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ORIGINAL ARTICLE

Gender Differences in Early Outcomes of Minimally Invasive Cardiac Surgery: A Cross-Sectional Analysis

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ABSTRACT

Background: Minimally invasive cardiac surgery via right mini-thoracotomy has become increasingly popular for mitral valve interventions and coronary artery bypass grafting owing to reduced surgical trauma and accelerated recovery. However, anatomical and physiological differences between men and women may influence intraoperative complexity and early postoperative outcomes.

Objective: To compare early outcomes of minimally invasive cardiac surgery in male versus female patients at a tertiary referral centre.

Methods: A descriptive cross-sectional analysis was performed on 160 consecutive adults (104 men, 56 women) who underwent elective minimally invasive mitral valve repair/replacement or single-/double-vessel coronary bypass on cardiopulmonary bypass at Mukhtar A. Sheikh Hospital, Multan, between February 1, 2022 and February 28, 2023. Primary endpoints were 30-day all-cause mortality and major adverse cardiac and cerebrovascular events (MACCE). Secondary endpoints included cardiopulmonary bypass (CPB) time, aortic cross-clamp time, intraoperative transfusion volume, new-onset atrial fibrillation, re-exploration for bleeding, and lengths of intensive care unit (ICU) and total hospital stay. Continuous variables were compared by Student's t-test and categorical variables by chi-square or Fisher's exact test, with $p<0.05$ denoting significance.

Results: Women were older (61.5 ± 9.7 vs. 58.3 ± 10.4 years; p=0.02) and had lower body surface area (1.70 ± 0.20 vs. 1.91 ± 0.21 m²; p<0.001). Mean CPB time was longer in women (112 ± 20 vs. 105 ± 18 min; p=0.02), as was cross-clamp time (82 ± 15 vs. 77 ± 14 min; p=0.03) and operative duration (190 ± 35 vs. 180 ± 30 min; p=0.04). Thirty-day mortality (1.8% vs. 1.9%; p=0.95) and MACCE rates (8.9% vs. 7.7%; p=0.80) were equivalent. Rates of new atrial fibrillation (19.6% vs. 16.3%; p=0.59) and re-exploration for bleeding (3.6% vs. 1.9%; p=0.47) did not differ. ICU stay (2.2 ± 0.8 vs. 2.0 ± 0.7 days; p=0.16) and total hospital stay (6.5 ± 1.6 vs. 6.2 ± 1.4 days; p=0.22) were similar.

Conclusion: Although women undergoing minimally invasive cardiac surgery experienced slightly longer operative times, early morbidity and mortality were equivalent to those of men. These findings support the safety and efficacy of right mini-thoracotomy approaches across genders.

Keywords: Minimally invasive cardiac surgery; gender differences; early outcomes; cross-sectional study; mini-thoracotomy.

INTRODUCTION

Minimally invasive cardiac surgery has emerged as a transformative approach in contemporary cardiothoracic practice, seeking to minimize the physiological stress of surgery while preserving or enhancing clinical efficacy[1]. By utilizing smaller intercostal incisions, refined instrumentation, and targeted perfusion strategies, surgeons can avoid the extensive disruption of the sternum, leading to reductions in postoperative pain, blood loss, and length of hospitalization. These advantages have encouraged wider adoption of minimally invasive techniques for a variety of cardiac procedures, including mitral valve repair or replacement and coronary artery bypass grafting, especially in high-volume centers with dedicated expertise and specialized operating-room infrastructure[2].

Despite these procedural innovations, disparities in perioperative risk and recovery trajectories between male and female patients have long been observed in conventional open-chest cardiac surgery. Women often present at an older age and with a higher burden of comorbid conditions such as hypertension and diabetes, and they tend to have smaller chest dimensions and vascular calibers all factors that can influence technical complexity and perioperative management[3]. In traditional sternotomy-based approaches, these anatomical and physiological differences have been associated with longer operative times, increased transfusion requirements, and extended stays in intensive care and hospital wards for women compared with men. Such disparities highlight the need to understand whether the same challenges persist, diminish, or even reverse in the context of less invasive access[4].

In minimally invasive cardiac surgery, limited visualization and working space can amplify the impact of subtle anatomical variations, potentially affecting instrument maneuverability, cardiopulmonary bypass cannulation, and myocardial protection strategies. Conversely, the reduced trauma and accelerated recovery inherent in minimally invasive access might mitigate some of the gender-related disadvantages seen with open sternotomy[5]. The interplay of these factors remains poorly characterized, and existing reports are often constrained by small patient numbers, single-procedure focus, or heterogeneous surgical techniques. Without a clear understanding of how sex influences early outcomes in a minimally invasive setting, cardiac teams may lack the guidance needed to optimize patient selection, tailor perioperative protocols, and inform preoperative counseling[6].

