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Original Article

Early Clinical Outcomes of Minimally Invasive Cardiac Surgery: A 10-Year Experience

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ABSTRACT

Objective: To evaluate the early clinical outcome of Minimally Invasive Cardiac Surgery (MICS) - A 10-year experience.
Study Design: Analytical Cross-sectional study.
Place and Duration of Study: Adult Cardiac Surgery Unit, Armed Forces Institute of Cardiology/National Institute of Heart Diseases (AFIC/NIHD), from Jan 1, 2014 to Dec 31, 2023.
Methodology: One hundred and fifty six consecutive patients with isolated aortic valve, mitral valve or tricuspid valve disease and atrial septal defect underwent elective MICS. Operations involving the right and or left atrium were done by right mini-thoracotomy while those of aorta were done by partial mini-sternotomy. Isolated Minimally Invasive Direct Coronary Artery Bypass (MIDCAB) was done via left minithoracotomy. Post-operative complications and 30-day post-op mortality were recorded as early clinical outcomes.
Results: Out of 156 patients, 92(59.0%) were males and 64(41.0%) were females. Median age of the study population was 36(29-48) years. Median ejection fraction was 60(50-60)%. Mean aortic cross-clamp time was 96.72±34.28 min, and median cardiopulmonary bypass (CPB) time was 146(121-176.25) min. Three most common procedures carried out in the series were MVR 59(37.8%), AVR 55(35.3%) and ASD closure 22(14.1%). The total rate of complication was 7.7%, and mortality within 30 days was 3(1.9%). A significant association was found between inotropic duration, ICU stay, ventilation time, and complications such as renal and respiratory failure, with mortality (p<0.05).
Conclusion: As per our experience, different cardiac procedures can be performed via minimally invasive approaches with acceptable and reproducible outcome.

Keywords: Cannulation Technique, Experience, Early Clinical Outcomes, Minimally Invasive Cardiac Surgery, Sternotomy.

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INTRODUCTION

Advancement in technology has revolutionized surgical approaches in almost all fields of surgery. Although little slow but cardiac surgery also has enjoyed this change. Technological advancements combined with patients' and surgeons' preference for minimally invasive procedures have led to inclination towards minimally invasive cardiac surgery (MICS).[1-4]

MICS is generally defined as conventional cardiac surgeries performed through incisions other than full median sternotomy. Various different approaches like partial sternotomy, limited access thoracotomy, totally endoscopic approach, catheter-based hybrid approach, and subxiphoid and subdiaphragmatic approaches were included in MICS.[5] But invasiveness of cardiac surgery is not only dependent on size of skin incision, it also involves use of cardiopulmonary bypass (CPB) machine and requirement of still heart. Improvement in instrumentation has led to the extent that about one third of all cardiac surgeries are currently done via minimally invasive approach. This number will grow further with development of more efficient endoscopic, robotic and trans-catheter procedure.[6]

Numbers of single institution studies have described that the quality of operation remain un-affected. Advantages claimed by MICS proponents include shorter hospital stays, lower hospital expenses, decreased surgical trauma and general increase in patient satisfaction and quality of life.[7,8] Moreover, long midline scar has poor cosmetic result and noticeable risk of chronic post-sternotomy pain, itching and hypertrophic scar/keloid formation may adversely affect the patient experience.[9]

Despite many constrains, MICS was introduced in our institution in 2013 and still running. A need was felt to audit the procedure to document our programme. There is a dearth of data on the risks and surgical outcomes related to minimally invasive cardiac surgery in our community. Objective of our study is to evaluate the early clinical outcomes of minimally invasive cardiac surgery. MICS has gained popularity globally due to its advantages of reduced

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surgical trauma, shorter hospital stays, lower costs, and improved cosmetic outcomes compared to traditional full sternotomy. Despite these benefits, the adoption of MICS in developing countries, including our institution, has been slower, with relatively few cases performed over the years. Given the scarcity of local data and the growing interest in minimally invasive techniques, an evaluation of our 10-year experience with MICS is crucial. This study will provide valuable insights into the early clinical outcomes and complications of MICS within our setting, helping to benchmark the success and challenges of this surgical approach in our community.

METHODOLOGY

An analytical Cross-sectional study was conducted at Adult Cardiac Surgery Unit, Tertiary Care Cardiac Hospital Rawalpindi from January 1, 2014 to December 31, 2023 after receiving approval from Institutional Ethical Review Board (Ltr#9/2/R&D/2024/311) dated 8th Apr, 2024. For data collection, non-probability consecutive sampling technique was used.

