EVALUATION OF VARIOUS PORT POSITIONS FOR MINIMALLY ACCESS CARDIOTHORACIC PROCEDURES

BY

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THESIS SUBMITTED TO **SINGHANIA UNIVERSITY**, PACHERI BARI, JHUNJHUNU, RAJASTHAN, INDIA IN PARTIAL FULFILLMENT FOR **THE AWARD OF MASTERS IN MINIMAL ACCESS SURGERY DEGREE. "MS (MAS)"**

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DECLARATION

I hereby declare that this Thesis Titled: **" EVALUATION OF VARIOUS PORT POSITIONS FOR MINIMALLY ACCESS CARDIOTHORACIC PROCEDURES"** is an original research done by me and submitted to **SINGHANIA UNIVERSITY**, Pacheri Bari, Jhunjhunu, Rajasthan, India In Partial Fulfillment For **THE AWARD OF MASTERS IN MINIMAL ACCESS SURGERY DEGREE** under the Supervision of **Professor Dr. R. K. Mishra**, Professor and Head of Minimal Access Surgery Department, The Global Open University, Nagaland and the Director, World Laparoscopy Hospital, Gurgaon, NCR Delhi, India.

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CERTIFICATION

This is to certify that this Thesis Titled: **" EVALUATION OF VARIOUS PORT POSITIONS FOR MINIMALLY ACCESS CARDIOTHORACIC PROCEDURES"** is an original research done by **DR. MD. ANWARUL ISLAM** (MBBS, F.MAS, D.MAS) under me and submitted to **SINGHANIA UNIVERSITY,** Pacheri Bari, Jhunjhunu, Rajasthan, India in partial fulfillment for **THE AWARD OF MASTERS IN MINIMAL ACCESS SURGERY DEGREE** under my Supervision. I am satisfied with the work done by him, which is presented as a thesis for MS (MAS) Examination.

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DEDICATION

I dedicate this thesis to all the Bangladeshi patients who suffered numerous surgical problems due to lack of skilled surgeon in the field of Minimal Access Cardiothoracic Surgery.

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I'm so proud to have my father Professor Dr. Md. Omar Ali who has inspired and trained to build my surgical career. Besides I am so much grateful to Professor Dr. Asit Baran Adhikary, Late Professor Dr. Aftab Uddin, Professor Dr. Md. Rezwanul Hoque, Professor Dr. Md. Mostafizur Rahman & Dr. Aslam Hossain to build my cardiothoracic surgical skills over a decade at department of cardiac surgery in BSMMU.

My all family member were the utmost sources of succour and prayers for the successful completion of this degree. My beloved wife Dr. Sheheli Jesmin, sons Abrar Anwar Shahil and little Adeeb Anwar Sadeed have sacrificed a lot and without their support I couldn't have reached this destination. I always felt their concerns, depravation and feelings.

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RESEARCH PROTOCOL

1. Name of Faculty : Faculty of Surgery
2. Name of Specialty : Minimal Access Surgery
3. Name of Discipline : Cardiothoracic Surgery
4. Title of Thesis : Evaluation of Various Port Positions for Minimally Access Cardiothoracic Procedures
5. Name of Candidate : Dr. Md. Anwarul Islam
6. Masters Enrollment : 180155097333
7. Name of Guide : Professor Dr. R. K. Mishra
8. Study Purpose : Thesis paper submitted to Singhania University, Rajasthan, India in partial fulfillment for the award of MS (MAS) Degree.
9. Year of Submission : December, 2018
10. Study Period : 9 (Nine) Months (15.01.2018 to 15.10.2018)
11. Objectives of study : To evaluate and compare task performance at different port positions during Minimally Access Cardiothoracic Surgery on swine
12. Materials and Methods:
    a. Study Place : World Laparoscopy Hospital, Gurgaon, Delhi, India.
    b. Sample Size : Minimal Access Cardiothoracic Surgery on 30 healthy adult swine.
        1) Lung resection on 6 swine
        2) Thymectomy on 6 swine
        3) ASD Closure on 6 swine
        4) LITA harvesting for Endoscopic CABG on 6 swine
        5) Oesophagectomy on 6 swine
13. Data Collection : Study data collected in details from the Wet Laboratory and Robotic Operation Theatre at WLH during each procedure in a particular proforma for recording information on all study variables over 9 months.
14. A Copy of Proforma attached.

