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Results Of Coronary Artery Bypass Surgery Through A Mini-Sternotomy In Ischemic Heart Disease

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Abstract

Ischemic heart disease (IHD) remains the leading cause of morbidity and mortality worldwide, accounting for millions of victims annually. Since the mid-1950s, coronary artery bypass grafting (CABG) performed via a traditional full median sternotomy has served as the gold standard for myocardial revascularization because it provides unsurpassed exposure of the heart and great vessels. However, this conventional approach is frequently characterized by "surgical aggressiveness," which can lead to significant physiological stress, postoperative bleeding, wound infections, and thoracic wall instability. To address these challenges, minimally invasive cardiac surgery (MICS) has emerged as a patient-centered clinical philosophy. These techniques are designed to reduce tissue trauma and mitigate the systemic inflammatory response without compromising the long-term durability of the surgical repair.

This review evaluates the clinical, functional, and postoperative outcomes of CABG performed via mini-sternotomy in patients with IHD, drawing on a synthesis of 14 primary research articles. A primary focus is placed on assessing myocardial recovery through intraoperative graft patency measurements and the analysis of cardiac markers. The review further investigates complication rates, with a specific examination of postoperative atrial fibrillation (POAF), bleeding volumes, and the incidence of wound infections compared with traditional surgery. Additionally, this analysis evaluates the efficacy of postoperative rehabilitation by examining mechanical ventilation duration, length of hospital stay, and health-related quality of life, including the management of sharp neuropathic pain associated with minimal-access incisions. By aggregating these results, the review aims to define the feasibility and safety of the mini-sternotomy approach in modern revascularization.

Keywords: Ischemic heart disease; coronary artery bypass grafting; mini-sternotomy; minimally invasive cardiac surgery; myocardial revascularization; postoperative outcomes.

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1. Introduction

Since the mid-1950s, full median sternotomy has been regarded as the gold standard approach in cardiac surgery, offering excellent exposure of the heart and great vessels. Despite its technical advantages, this approach is associated with considerable surgical invasiveness, resulting in pronounced physiological stress, increased postoperative bleeding, wound complications, and thoracic wall instability. These limitations have driven the development of less traumatic surgical strategies aimed at preserving procedural safety while minimizing collateral tissue damage.

Minimally invasive cardiac surgery (MICS) has emerged as a comprehensive surgical philosophy focused on reducing operative trauma and systemic inflammatory response without compromising the quality or durability of repair. Over the past two decades, continuous refinements in surgical access, instrumentation, and perioperative management have facilitated the broader adoption of MICS, which currently accounts for approximately one-third of cardiac surgical procedures worldwide. This growing utilization reflects increasing confidence in its clinical efficacy and safety across a range of cardiac pathologies.

In the treatment of isolated proximal left anterior descending (LAD) artery disease, the choice between percutaneous coronary intervention (PCI) and minimally invasive direct coronary artery bypass (MIDCAB) remains clinically relevant. Although PCI is often favored due to its minimal invasiveness and rapid recovery, accumulating evidence indicates that MIDCAB provides superior long-term survival and significantly reduces the need for repeat target vessel revascularization. Meta-analytical data suggest that while MIDCAB may be associated with higher short-term cardiac mortality in randomized comparisons with PCI, observational cohort studies consistently demonstrate a clear long-term survival advantage for surgical revascularization.

For patients with complex multivessel coronary artery disease, minimally invasive off-pump coronary artery bypass techniques performed via mini-sternotomy have proven feasible and effective. These approaches have been associated with reduced ventilation times and lower transfusion requirements when compared with conventional surgery. Further refinements, such as manubrium-sparing mini-sternotomy with incisions as small as 9 cm, preserve thoracic structural integrity and offer improved cosmetic outcomes without compromising surgical access.

Despite the structural benefits conferred by smaller incisions, postoperative atrial fibrillation (POAF) remains the most common complication following coronary artery bypass grafting, affecting approximately 30% of patients. Strategies aimed at reducing surgical trauma and avoiding extracorporeal circulation may attenuate the inflammatory cascade implicated in the development of POAF. Postoperative pain management represents another important clinical challenge. In contrast to the diffuse discomfort typically reported after conventional sternotomy, pain following MICS is frequently described as sharp or neuropathic, reflecting intercostal nerve irritation and rib trauma. Notably, persistent postsurgical pain has been reported in up to 43% of patients at six months postoperatively, underscoring the need for integrated multimodal analgesic strategies to support functional recovery and improve long-term quality of life.