To address this knowledge gap, the present study undertakes a cross-sectional analysis of early clinical outcomes in men and women undergoing minimally invasive mitral valve surgery or coronary bypass via right mini-thoracotomy at a tertiary care center[7]. By comparing 30-day mortality, major adverse cardiac and cerebrovascular events, operative parameters, transfusion requirements, and lengths of intensive care and total hospitalization, this study aims to elucidate whether gender remains a determinant of early postoperative course when traditional sternotomy is replaced by a less invasive alternative. The insights gained will inform strategies to ensure equitable care and may guide the refinement of minimally invasive techniques to benefit all patients, regardless of sex[8].

MATERIALS AND METHODS

Study Design and Setting: This descriptive cross-sectional analysis was conducted at Mukhtar A. Sheikh Hospital in Multan over a thirteen-month period, from February 1, 2022 through February 28, 2023. As a high-volume referral centre for adult cardiac surgery, the hospital maintains a prospectively compiled electronic registry of all operative cases. The investigation followed institutional guidelines for retrospective research and was approved by the hospital's ethics committee, which waived the requirement for individual informed consent because all data were anonymized.

Patient Selection and Eligibility: During the study period, 160 consecutive adult patients comprising 104 men (65%) and 56 women (35%) who underwent elective minimally invasive cardiac surgery via a right mini-thoracotomy were identified from the registry. Eligible procedures were limited to isolated mitral valve repair or replacement and single- or double-vessel coronary artery bypass grafting on cardiopulmonary bypass. All patients had completed a preoperative evaluation including transthoracic echocardiography, and those scheduled for bypass also underwent coronary angiography. Patients were excluded if they required urgent or emergent intervention, underwent combined valve and coronary procedures, required concomitant aortic root or ascending aortic surgery, had a history of prior sternotomy or thoracotomy for cardiac procedures, weighed less than forty kilograms, or had incomplete entries for any key perioperative variables.

Data Collection and Definitions: Two independent investigators abstracted data from the electronic record onto a standardized case-report form. Demographic variables included age, sex, height and weight; body surface area was calculated by the DuBois formula. Comorbidities were defined as follows: hypertension by systolic blood pressure ≥ 140 mmHg, diastolic ≥ 90 mmHg or use of antihypertensive therapy; diabetes mellitus by fasting plasma glucose ≥ 126 mg/dL or ongoing treatment with insulin or oral hypoglycemic agents; and chronic kidney disease by estimated glomerular filtration rate < 60 mL/min/1.73 m². Baseline cardiac status was assessed by left ventricular ejection fraction and New York Heart Association functional class on preoperative echocardiography.

Operative variables comprised total cardiopulmonary bypass time (minutes), aortic cross-clamp time (minutes) for valve procedures, skin-to-skin operative duration, volume and type of intraoperative blood products transfused and any conversion to full sternotomy. Postoperative outcomes included thirty-day all-cause mortality; major adverse cardiac and cerebrovascular events defined as new stroke, perioperative myocardial infarction or repeat cardiac intervention; unplanned re-exploration for bleeding; onset of atrial fibrillation; length of intensive care unit stay; and total hospital stay.

Surgical Technique: All operations were performed under general anesthesia with single-lung isolation via a double-lumen endotracheal tube. A five- to six-centimetre incision was made in the right fourth intercostal space, with careful preservation of the pectoralis major muscle and intercostal structures. Femoral arterial and venous cannulation established cardiopulmonary bypass under continuous transesophageal echocardiographic guidance. Mitral valve procedures employed antegrade cold blood cardioplegia after aortic cross-clamping to achieve myocardial arrest. Coronary bypass grafts were constructed on a beating heart under full bypass support using continuous polypropylene sutures for each distal anastomosis. Hemostasis was meticulously verified at the thoracotomy site and within the pericardial space, and transfusion thresholds followed a restrictive protocol targeting a hemoglobin level of 8 g/dL unless contraindicated by ongoing ischemia or hemodynamic instability.

Outcome Measures: The primary endpoints were thirty-day all-cause mortality and the incidence of major adverse cardiac and cerebrovascular events. Secondary endpoints included unplanned return to the operating room for bleeding control, new postoperative atrial fibrillation, intensive care unit length of stay and total hospital length of stay.

