Establishing a New Minimally Invasive and Robotic Cardiac Surgery Program at a New Tertiary Care Centre: A Retrospective Analysis of our Experience and Results

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Abstract: *Background*: Over the past two decades, minimally invasive techniques have gained popularity in cardiac surgery that enable access to the heart via sternotomy free approaches for most adult procedures and isolated coronary artery bypass grafting. Here we present our experience and the strategies we used and the challenges we faced while starting a minimally invasive and robotic cardiac surgery program at a newly established tertiary care centre. *Methods*: We looked back at our methods and retrospectively analyzed our results of minimally invasive and robotic cardiac surgery in terms of morbidity and mortality and complications and other quality parameters like ICU stay and re-exploration rate etc as described later in detail. A step wise approach was adopted that introduced every team member to minimally invasive and robotic surgery in a gradual fashion slowly gaining confidence and increasing the complexity of the procedures. *Results*: 105 cases of minimally invasive and robotic cardiac surgery were performed over past one year. Out of these 92 were done by minimally invasive technique and 13 were done by robotic assistance. There was no mortality and none of the patient required any conversion to sternotomy or emergency bypass. One patient had to be re-explored for bleeding. The quality indicators were noted in terms of results and complications. *Conclusion*: Minimally invasive and robotic cardiac surgery is fast becoming procedure of choice across the world including in our country due to its many advantages in terms of early recovery, cosmesis and less blood product requirement but has got steep learning curve and is technically more difficult. So a gradual step wise technique with proper training and guidance has to be adopted to establish a successful program.

Keywords: Robotic, Minimally invasive, Step wise, Complications, Training.

INTRODUCTION

Minimally invasive cardiac surgery (MICS) has undergone numerous changes in technique and philosophy with newer developments coming every other day and is the latest in the field of cardiac surgery along with interventional techniques and hybrid procedures. The origins of minimally invasive surgery date back to the 1950s [1]. Laparoscopic and fully endoscopic procedures have in the meantime become the standard in visceral surgery and gynecology [2]. In cardiac surgery, it was only in the mid-1990s that cardiac surgical procedure were performed via the partial sternotomy [3] or through a mini-thoracotomy[4] with Cosgrove describing the first minimally invasive valve surgery in 1996 [5]. In order to avoid the postoperative respiratory dysfunction, chest instability, chronic pain and incidence of deep sternal wound infection associated with a median sternotomy, numerous alternative incisions have been evaluated for MICS. In the initial period of MICS, mitral and aortic valve surgeries were performed with a right parasternal incision [5,8] that necessitated resection of the third and fourth Coastal cartilages. This approach resulted in potential chest wall instability and conversion to median sternotomy was difficult in case of emergency. Currently, the right antero-lateral thoracotomy in the fourth intercostal space [6, 7, 8,9,10,11] is the incision of choice for minimally invasive mitral-valve surgery [fig1]. Minimally invasive aortic valve surgery is usually performed through a partial upper sternotomy that extends into the third or fourth intercostal space (also known as a 'J'-sternotomy) [12,13,14] or Right anterior thoracotomy via second inter-coastal space depending on the position of aorta [15] [fig 2] and pulmonary bifurcation on NCCT chest. Left anterior mini thoracotomy in fourth or fifth inter-coastal space [fig 3] is preferred incision for minimally invasive coronary artery bypass surgery[16,17,18,19,20,21]. Other reported incisions have included a right infra-axillary thoracotomy [22], trans-sternal approach [23], inverted T sternotomy [24] and 'V'-incision [25].

Main advantages of minimally invasive surgery as in any other surgical field include shorter convalescence period and cosmesis [26,27,28] (Box 1). There is lesser requirements of blood and blood products and lower post-operative infections adding to the recovery. This becomes even more important in cardiac surgery as the patient population is usually older with multiple co-morbidities and pain and morbidity associated with a mid line sternotomy is sometimes too much. So an incision that avoids sternotomy gives the patient confidence and positivity to get involved in the post-operative period physically as well as psychologically [26,27,28]. On the other hand, a steep learning curve and technical difficulties in handling some steps (myocardial protection, de-airing maneuvers, and so on), reduced work space and limited vision discourage many surgeons to include these minimally invasive procedures within their routine practice (Box 2). In addition position of patient and limited space for instruments needs close communication between surgical team and perfusionists and anesthesiologists. All this requires special training and have been the main reason why minimally invasive techniques have not been picked up widely at most centres despite of its advantages as listed above.