A sample size of 62 was determined using the WHO sample size calculator, based on a 4.7% mortality rate, with a 95% confidence level and a 5% margin of error. However, data was collected from 156 patients.[10] AFIC being a tertiary care cardiac center facilitates the cardiac patients from all over the country. Open heart surgeries, including Median Full Sternotomy and Minimally Invasive Cardiac Procedures, are routinely conducted on a daily basis. Notably, the incidence of Minimally Invasive Cardiac Surgery (MICS) at our institute has been relatively low when compared with developed countries, with a total of 156 procedures performed in our institute between 2014 and 2023, constituting the sample size for our study.

Inclusion Criteria: Isolated aortic valve disease, isolated mitral valve disease or mitral and tricuspid valve disease, isolated atrial septal defect (ASD) or ASD with Mitral valve disease, single vessel coronary artery disease of LAD (for MIDCAB)

Exclusion Criteria: CAD with valvular disease, patients with history of previous cardiac surgery, right pleural adhesions (Past history of Pneumonia or Pulmonary Tuberculosis with pleurisy)

Patients who fulfilled the eligibility criteria gave their written, informed consent before initiation of data collection procedure. Data on patient demographics, operative parameters, and early clinical outcomes morbidity [post-operative composite complications including respiratory failure (stayed on 24-hour ventilatory support post-operatively), renal failure (creatinine level ≥2mg/dL), re-exploration for bleeding were seen] and mortality (within 30-days of operation) were recorded in a pre-defined proforma.

Statistical Package for Social Sciences (SPSS) version 20:00 was used for data analysis. The normality of all conituous variables (age, BMI, EF, CPB time, ICU stay, ventilation time, chest drainage, cross-clamp time and inotropic duration) was evaluated using the Kolmogorov-Smirnov test. All these variables, except cross-clamp time and BMI, were not normally distributed. Frequencies and percentages were calculated for categorical variables like gender, risk factors, types of MICS operations, types of approaches, cannulation techniques, complications and mortality and were compared using the chi-square test. Continuous variables such as age, EF, CPB time, ICU stay, ventilation time, chest drainage, and inotropic duration were reported as median (IQR) due to non-homogeneity of data, whereas Cross clamp time and BMI were reported as mean±SD. Effects of multiple variables like age,BMI, gender, CPB time, EF, CX time, ICU stay, Ventilation time, inotropic duration, chest drainage, and risk factors on mortality were assessed by applying independent samples t-test and Mann-Whitney U test was applied for non-homogenous data. The Chi-square and Fisher's exact tests were used to evaluate the association of gender, risk factors, types of MICS operations, surgical approaches, cannulation techniques, and complications with mortality. *p*-value ≤0.05 was considered as statistically significant.

RESULTS

Out of 156 patients, 92(59.00%) were males and 64(41.0%) were females. Median age of the study population was 36.50(29.00-48.00) years. 24.31±4.45 kg/m2 was the mean body mass index (BMI). Median ejection fraction was 60.00(50.00-60.00)%. Hyper-tension was the most frequent co-morbid condition 24(15.4%) followed by diabetes mellitus 6(3.8%). History of smoking was present in 19(12.2%) patients. The median CPB time was 146.00(121.00-176.25)min and mean aortic cross-clamp time was 96.72±34.28 min for the entire series. The three most common procedures performed were MVR 59(37.8%), AVR 55(35.3%) and ASD closure 22(14.1%) (Table-I).

Table-I: Baseline Parameters and Early Clinical Outcomes of Study Population (n=156)

Variables		Frequency (%)
Demographics		
Gender	Male	92(59.0)
	Female	64(41.0)
Age (years)		Median(IQR)
		36.50(29.00-48.00)
BMI (kg/m²)		Mean±SD
		24.31±4.45
Co-morbids		Frequency (%)
Smoking Status	Ex-Smoker	10(6.4)
	No Smoking	137(87.8)
	Smoking	9(5.8)
Diabetes Mellitus	Yes	6(3.8)
	No	150(96.2)
Hypertension	Yes	24(15.4)
	No	132(84.6)
Types of MICS operations		
Types of MICS operations	ASD closure	22(14.1)
	AVR	55(35.3)
	MIDCAB	13(8.3)
	MV repair	3(1.9)
	MVR	59(37.8)
	MVR+ASD closure	2(1.3)
	MVR+TV repair	2(1.3)
Pre-operative variables		Median(IQR)
Ejection Fraction (%)		60.00(50.00-60.00)
Intra-operative variables		
Cross Clamp Time (mins)		Mean ± SD
		96.72±34.28
CPB Time (mins)		Median(IQR)
		146.00(121.00-176.75)
Post-operative variables		
ICU Stay (hours)		32.00(21.00-46.75)
Ventilation time (hours)		5.00(4.00-8.75)
Inotropic duration (hours)		20.00(10.00-41.00)
Chest drainage (ml)		410.00(200.00-702.50)
Early Clinical Complications		Frequency (%)
Respiratory Failure	No	144(92.3)
	Yes	12(7.7)
Renal Failure	No	152(97.4)
	Yes	4(2.6)
Re-exploration		10(6.4)
Outcome		
Outcome	Alive	153(98.1)
	Dead	3(1.9)