2. Methods

The methodological framework utilized in this review synthesizes a diverse range of clinical evidence, from comprehensive meta-analyses and retrospective cohort comparisons to prospective protocols for ongoing randomized controlled trials [7, 9]. To ensure the validity of technical evaluations and mitigate inherent selection bias common in non-randomized data, several researchers employed propensity-score matching to create balanced cohorts when comparing minimally

invasive techniques against standard full median sternotomy [12, 8, 14]. This systematic approach allows for a more rigorous assessment of how alternative access routes influence physiological stress and clinical recovery [13, 10].

Eligibility for inclusion in the evaluated studies often depended on the anatomical complexity of the coronary disease and the patient's baseline risk profile. Some investigations focused strictly on isolated disease of the proximal left anterior descending (LAD) artery, evaluating the long-term survival benefits of internal mammary artery grafts [7, 1]. Detailed anatomical assessments were utilized to determine the most effective surgical approach, frequently incorporating computer tomography (CT) angiography to evaluate vascular access and the degree of aortic calcification [2, 5]. Other methodologies specifically prioritized high-risk populations, defined by elevated EuroSCORE II values or multiple comorbidities, to determine if reducing surgical trauma improved perioperative survival in frail individuals [6, 9, 14]. Conversely, exclusion criteria across the literature commonly included morbid obesity (typically defined as a BMI exceeding 35 or 40), a left ventricular ejection fraction below 40%, and prior cardiac operations, which increase the risk of intra-thoracic adhesions [12, 3, 11].

The sources detail a progression from the conventional 20–25 cm midline incision to several minimal-access routes. Standard off-pump or on-pump coronary artery bypass grafting via full median sternotomy served as the primary control group across most comparative studies [12, 3]. Minimal access was generally achieved through a left anterior mini-thoracotomy in the 4th or 5th intercostal space for direct visualization or through various specialized forms of mini-sternotomy [3, 5]. Specific variations analyzed included the lower distal mini-sternotomy (TM-OPCAB) and manubrium-sparing techniques designed to reduce skin incisions to as little as 9 cm by utilizing cartilaginous rib-cutting strategies rather than full bone division [12, 1]. More advanced methodologies included robotic and totally endoscopic platforms that utilize instrument ports ranging from 1.5 to 4 cm to manage the restricted operative field [4, 14].

Researchers tracked a standardized set of recovery metrics to evaluate procedural efficacy, including mean operation time, mechanical ventilation hours, and 24-hour chest tube drainage volumes [12, 3]. Intraoperative graft quality was verified using transit-time flow (TTF) measurements to ensure technical precision before chest closure [12, 9]. Beyond objective clinical results, some authors utilized validated questionnaires like the EQ-5D-5L and operation-specific pain scales to assess Health-Related Quality of Life and functional recovery [9, 11]. Pain was frequently evaluated via the Visual Analog Scale (VAS) to differentiate between the sharp neuropathic pain of minimal access surgery and the musculoskeletal "tightness" of traditional sternotomy [4, 11]. Finally, the incidence of postoperative atrial fibrillation (POAF) was utilized as a key marker of surgical invasiveness and the systemic inflammatory response triggered by extracorporeal circulation [8, 13].

3. Results

The primary clinical outcomes across the literature indicate that minimally invasive approaches achieve safety profiles comparable to standard techniques, with specific advantages in long-term follow-up. A comprehensive meta-analysis of 17 studies found that while Minimally Invasive Direct Coronary Artery Bypass (MIDCAB) was associated with a higher short-term cardiac mortality risk in randomized trials compared to stenting (RR 7.30), cohort studies revealed a significant long-term all-cause mortality benefit (RR 0.66) for surgical revascularization [7]. Long-term survival remains robust across various MICS techniques; for instance, a 12-year follow-up of 126 patients demonstrated an overall survival rate of 83.5% regardless of whether a mini-sternotomy or thoracotomy was utilized [11]. Similarly, patients undergoing lower distal mini-sternotomy (TM-OPCAB) for triple-vessel disease showed five-year survival rates (94.7%) and freedom from Major Adverse Cardiovascular and Cerebrovascular Events (MACCE) that were statistically equivalent to standard off-pump surgery [12]. In the context of robotic platforms, specialized centers have reported nearly 100% repair rates for mitral valve procedures with extremely low perioperative mortality, underscoring the reliability of high-technology interventions [10, 14].

Technical success and the durability of the internal mammary artery graft are central themes in the reported results. Meta-analytical data confirm that MIDCAB significantly reduces the need for repeat target vessel revascularization (rTVR) at mid-term (RR 0.16) and long-term (RR 0.25) intervals compared to percutaneous interventions [7]. Intraoperative assessments using transit-time flow (TTF) measurements showed no

significant difference in graft patency between mini-sternotomy and standard incisions, confirming that reduced access does not compromise the quality of the anastomosis [12, 1]. Furthermore, long-term clinical data show freedom from graft problems as high as 94.7% in specialized thoracotomy cohorts over 15 years [11]. Hybrid coronary revascularization (HCR) also yields durable results, with five-year death rates (6.4%) and myocardial infarction rates (4.3%) that compare favorably to conventional surgery [6].