A wide array of cardiac lesions with varying minimal cardiac surgical techniques and approaches poses challenges to cardiac anesthesiologists and perfusionist also [29, 30, 31]. They include but are not limited to lung isolation techniques, use of fiber-optic bronchoscopy, use of trans-esophageal echocardiography (TEE) [30], specialized perfusion cannulae for peripheral bypass [29,31] etc. TEE has a very important role at very step in minimally invasive surgery right from pre-operative assessment to cannulae placement to going on bypass and coming off. TEE and external defibrillator pads are norms in minimally invasive procedures. It helps to confirm preoperative diagnosis and reveals any additional cardiac lesions that can change the proposed MICS procedure. It further helps in guided cannulation, cardioplegia delivery and de-airing. TEE assessment of systolic and diastolic function is useful in predicting postoperative inotrope, vasopressor, or vasodilator requirement and evaluating adequacy of repair and any residual lesions.

Box-1: Advantages of Minimally Invasive Cardiac Surgery

1. Cosmetically better scar
2. Avoidance of sternal complications
3. Less use of Blood and Blood products
4. Lesser post-operative ICU and Hospital Stay
5. Earlier return to activity and faster post-operative recovery
6. Less wound infection rate
7. Psychologically better for the patient
8. Specially useful in some Redo cases

Box 2: Why Minimally Invasive Surgery has not been very Popular

1. Steep learning curve
2. Reduced working space
3. Limited vision
4. Need for special training
5. Availability of specialized instruments and facilities
6. Technical difficulties in handling some steps

In a report published in German Heart Surgery in 2015, 92% of all cardiac surgical procedures and 98% of isolated bypass procedures are performed by mid-line sternotomy [34]. We don't have any particular registry for the numbers of cardiac surgical procedures carried out annually or number of minimally invasive cardiac procedures carried out per year in our country but there is no reason to believe it will be any different in our country. In fact the proportion of cardiac surgical procedures carried out by minimally invasive techniques is likely to be lesser only than an advanced country like Germany. The use of MICS currently seems center-specific or surgeon-specific, presumably because such procedures are of notably greater complexity as discussed above.

Trying to schedule a program for starting and teaching minimally invasive cardiac surgery program at a new centre is a step forward and a challenge and requires a lot of thought process and planning to make it successful. The above mentioned program not only has to be qualitatively at par with the various accredition norms but should also be financially viable. In the next paragraphs, we will depict our experience in developing a minimally invasive cardiac surgery program, pointing out the steps followed as well as our own experience.

Figure 1: Left anterolateral thoracotomy Scar following Minimally invasive mitral valve surgery.

Figure 2: Right anterior thoracotomy scar in 2nd inter-coastal space following minimally invasive aortic valve surgery

Figure 3: Left 3rd Inter-coastal space scar following minimally invasive multi-vessel coronary artery bypass grafting.

METHODS

We started our minimally invasive program at our new center immediately upon arrival. We had the experience of over 30 years in the field of cardiac surgery and over 20 years in the field of minimally invasive cardiac surgery and I have been a pioneer in the field in the country[10,11,27,28,29,30]. But in-spite of all this, it was a challenge to start a new MICS and Robotic cardiac surgery program at a new centre. We decided to take up the challenge right from the inception of our program with the determination to give our best in term of affordability as well as as quality to make it a viable as well as successful program and we have been able to make it both as our results suggest which we will discuss subsequently. So what did we do make it a successful program in every aspect

We retrospectively analysed our data of all minimally invasive and robotic cardiac surgical procedures performed at our institute during our first year in terms of number of procedures, patient results in terms of intra-operative results and post-operative parameters and complication rate and then retrospectively analysed the methods adopted by us that helped us gain the results that we got.

At our centre we have performed 105 cases of minimally invasive and robotic surgery, 92 cases by MICS and 13 cases of robotic assisted Coronary artery bypass grafting in the first year. Out of the 92 cases of minimally invasive procedures, 55 cases were completed on CPB and 37 cases by the off pump technique. The off pump cases were all isolated coronary artery bypass grafting. The details of the procedures are given in Table 1. All the coronary artery bypass grafting were achieved by off pump technique and included both single vessel and multi-vessel disease. With our team's vast experience, any patient who was willing for minimally invasive surgery and had no other clinical contra-indication for minimally invasive surgery was taken up for the same. The pre-operative characteristics of the patients have been discussed in Table 2. Mean age of patient for surgery on CPB was 43 years and those for coronary artery bypass grafting was 64.3 years. The patient for valve surgeries included all kinds of valvular lesions including mixed lesions but requiring intervention only of either mitral or aortic valve. Table 3 and table 4 tabulates the intra-operative details of the patient and post-operative results respectively including CPB and cross-clamp times. All the patients were extubated on the same day and mean time to extubation was 5.4 hours. No patient required any conversion to midline sternotomy and there were no re-explorations. In the group of patients undergoing coronary artery bypass grafting, 28 patients had multi-vessel coronary artery disease and 9 had single vessel disease. Mean Left ventricular ejection fraction (LVEF) of patients undergoing coronary artery bypass grafting was 37% and with 7 patients having severe left ventricular dysfunction less than 30%. Mean number of grafts in patients undergoing coronary artery bypass for multi-vessel disease was 2.8 with 10 patients having more than 4 grafts. All surgeries were completed by off pump technique and no patient required conversion to mid-line sternotomy. The groin was draped in all the cases but femoral vessels were not exposed electively. None of the patient required insertion of Intra-aortic balloon pump or conversion to CPB. All patients were extubated same day and mean time to extubation was 5.2 hours. One patient post minimally invasive CABG required re-exploration for bleeding and it was diffuse oozing form chest wall and was controlled.