BMI= Body Mass Index; MICS= Minimally Invasive Cardiac Surgery; CPB= Cardiopulmonary Bypass; ICU= Intensive Care Unit

Operations involving the right and or left atrium were done by right minithoracotomy 13(8.3%) while those of aorta were done by partial ministernotomy 55(35.3%). Isolated MIDCAB was done via left minithoracotomy 88(56.4%) (Figure-1). For arterial access, depending on the size preferably right or left femoral arterial cannulation was performed in all operations. Although, ascending aortic cannulation was possible in aortic valve cases. For atrial cases, bi-caval approach was most frequently used for venous drainage. The most common venous drainage configuration was SVC cannulation percutaneously and IVC cannulation via open access to right Femoral vein. While for aortic cases, venous cannulation was performed with a single two stage cannula inserted via right atrium 54(34.6%).

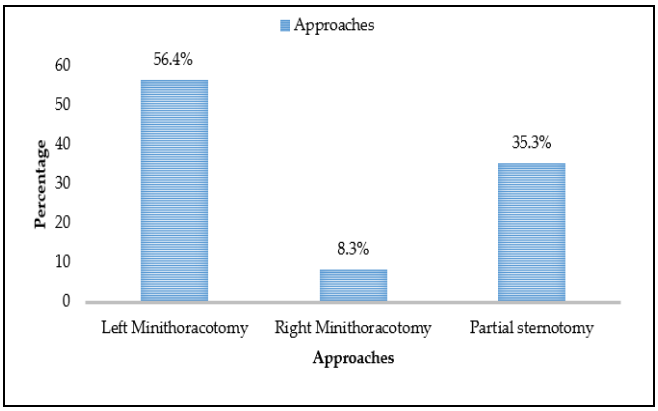

Figure-1: Distibution of Approaches (n=156)

Two patients were converted to full sternotomy, and median length of in-hospital stay was 7 days. The median ventilation time was 5.00(4.00-8.75) hours and median ICU stay was 32.00(21.00-46.75) hours. 410.00(200.00-702.50) ml was the median chest drainage. Total complication rate was 7.70%, and rate of mortality within 30-days was 1.9%. The most common complications were respiratory failure 12(7.7%), bleeding that required re-exploration 10(6.4%) and renal failure 4(2.6%). In the series, there were no cases of acute aortic dissection (Table-I).

Figure-2 shows the distribution of cannulation techniques.

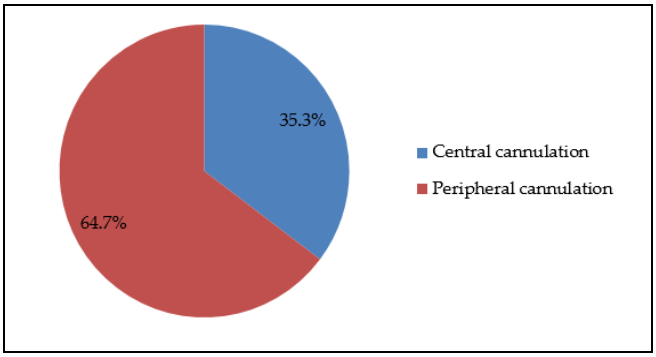

Figure-2: Cannulation Techniques Utilized (n=156)

Significant association between inotropic duration, ICU stay, ventilation time and complications (respiratory and renal failure) and mortality were found ($p \leq 0.05$) (Table-II).

