance was associated with reduced nonsurgical bleeding (RR: 0.66 [95% CI: 0.51–0.85]; p = 0.002) without an increase in strokes or other thromboembolic events.

Fig. 5 (A–D) Survival rate according to treatment modality and TRI-Score category from a multi-center registry of 2,413 patients with isolated severe tricuspid regurgitation. From Dreyfus et al.75
In 2023, the size of the aorta and its relationship to aortic dissection was the main focus of publications. An analysis of 964 unoperated thoracic aortic aneurysms, followed over a median of 7.9 years, showed that the risk of adverse aortic events was relatively flat until 5 cm of ascending aortic size, at which it began to increase rapidly. The mean annual growth rate was estimated to be 0.1 cm/year. The authors conclude that an aortic size of 5 cm, rather than 5.5 cm, may be a more appropriate intervention criterion for prophylactic surgery.

An analysis on 407 naturally occurring, acute, flap-type ascending or descending aortic dissections between 1990 and 2022 suggested that a “left shift” to 5.0 cm in the criteria for ascending aortic intervention in the American guidelines could prevent an additional 29.3% of type A dissections. They also demonstrate that type B dissections generally occur at smaller aortic diameters and would not benefit from alterations in size criteria.

A publication comparing the perioperative outcomes of patients with acute type A aortic dissection undergoing hemiarch versus extended arch repair in nine centers (923 patients) showed that extended arch interventions pose similar perioperative mortality and neurologic risks to hemiarch.

**Surgery of the Aorta**

Conflict of Interest
None declared.

Acknowledgment
We would like to thank Benjamin May for expert technical assistance in the preparation of the manuscript.

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