The Robotic cardiac surgery program at our centre is one of the most successfully running robotic cardiac surgery program across the country. We have performed 13 cases of robot assisted coronary artery bypass grafting in last 1 year. Out of these 10 were Multi-vessel disease and 3 were single vessel disease. Average number of grafts were 2.4. All the procedures were completed by off pump techniques. Table 5 gives the detailed pre-operative and post-operative results of the patients. No patient required conversion to midline sternotomy or institution of CPB. As in minimally invasive CABG, groin was draped in all patient but femoral vessels were not exposed electively.

		On CPB	OFF CPB (MICAS/MIDCAB/ROBOTIC)
Total	105		
AVR		13	
MVR/Repair		32/3	
Atrial Septal Defect		6	
MIDCAB			12 (9 MIDCAB, 3 Robotic)
MICAS			38 (28 MICAS, 10 Robotic)
Miscellaneous		1	

Table 1: Number of Minimally invasive and Robotic cases.

	On CPB	OFF CPB
Age	43 yrs	64.3 yrs
LVEF	48	37
Severe LV dysfunction (<30%)	-	7
Diabetes Mellitus	7	27
Hypertension	10	32
Smoker	6	15
Obesity	6	11

Tabel 2: Pre-operative characteristic of patients.

	CPB (min.)	AOXL (min.)
Mitral	126	61
Aortic	140	76
ASD	48	26

Table 3: Mean CPB and Clamp times.

	On CPB	OFF CPB
Time to extubation	5.4	11.7
Re-exploration	-	1
Conversion to sternotomy	-	-
ICU stay (median days)	2	3
Hospital stay (median days)	5	6
Wound infection	1	2

Table 4: Post-operative Results.

Number	13 (10/3)
Mean LVEF	42%
Average number of grafts	2.4
Time to extubation	9.8
Re-exploration	none
Conversion to sternotomy	none
ICU stay (median days)	2
Hospital stay (median days)	5
Wound infection	none

Table 5: Robotic cardiac surgery.

DISCUSSION

The healthcare system is going through major changes everywhere now a days with more and more tertiary care centres providing multidisciplinary care becoming the patient's preferred choice to get optimum care. It was a challenge to establish a new cardiac surgery unit at an upcoming tertiary care centre in the heart of the city and it was a bigger challenge to establish the unit with minimally invasive and robotic surgery program which is not so common in our country even in established cardiac surgical units. The endeavour included everything from infrastructure planning to recruitment of the staff and involved continuous active participation of surgical team and hospital management. Designing of the facility is the first challenge, wherein a definite need for sizing of the facility and the level of care needs to be decided to ensure that the unit is optimally poised to cater to the current load, with an option to upgrade to meet the likely increase in demand for more beds. Financial support for the project is the key for making such decisions. This has to be achieved in the beginning itself as often there is a mismatch in the requirement to availability ratio in the later stages as the facility grows. On the other hand, an under-planned facility will compromise the basic functions and will adversely impact the quality of healthcare delivery. The local as well as international accreditation norms like NABH and JCI and relevant guidelines were kept in mind at planning stage itself and compliance to these norms was ensured. Ensuring staff adequacy was another big challenge. Selecting the correct requirement decides the performance of the facility. The equipment planning for a cardiac unit needs to be carried out thoughtfully after a proper need analysis taking into consideration the future trends. The Operating rooms for minimally invasive cardiac services are required to cater to various types of equipments like TEE machine, monitors, camera etc. and thus requires more space than the conventional cardiac operating rooms. The

administrative unit of the hospital worked in consultation with the senior members of the team to gain input about the requirements from the perspective of surgeon seeking to create an efficient unit. The vision was to create a functionally perfect unit that should be able to fulfil the every necessary criteria of quality providing the patient with utmost care. Quality assurance in any cardiac unit is paramount as it allows to measure the quality of the healthcare delivery at all times. A strong credentialing and privileging mechanism was placed to ensure that only adequately qualified and trained people were authorized to undertake any activity within the system. The identification of training needs of each individual and organizing in-house or specialized training at defined regularity has been the key to meet this challenge.