Table-II: Association of Multiple Variables with Mortality (n=156)

Variables			Outcome		*p*-value
			Alive(n=153) Frequency(%)	Dead(n=3) Frequency(%)	
Demographics					
Gender	Male		90(58.8)	2(66.7)	1.00
	Female		63(41.2)	1(33.3)	
Age (years)			Median(IQR)		
			39.00(38.00-67.00)	36.00(29.00-48.00)	0.28
BMI (kg/m2)			Mean ± SD		
			24.33±4.46	23.38±4.67	0.71
Co-morbids			Frequency(%)		
Smoking Status	Ex-Smoker		9(5.9)	1(33.3)	0.32
	No Smoking		135(88.2)	2(66.7)	
	Smoking		9(5.9)	0(0.0)	
Diabetes Mellitus	Yes		5(3.3)	1(33.3)	0.11
	No		148(96.7)	2(66.7)	
Hypertension	Yes		23(15.0)	1(33.3)	0.39
	No		130(85.0)	2(66.7)	
Types of MICS operations					
Types of MICS operations	ASD closure		22(14.4)	0(0.0)	1.00
	AVR		54(35.3)	1(33.3)	
	MIDCAB		13(8.5)	0(0.0)	
	MV repair		3(2.0)	0(0.0)	
	MVR		57(37.3)	2(66.7)	
	MVR+ASD closure		2(1.3)	0(0.0)	
	MVR+TV repair		2(1.3)	`0(0.0)	
Pre-operative variables			Median(IQR)		
Ejection Fraction (%)			60.00(60.00-65.00)	60.00(50.00-60.00)	0.14
Intra-operative variables					
Cross Clamp Time (mins)			(Mean ± SD)		
			96.62±34.17	101.67±47.52	0.80
CPB Time (mins)			Median(IQR)		
			125.00(81.00-231.05)	146.00(121.00-176.01)	0.66
Approach			Frequency(%)		
	Right minithoracotomy		13(8.5)	0(0.00)	1.00
	Left minithoracotomy		86(56.2)	2(66.)	
	Partial Sternotomy		54(35.3)	1(33.3)	
Cannulation techniques	Central cannulation		54(35.3)	1(33.3)	1.00
	Peripheral Cannulation		99(64.7)	2(66.7)	
Post-operative variables			Median(IQR)		
ICU Stay (hours)			32.00(21.01-46.20)	138.00(38.00-148.65)	0.05
Ventilation time (hours)			4.00(4.00-8.00)	16.00(14.00-68.00)	0.009
Inotropic duration (hours)			20.00(10.00-41.10)	66.00(38.00-116.00)	0.02
Chest drainage (ml)			400.12(200.00-680.15)	1060.00(130.00-1270.00)	0.54
Early clinical complications			Frequency(%)		
Early clinical complications	Respiratory failure	Yes	9(5.9)	3(100)	<0.001
		No	144(94.1)	0(0.00)	
	Renal failure	Yes	1(0.7)	3(100)	<0.001
		No	152(99.3)	0(0.00)	
	Re-exploration	Yes	10(6.5)	0(0.00)	1.00
		No	143(93.5)	3(100)	

BMI= Body Mass Index; MICS= Minimally Invasive Cardiac Surgery; CPB= Cardiopulmonary Bypass; ICU= Intensive Care Unit

DISCUSSION

Cardiac surgery is unique among other types that it is performed in a controlled environment in the vicinity of vital structures. Minimally invasive approaches in cardiac surgery were slow to develop due to concerns over intracardiac air, limited exposure due to rigidity of the chest wall, motion of the target organ (beating heart) and lack of advances in cardiac instrumentation. Performance of surgical tasks on an organ in motion, full of blood, not distractable without haemodynamic circulatory compromise was a challenge. After advancement in technology in mid-1990, many centers have adopted MICS for number of cardiac procedures.[11] 36.80% of aortic valve (AV) procedures and 55.70% of mitral valve (MV) surgeries were conducted using minimally invasive techniques, according to a study conducted in Germany in 2021.[12] In 2016,[13] European institutions were performing robotic cardiac surgery. In just 3 years, this number was increased to 26.[3] A shorter hospital stay and associated expenses, a lower risk of infection, decreased surgical trauma, reduced postoperative pain, rapid recovery, quicker return to regular activities, and better cosmetic results were all contributing factors to this rapid development.[7,8] Reduced systemic inflammation, requirement of blood transfusions, renal dysfunction, vascular and neurological complications, and a shorter cross-clamp period have all been linked to the less invasiveness.[13]