Statistical Analysis: Analyses were performed in SPSS version 25.0. Continuous variables are reported as mean ± standard deviation and were compared between male and female cohorts using Student's t-test. Categorical variables are presented as counts and percentages and were compared by chi-square test or Fisher's exact test when expected cell counts were small. A two-sided p value below 0.05 was considered statistically significant. Data integrity was ensured by cross-checking a random sample of twenty records for accuracy of abstraction.

Ethical Considerations: The Institutional Ethics Committee of Mukhtar A. Sheikh Hospital approved the study protocol. Given the retrospective design and anonymization of data, the requirement for individual informed consent was waived in accordance with national regulations and the Declaration of Helsinki.

RESULTS

A total of 160 patients met inclusion criteria, of whom 104 (65%) were men and 56 (35%) were women. The distribution of baseline characteristics, operative parameters and early postoperative outcomes is summarized in Tables 1 and 2 below, with detailed interpretations following each section.

Patient Demographics and Baseline Characteristics: Women presented at a slightly older age than men (61.5 ± 9.7 years vs. 58.3 ± 10.4 years; p = 0.02) and had a lower mean body surface area (1.70 ± 0.20 m² vs. 1.91 ± 0.21 m²; p < 0.001). Hypertension was more prevalent among women (39 of 56, 69.6%) than men (56 of 104, 53.8%; p = 0.04), while rates of diabetes mellitus (26 of 56, 46.4% vs. 41 of 104, 39.4%; p = 0.33) and chronic kidney disease (7 of 56, 12.5% vs. 11 of 104, 10.6%; p = 0.69) were comparable. Baseline left ventricular ejection fraction and New York Heart Association functional class also did not differ significantly between sexes. The proportions of mitral valve procedures versus bypass grafting were similar in women and men (Table 1).

Table 1: Baseline Characteristics of Patients Undergoing Minimally Invasive Cardiac Surgery (n = 160)

Characteristic	Men (n = 104)	Women (n = 56)	p-value
Age (years)	58.3 ± 10.4	61.5 ± 9.7	0.02
Body surface area (m²)	1.91 ± 0.21	1.70 ± 0.20	< 0.001
Hypertension, n (%)	56 (53.8%)	39 (69.6%)	0.04
Diabetes mellitus, n (%)	41 (39.4%)	26 (46.4%)	0.33
Chronic kidney disease, n (%)	11 (10.6%)	7 (12.5%)	0.69
Left ventricular ejection fraction (%)	55 ± 7	53 ± 6	0.09
NYHA class III–IV, n (%)	33 (31.7%)	25 (44.6%)	0.08
Procedure type (MVR vs. CABG), n (%)	61/43	32/24	0.87

In this cohort, although women were older and more often hypertensive, both sexes entered surgery with equivalent systolic function and symptom burden. The similarity in procedure mix (mitral valve versus bypass) indicates balanced allocation of surgical interventions between genders.

Operative Parameters and Early Postoperative Outcomes: Operative metrics revealed that women had modestly longer cardiopulmonary bypass times (112 ± 20 min vs. 105 ± 18 min; p = 0.02), aortic cross-clamp times (82 ± 15 min vs. 77 ± 14 min; p = 0.03) and overall skin-to-skin durations (190 ± 35 min vs. 180 ± 30 min; p = 0.04). Despite these prolongations, intraoperative transfusion volumes and conversion rates to full sternotomy were similar. Early postoperative events including new-onset atrial fibrillation, re-exploration for bleeding, thirty-day mortality and major adverse cardiac and cerebrovascular events were low and did not differ by sex. Lengths of intensive care unit stay and total hospitalization were also equivalent (Table 2).

Although women required slightly longer operative times likely reflecting smaller thoracic dimensions and vessel calibers these differences did not result in increased transfusion needs or conversion to open sternotomy. Postoperative morbidity and mortality, as well as resource utilization, were statistically indistinguishable between men and women.

The adjusted distribution of 65% men and 35% women in this cohort confirms that, despite marginally longer bypass and cross-clamp durations in female patients, early outcomes following minimally invasive cardiac surgery remain equivalent across sexes. Comparable rates of atrial fibrillation, re-exploration, thirty-day mortality and major adverse events indicate that meticulous surgical technique and standardized perioperative care effectively

mitigate the impact of anatomical differences. Similar lengths of ICU and hospital stay further support the safety and efficacy of right mini-thoracotomy approaches for both male and female patients. These findings reinforce the role of minimally invasive techniques in delivering equitable cardiac surgical care regardless of patient sex.

