

The Evolution and Current State of Minimally Invasive and Robotic Cardiac Surgery

Smaller Incisions, Smarter Robots, Better Outcomes

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BACKGROUND

- Cardiac surgery has progressively shifted from full sternotomy toward minimally invasive and robotic approaches over the past three decades.
- Minimally invasive cardiac surgery (MICS) now accounts for approximately one-third of cardiac operations globally.
- Techniques include mini-thoracotomy, port-access, video-assisted, and fully robotic (da Vinci) platforms.
- Robotic mitral valve repair volume surged 30% between 2015 and 2021 in the STS database, while sternotomy-based repair declined.
- Despite demonstrated safety, adoption remains limited by learning curves, cost, and training infrastructure.

OBJECTIVES

- Synthesize 30 years of evidence on minimally invasive and robotic CABG and valve surgery.
- Report cumulative perioperative outcomes across 74 patient series (11,135 procedures) and 85 selected studies.
- Evaluate the technical evolution, expanding indications, and barriers to adoption of MICS and robotic cardiac surgery.

METHODS

- Design:** Comprehensive narrative synthesis integrating two major reviews:
 - 25-year assessment of minimally invasive and robotic CABG (74 series; 11,135 procedures; 1996–2019)
 - State-of-the-art review of MICS (85 selected studies)
- Data extracted:** Technical approaches, perioperative mortality, stroke, bleeding revision, renal failure, wound infection, hospital stay, and procedural evolution.
- Scope:** Six main versions of minimal-access and robotically assisted CABG; expanded robotic applications in mitral, multi-valve, and hybrid procedures.