The mean cross-clamp and median CPB times were 96.72±34.28 min and 146.00(121.00-176.25)min, respectively. It showed that MICS can be performed without inappropriately increasing the operative time. Contrary to this, Dieberg in his meta-analysis showed that MICS requires longer CPB time (MD 26.68 min (95% CI 10.31 to 43.05, p=0.001)), longer cross-clamp time (MD 6.7 min (95% CI 1.24 to 12.17, p=0.02)), and longer operation time (MD 55.03 min (95% CI 22.76 to 87.31, p=0.0008)).[14] Doenst *et al.,* had further demonstrated asscociations between low cardiac output syndrome and acute renal injury, cross-clamp time and mortality (all p<0.001).[15] Initial phases of MICS require long learning curve which affect overall result as demonstrated Vo *et al.*[16] MICS requires extensive preoperative planning, adequate training and use of sophisticated instruments and tools. Despite these, our failure rate of the approach where operation was converted into full sternotomy was 2(1.30%). This rate is similar to Yadava *et al.,* and is due to by unforeseen complications lie difficult cannulation, hemorrhage, lung adhesions, or damage to adjacent structure.[17,18] This conversion is associated with more peri-operative complications and 30-day mortality rate greater than 23.00% as reported by Vollrath *et al.,* in association with MIMVS.[19] Despite same rate of conversion, our mortality remained 1.90%(3 cases only). This difference may be due to controllable complications we faced.

Our three most common complications were respiratory failure due to unilateral pulmonary edema 12(7.7%), bleeding that required re-operation 10(6.40%) and renal failure 4(2.60%).

Stroke had not occurred in any patient both in early and late postoperative period. In one of case series, Deshpande *et al.,*[20] has claimed similar results but their operative time was longer than standard approach. This difference may be due to lower number of cases 58/156 and our procedures were carried out by surgeons with more than 5 years' experience and operative volume of more than 100 cases each of all kind per year.

Due to availability of perioperative TOE and adequate instruments, we preferred peripheral cannulation for operation on right and left atrium. While aortic procedures were done through central cannulation. While Iribarne *et al.,*[21] performed standard arterial cannulation via the central aortic approach. It may be because of lack or in expertise in TOE which has adequately guided us for cannulation without any complication. In their review, White *et al.,* has also stressed the usefulness of TOE in directing various steps of operation, like positioning of cannulae. Increased incidences of stroke, groin seroma, infections, and, in rare instances, arterial trauma or retrograde aortic dissection are linked to peripheral cannulation.[22] We have avoided such complications due to mandatory TOE guidance while cannulation, excluding patients with peripheral vascular diseases and involving only experienced surgeon in the programme. A study conducted by Lamelas et al. on 2400 MICS cases who underwent femoral cannulation showed that 174(6.65%) had groin wound seromas, no aortic dissections, 0.80% compartment syndromes, 0.70% femoral arterial pseudoaneurysms, and 1.17% had cerebrovascular episodes following surgery.[23]

Notably, risk factors that were found to be associated with clinical complications following MICS (such as age, CPB time, diabetes, renal failure, etc.) were also found to be associated with patients having

cardiac surgery via sternotomy.[24] Likewise, the risk factors linked to mortality were nearly the same as those mentioned in the literature for conventional sternotomies.[25] This indicated that MICS and sternotomy can be compared in terms of risk assessment.

Although long term data is not available in our study due to multiple factors, previous data has claimed that at 7 years, all main MICS operations had above 85.00% survival rates; there was no discernible variation in survival between these MICS techniques. With this study, we have added to the growing literature on MICS especially from developing countries. We have demonstrated that MICS can be safely performed on patients with both extremes 15 to 81 years of age and thin lean to obese patients (BMI 24.31±4.45kg/m2). Thus, choice of approach MICS/ full sternotomy depends upon more on surgeon's experience rather than patient-specific characteristics.

LIMITATIONS OF STUDY

Because we did not have a sternotomy control group for suitable comparison, the implications of our study's results are limited. Due to multiple factors, data on long-term follow-up on functional status and echocardiographic measurements was unavailable.

CONCLUSION

In this era of tremendous technological advancement in hybrid procedures, robotic and percutaneous valve interventions, MICS offers a satisfactory approach for wide array of cardiac operations. It is a multidisciplinary endeavor that requires a dedicated team trained together and contribute in the same way. Moreover it is an effective and reproducible approach with nearly comparable morbidity and mortality.

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Authors' Contribution

Following authors have made substantial contributions to the manuscript:

MAK & TA: Concept, study design, drafting the manuscript, approval of the final version to be published.

MW: Concept, data acquisition, critical review, approval of the final version to be published.

Authors agree to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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