Table 2: Operative Parameters and Early Postoperative Outcomes by Sex

Outcome	Men (n = 104)	Women (n = 56)	p-value
Cardiopulmonary bypass time (min)	105 ± 18	112 ± 20	0.02
Aortic cross-clamp time (min)	77 ± 14	82 ± 15	0.03
Operative duration (min)	180 ± 30	190 ± 35	0.04
Intraoperative transfusion (units)	1.3 ± 0.7	1.5 ± 0.8	0.11
Conversion to full sternotomy, n (%)	2 (1.9%)	1 (1.8%)	0.95
New-onset atrial fibrillation, n (%)	17 (16.3%)	11 (19.6%)	0.59
Re-exploration for bleeding, n (%)	2 (1.9%)	2 (3.6%)	0.47
Thirty-day mortality, n (%)	2 (1.9%)	1 (1.8%)	0.95
Major adverse cardiac and cerebrovascular events, n (%)	8 (7.7%)	5 (8.9%)	0.80
ICU length of stay (days)	2.0 ± 0.7	2.2 ± 0.8	0.16
Total hospital stay (days)	6.2 ± 1.4	6.5 ± 1.6	0.22

DISCUSSION

In this descriptive cross-sectional analysis of 160 patients undergoing minimally invasive cardiac surgery, women comprised 35 percent of the cohort and were, on average, older and more frequently hypertensive than their male counterparts[9]. They also had a lower body surface area, which correlated with modest prolongations in cardiopulmonary bypass, aortic cross-clamp and total operative times. Despite these procedural differences, early postoperative morbidity and mortality were equivalent across sexes, with similar rates of new-onset atrial fibrillation, re-exploration for bleeding, thirty-day mortality and major adverse cardiac and cerebrovascular events. Lengths of intensive care unit and total hospital stay did not differ by gender, suggesting that the additional intraoperative time required for women did not translate into prolonged recovery or increased resource utilization[10, 11].

The slightly longer operative durations observed in female patients likely reflect the anatomical challenges posed by smaller intercostal spaces and vascular calibers when performing right mini-thoracotomy approaches. Precise port placement and instrument navigation through a more confined operative field require deliberate dissection and careful cannulation, which naturally extend procedure times[12]. Nevertheless, the absence of increased transfusion requirements or conversion rates to full sternotomy indicates that meticulous surgical technique and standardized hemostatic protocols effectively mitigate risks associated with these anatomical differences. This finding underscores the ability of experienced surgical teams to adapt minimally invasive strategies to diverse patient anatomies without compromising safety[13].

Our results align with emerging evidence that minimally invasive access may attenuate the gender-related disparities historically reported in conventional sternotomy-based surgery. In traditional open approaches, female patients often experience higher transfusion rates, longer intensive care stays and increased postoperative complications[14]. By contrast, the right mini-thoracotomy technique appears to equalize these early outcomes, likely owing to reduced surgical trauma, improved postoperative analgesia and accelerated functional recovery. The comparable thirty-day mortality and major adverse event rates observed here reinforce the notion that minimally invasive procedures can deliver uniformly high standards of care across sexes[15].

Several limitations merit consideration. The retrospective design and single-center setting limit the generalizability of our findings, and the sample size while sufficient to detect moderate differences may lack power for rarer complications[16, 17]. We also focused exclusively on early outcomes; longer-term follow-up is needed to assess functional status, quality of life and late complications such as prosthetic dysfunction or graft patency. Potential confounders, including subtle variations in comorbidity severity or surgeon experience, may have influenced operative times and outcomes despite our standardized protocols. Future prospective, multicenter studies with extended follow-up and stratification by specific procedure types will be essential to confirm these observations and to explore strategies such as patient-tailored port sizing to further optimize operative efficiency[18, 19].

CONCLUSION

In a cohort of 160 patients undergoing right mini-thoracotomy cardiac surgery, women required slightly longer cardiopulmonary bypass and cross-clamp times but achieved early safety and efficacy outcomes equivalent to those of men. Thirty-day mortality, major adverse cardiac and cerebrovascular events, and lengths of intensive care and hospital stay did not differ by sex. These findings support the broad applicability of minimally invasive approaches in both male and female patients and highlight the importance of surgical expertise and standardized perioperative care in overcoming anatomical challenges. Further prospective investigations are warranted to validate these results and to refine techniques that ensure optimal outcomes for all patients.

Availability of Data and Materials: The datasets generated and analyzed during the current study are available from the corresponding author on reasonable request, subject to institutional data-sharing policies and protection of patient confidentiality.

Competing Interests: The authors declare that they have no competing interests.

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Authors' Contributions: All authors contributed equally to the study conception, design, data collection, analysis, and manuscript drafting, and approved the final version.

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