The team was divided in two teams in the initial phase of MICS program to give the best results and quality to the patients with me taking full control of team but at the same time both teams and all the members of the team were involved in the program gradually to familiarise everyone with tips and tricks of minimally invasive surgery to develop the program in a strong well established program over the time. The vision and time to achieve the same was set at 1-2 years. I have a vast experience in both minimally invasive and open cardiac surgery and though the rest of team members had exposure to minimally invasive cardiac surgery, but we took it upon ourselves to train the team and develop the program as one of the best in the country.

The strategy to establish the program was split in parts:

1. Performing minimally invasive cases with every member of the surgical team and staff to let them become familiar and confident with the new approaches
2. Introducing junior colleagues to minimally invasive surgery in a stepwise and customized way, according to expertise and skills
3. Developing new strategies together with the team and taking care of their training

On the other hand, some quality indicators were measured, such as:

1. Conversion rate and if converted to which approach
2. Complications
3. Post-operative indicators like time to extubation, re-exploration, intensive care unit stay etc

Before starting any procedure, the proposed incision is drawn with a sterile pen for teaching purposes and all investigations discussed. Should an enlargement or conversion be needed, the possibilities are discussed and decided (e.g., upper mini-sternotomy enlargement to full sternotomy, or axillary incision conversion to postero-lateral one etc.).

The steps of the procedure are discussed with the whole team. Space management is very important in patients undergoing MICS due to lot of special instruments and machines and so patient positioning and invasive monitoring lines are always discussed with the team and anaesthetist. All patients have a pre-operative angiogram of the aorta to see for the anatomy of aorta and peripheral vessels to avoid any intra-operative surprises. All the patient have a TEE probe and a detailed TEE is done before starting any procedure. All the patient have external defibrillator pads applied and NIRS pads for cerebral oximetry. The patient is positioned in such a way so as if need arises for conversion to midline sternotomy it can be done quickly. Groin is draped in all the cases and though we don't expose femoral vessels routinely due to our vast experience, it will be advisable to expose the femoral vessels in the initial part of program to increase the margin of safety in case of an emergency. An experienced perfusionist is always there in the operation theatre ready to go on CPB should a need arise. All the cannulae for peripheral bypass should always be there in operation theatre. Minimal groin vessel dissection should be done for going on CPB to decrease the chances of post-operative lymphorrea. All the cannulation should be done under TEE guidance only and no cannulae should be forced. The position of cannulae should be confirmed by TEE before going on CPB. Carbon-dioxide insufflation is done during the procedure and de-airing is done under TEE guidance. Post procedure TEE is very important to confirm successful completion of the procedure. These are some of the protocols that we developed with our experience to give our patients the quality that one strives to achieve in any cardiac surgical program.

The step wise approach to introduce a program of minimally invasive surgery in a new place has proven successful for several reasons. First of all, the results are good and patients are satisfied. All members in the team familiar with the new technique and also it allows every member of the team to take up their roles according to their interests. With time, each member of the team takes up more responsibility as par individual preference and skill. More complex cases are added as the team gains experience.

Before embarking on a minimally invasive program, one has to assume that any drawback is going to be regarded as linked to the alternative approach. Whether it is true or not is irrelevant, unless invasive and minimally-invasive patients are matched.

After gathering some experience, the eternal question always is how to move forward with the program? There is no clear answer. Thinking in terms of contraindications rather than indications, as a last step of training, could be a reasonable marker. In other words, we are not expecting for the "perfect patient" to come and be an ideal candidate for a minimally invasive approach. We rather think about

the contraindications, if any, for a minimally invasive procedure in every patient.

As is the aphorism “The Quality has to result in increasing probability of achieving the desired outcome.” Recording of the outcomes and putting a trend analysis in place to ensure continuous quality improvement has to be a part of the whole process. All the investment in terms of infrastructure, effort, time and money needs to converge in getting the desired results and as we have discussed our results speak for us over past 15 months at our own newly established cardiac surgical unit doing all varieties of minimally and robotic cardiac surgery along with conventional cardiac surgery.

CONCLUSION

Minimally invasive cardiac surgery is currently becoming a routine practice in many centres worldwide. This has been true in our experience also as patients’ perceptions and expectations have changed. Cardiac surgical patients are increasingly asking for approaches that leaves the sternum intact. The surgeons who want to meet this new challenge realize that minimal incisions in cardiac surgery require greater technical skills. The different approaches have their own learning curve. Our recent experience demonstrates that a comprehensive, step wise schedule allows a safe and custom-made approach to train new surgeons in the field and enhances enthusiasm in developing further strategies on their own. A record of conversion-rate and complications should be used as marker of performance and quality standard. Interestingly, the wider the offer of approaches, the more ideas come up for new alternative minimally invasive methods. Our initial results at our newly established centre proves the efficacy of our approach.

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