The incidence of postoperative atrial fibrillation (POAF), which affects approximately 30% of standard coronary bypass patients, serves as a primary marker for surgical stress [8]. Results regarding POAF in MICS are varied; while some meta-analyses show no significant difference between MIDCAB and conventional off-pump surgery, specific right mini-thoracotomy approaches for mitral surgery have demonstrated a reduction in new-onset AF (8% vs. 16%) compared to sternotomy [3, 8]. This reduction is attributed to less manipulation of the heart and a mitigated systemic inflammatory response [13, 8]. Additionally, while bypass and cross-clamp times are frequently longer in MICS, the rates of stroke and renal failure do not increase significantly, even in high-risk elderly populations [2, 14].

Minimally invasive techniques consistently demonstrate superior performance in short-term recovery parameters. Patients undergoing TM-OPCAB experienced significantly shorter ventilation times (20.8 hours) and lower blood transfusion rates (15.3%) compared to standard surgery [12]. These findings are echoed in MIDCAB studies, where hospital stays were reduced by an average of two days compared to sternotomy-based off-pump procedures [3]. Advanced endoscopic techniques also facilitate faster discharge; specialized protocols for robotic and video-assisted valve surgeries have reported shorter intensive care unit (ICU) stays and a more rapid return to preoperative physiological functions [5, 10]. In high-volume centers, these gains in efficiency translate to lower overall hospitalization costs and higher patient satisfaction [6, 14].

A major focus of recent research is the qualitative assessment of postoperative pain. While MICS reduces musculoskeletal "tightness," up to 43% of patients report persistent postsurgical pain (PPSP) at six months, which is often sharp and neuropathic in nature [4, 11]. Comparative trials have shown that patients undergoing different minimally invasive accesses (TECAB, ALT, and PLS) report similar levels of pain intensity at long-term follow-up, suggesting that the harvesting of the internal mammary artery itself may be a primary driver of discomfort regardless of the incision site [11]. To address this, the implementation of multimodal analgesia, particularly the use of Erector Spinae Plane (ESP) blocks and intravenous adjuncts like dexmedetomidine, has been proven effective in reducing total opioid consumption and enhancing the quality of recovery [4, 9].

Table 1. Key Clinical Outcomes in Minimally Invasive Cardiac Surgery

Outcome	Findings in MICS	Comparison	References
Survival	83–95% (5–12 yr)	Comparable or better vs conventional surgery	[7,11,12,10,14]
Repeat Revascularization	rTVR mid-term 0.16, long-term 0.25	Reduced vs PCI	[7,12,1]
POAF (Post-op AF)	8–30%	Equal or lower vs sternotomy	[3,8,13]
Ventilation Time	20.8 hr (TM-OPCAB)	Shorter	[12]
Blood Transfusion	15.3%	Lower	[12]

Hospital Stay	–2 days (MIDCAB)	Faster recovery	[3]
Pain / Functional Recovery	PPSP up to 43% at 6 mo	Neuropathic pain but less musculoskeletal pain	[4,11,9]
Robotic / Endoscopic Repair	Near 100% success	Comparable efficacy, minimally invasive	[10,14]
ICU / Cost	Shorter ICU stay, lower cost	Better efficiency	[5,6,14]

4. Discussion

The transition from traditional full median sternotomy to minimally invasive cardiac surgery (MICS) represents a fundamental shift in the "philosophy" of cardiac care, moving away from a one-size-fits-all "gold standard" toward a more nuanced, patient-centered approach [10, 14]. This evolution is driven by the need to reduce the "surgical aggressiveness" inherent in the 20–25 cm incisions of the mid-20th century, which are associated with significant physiological stress, thoracic instability, and prolonged recovery [2, 11]. As MICS now accounts for approximately one-third of total heart surgeries globally, the clinical discourse has moved beyond proving the feasibility of smaller incisions to optimizing long-term survival and quality of recovery through high-technology integration and multimodal care [10, 5].