RESULTS

Cumulative Outcomes: Minimally Invasive & Robotic CABG

1.0%

Hospital Mortality

0.6%

Stroke Rate

5.6 days

Mean Hospital Stay

2.5%

Bleeding Revision

0.9%

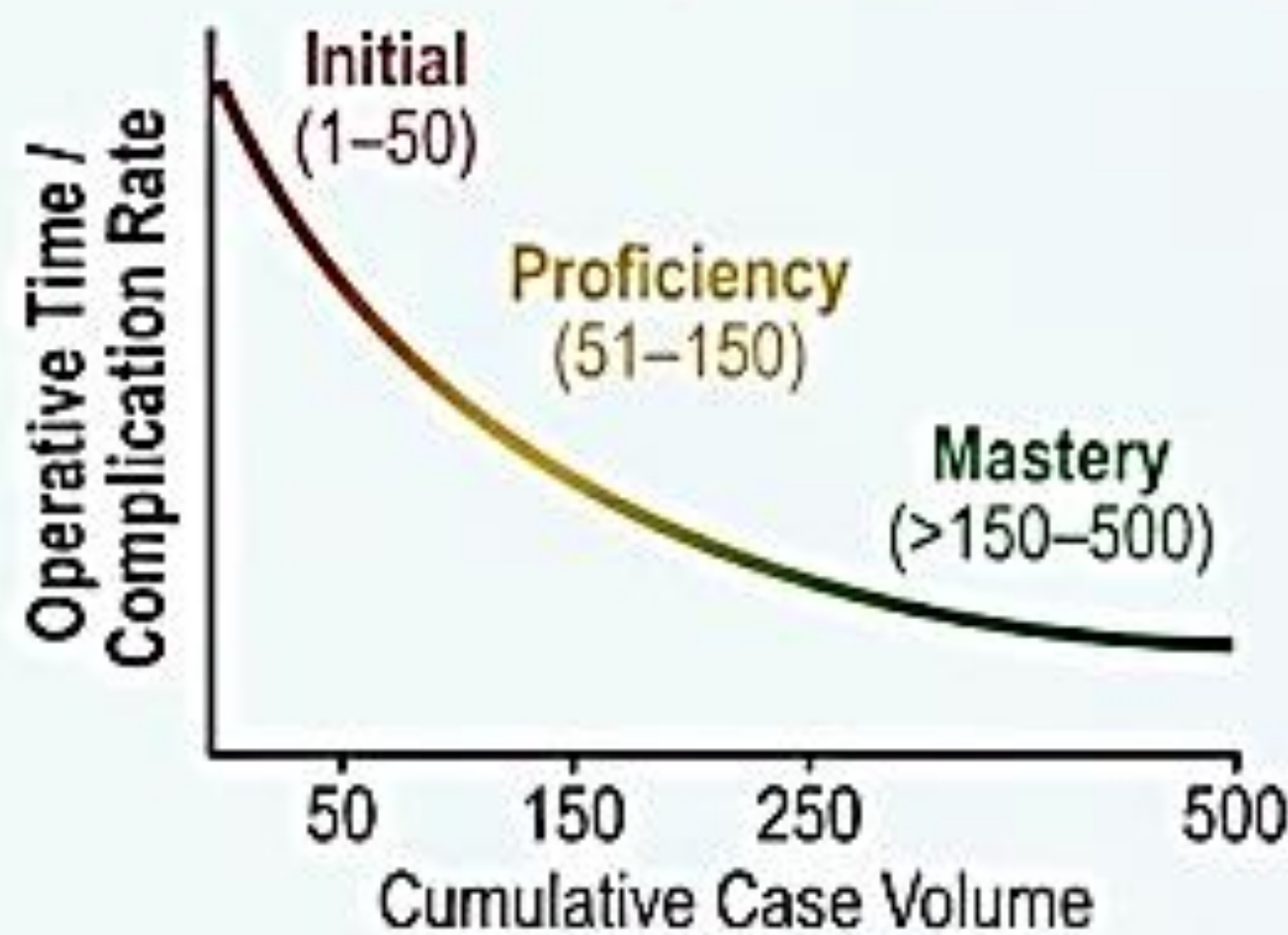
Renal Failure

1.2%

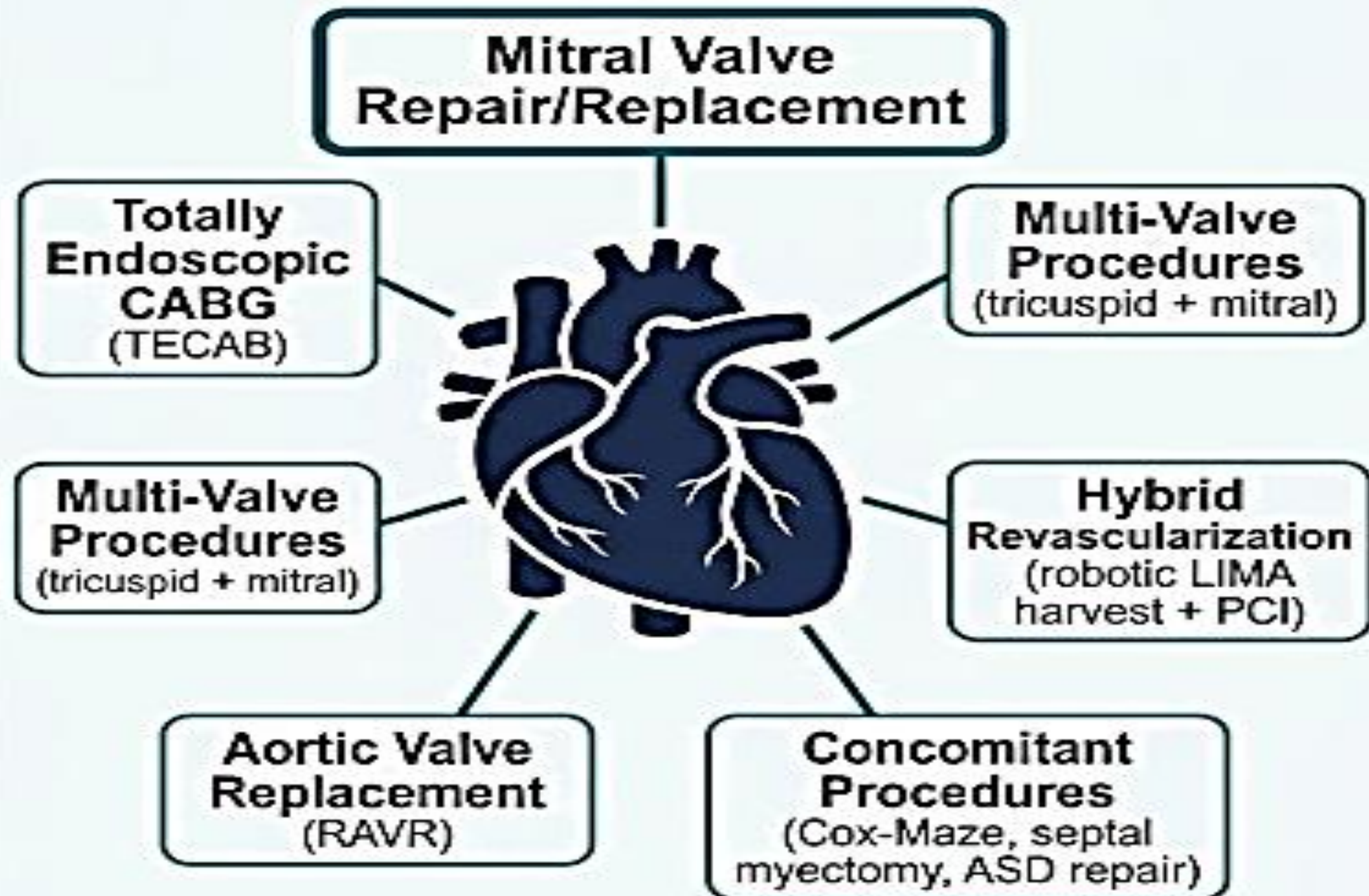
Wound Infection

74 series | 11,135 procedures | 1996–2019 |
Mean grafts: 1.3 ± 0.6 | Mean OR time: 222 ± 75 min

Trade-offs & Learning Curve



Expanding Robotic Applications



MICS vs. Sternotomy

Operative Time	Longer	Shorter	↑
Hospital Stay	Shorter	Longer	↓
Wound Infection	Lower	Higher	↓
Recovery	Faster	Slower	↓
Surgical Trauma	Reduced	Standard	↓

CONCLUSIONS

- Minimally invasive and robotic CABG achieves 1.0% hospital mortality and 0.6% stroke rate across >11,000 procedures—comparable to conventional benchmarks with significantly reduced surgical trauma.
- Robotic applications have expanded well beyond single-vessel CABG to encompass mitral valve repair, multi-valve surgery, TECAB, hybrid revascularization, and aortic valve replacement.
- MICS and robotic approaches consistently demonstrate shorter hospital stay, fewer wound complications, and faster functional recovery versus sternotomy.
- Key barriers remain: notable learning curves (50–500 cases to mastery depending on procedure), higher operative times, cost considerations, and limited training infrastructure.
- Successful integration demands structured training pathways (as outlined in the 2026 STS Expert Consensus), cost-effectiveness evaluation, and expansion into complex surgical populations.

FUTURE DIRECTIONS

- Ongoing RCTs (MIST trial, MICS-CABG PRPP) will provide first prospective randomized data comparing MICS CABG to sternotomy.
- New robotic platforms and next-generation instrumentation may lower cost barriers and accelerate adoption.
- Standardized competency-based credentialing models are needed to support safe program expansion globally.

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