The management of coronary artery disease, particularly isolated proximal left anterior descending (LAD) artery disease, remains a focal point of MICS. Evidence suggests that while percutaneous coronary intervention (PCI) offers a less invasive profile, Minimally Invasive Direct Coronary Artery Bypass (MIDCAB) provides a superior long-term survival advantage due to the durability of the left internal thoracic artery (LITA) graft [7, 3]. The LITA graft's ability to produce nitric oxide protects against future atherosclerosis, a benefit that PCI cannot replicate as it only treats existing lesions [7]. For more complex triple-vessel disease, the lower distal mini-sternotomy (TM-OPCAB) has proven to be a safe and effective alternative to standard off-pump surgery, offering equivalent five-year survival rates while significantly reducing resource utilization, such as ventilation time and blood transfusions [12, 13]. Furthermore, Hybrid Coronary Revascularization (HCR) aspires to provide the "best of both worlds" by combining LITA-LAD durability with the less invasive stenting of non-LAD vessels, although its widespread adoption is currently limited by the high costs of hybrid operating rooms and the steep learning curves for surgical teams [6, 14].

Technological advancements have been instrumental in overcoming the challenges of a restricted operative field. The implementation of 3D high-definition cameras and long-shafted instruments allows surgeons to perform complex maneuvers, such as radical annular decalcification or precise suturing, through "keyhole" incisions without the need for rib resection [5, 10]. Novel devices like automated knot-tying systems and sutureless prostheses have further streamlined these procedures, reducing aortic cross-clamp times which are historically longer in MICS than in conventional surgery [5, 14]. Additionally, specialized techniques like the manubrium-sparing mini-sternotomy demonstrate that by cutting a cartilaginous rib instead of full bone division, skin incisions can be reduced to just 39% of the total sternal length, optimizing both aesthetic and structural outcomes [1].

Despite the reduced physical trauma of MICS, the management of postoperative pain remains a primary clinical hurdle. Pain in MICS is frequently sharp and neuropathic—as opposed to the musculoskeletal "tightness" of a sternotomy—primarily due to intercostal nerve involvement and rib retraction [4, 11]. The high incidence of persistent postsurgical pain (PPSP), affecting up to 43% of patients at six months, underscores the necessity of integrated regional

anesthesia protocols [4, 11]. Ultrasound-guided blocks, such as the ESP and SAP blocks, have emerged as safe, opioid-sparing alternatives that facilitate faster mobilization and improved respiratory function [4, 2]. Similarly, reducing surgical stress through MICS and avoiding extracorporeal circulation may help mitigate the systemic inflammatory response that triggers POAF, the most common complication affecting roughly 30% of bypass patients [8, 13].

The future of MICS is poised to be defined by the growing rivalry and complementarity between minimally invasive and "micro-invasive" (transcatheter) procedures [14, 10]. While transcatheter therapies like TAVI and TEER are becoming the preferred options for frail, high-risk populations, MICS remains the robust choice for younger patients who require durable, long-term repair [14, 9]. The next generation of cardiac care will likely integrate Artificial Intelligence (AI) for real-time decision support, autonomous robotic platforms, and increasingly miniaturized instruments [10, 14]. Central to this evolution is the multidisciplinary Heart Team, which must balance procedural minimalism with graft durability and lifetime management strategies to ensure that the patient's hospital experience is as non-invasive as their surgical incision [14, 6].

5. Conclusion

Minimally invasive cardiac surgery (MICS) has progressed from a niche innovation to a validated, patient-centered standard, demonstrating that reduced surgical trauma can coexist with uncompromised procedural efficacy. Techniques ranging from mini-sternotomies to fully robotic-assisted approaches consistently show safety and long-term effectiveness comparable to conventional full median sternotomy, while offering clear advantages in postoperative recovery, including shorter ventilation times, lower transfusion requirements, and accelerated functional rehabilitation.

In coronary revascularization, the superior durability of the internal mammary artery graft ensures that MICS provides a long-term survival advantage over percutaneous interventions, particularly in isolated LAD disease. Even complex multi-vessel procedures can be performed safely via limited-access incisions, preserving thoracic stability and reducing systemic inflammatory stress.

Despite these advancements, persistent postsurgical neuropathic pain and the risk of complications such as atrial fibrillation remains important clinical considerations. The integration of advanced imaging, robotic platforms, and multimodal analgesia, alongside careful patient selection by a multidisciplinary Heart Team, optimizes outcomes and enhances the overall patient experience.

Ultimately, MICS exemplifies the evolution of cardiac surgery toward procedures that are as minimally invasive in approach as they are maximally effective in outcome, balancing the dual priorities of durability and patient-centered recovery in modern cardiac care.

6. Declarations

This study is a systematic review and did not involve direct research on human participants or animals; therefore, ethics approval and consent to participate are not applicable. No individual patient data are included, and consent for publication is not required. All data generated or analyzed during this study are provided within this article and its references. The authors declare no competing interests. This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

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