Dr. Md. Anwarul Islam

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ABBREVIATIONS

MITS	: Minimal Invasive Thoracic Surgery
BDP	: Baseball Diamond Principle of Port Position
TTP	: Triangle Target Principle of Port Position
MAS	: Minimal Access Surgery
VATS	: Video assisted thoracic Surgery
RATS	: Robot Assisted Thoracic Surgery
ASD	: Atrial Septal Defect
CPB	: Cardio pulmonary bypass
ITA	: Internal Thoracic Artery
LIMA	: Left internal mammary artery
RIMA	: Right Internal Mammary Artery
LAD	: Left Anterior Descending Artery
LCA	: Left Coronary Artery
LCX	: Left Circumflex Artery
RCA	: Right Coronary Artery
PDA	: Posterior Descending Artery
CABG	: Coronary Artery Bypass Grafting
SD	: Standard Deviation
SPSS	: Statistical Package for the Social Sciences
CI	: Confidence interval
CM	: Centimeter(s)
WHO	: World Health Organization
SDS	: Standard deviation score
USA	: United States Of America
F.MAS	: Fellowship in minimal access surgery
D.MAS	: Diploma in minimal access surgery
M.MAS	: Masters in minimal access surgery
FICRS	: Fellowship of International College of Robotic Surgeons
BSMMU	: Bangabandhu Sheikh Mujib Medical University

ABSTRACT

Background:

Video-assisted thoracoscopic surgery (VATS) refers to minimally invasive thoracic surgical (MITS) procedures used to diagnose or treat conditions of the chest (pulmonary, cardiac, mediastinal, chest wall). Most of those procedures traditionally performed with open thoracotomy can be done using smaller incisions with video assistance. Robotic-assisted thoracic surgery (RATS), a related new technology, uses computers to help surgeon for precise tremor less instrument control in a confined space. Baseball Diamond Principle of port position (BDP) is the conventional procedure whereas Triangle Target Principle of port position (TTP), another procedure, is also used for minimal access cardiothoracic surgery. Different manipulation angles (30^0, 60^0 and 90^0) are used to perform the task. Every principle of port placement has both advantages and disadvantages for task performance regarding time required, errors occurred and surgeon's discomfort during operation.

Objectives:

To evaluate and compare task performance at different port positions during Minimally Access Cardiothoracic Procedures in swine models.

Methodology:

The study is a Prospective Experimental Study done in partial fulfillment for the award of Masters in Minimal Access Surgery (M.MAS) degree from Singhania University, Rajsthan, India. The Study was granted and conducted at the Institute of Minimal Access Surgery at the World Laparoscopy Hospital, Gurgaon, NCR Delhi, India under the regulation of Singhania University, India. 3 thoracic & 2 cardiac procedure were selected for this study. Total Thirty (30) Video-Assisted Thoracic Surgery (VATS) procedures were conducted on 30 swine models at the Institute of Minimal Access Surgery, World Laparoscopy Hospital, Gurgaon India over 9 months between 15/01/2018 and 15/10/2018. At the end of the procedure Euthanasia was conducted humanly by giving high dose of Succinylcholine and the carcasses disposed appropriately as per

regulation under the provisions of Section 15 of the Prevention of Cruelty to Animals Act, 1960 and the rules under the Act of 1998 and 2001.

Results:

A total of 30 procedures were done in this study. Triangle Port Placement (TTP) was used. The details of the procedures are- 6 (20%) Lung Resection, 6 (20%) Thymectomy, 6 (20%) Atrial Septal Defect closure, 6 (20%) Internal Thoracic Artery Harvesting for Endoscopic CABG and 6 (20%) Oesophagectomy on 30 animals through minimal access techniques. It is to evaluate the Execution time (sum of the ports Access Time and the Actual Procedure Time), Error rates and the Surgeon's discomfort for each of the three angles of manipulation. The average timing of all tasks was shorter with 60º manipulation and all were reproducible. Irrespective of the difficulty of the tasks then it was followed by 30º and 90º angle. The closer the manipulation angle is to the 90º and above, the more the likely to take longer operative time. It may be due to fatigue from increased elevation angle and shoulder over stretching. It was demonstrated that surgeon's discomfort level was least at 60 degree port position.

Conclusion:

There is no anatomical landmark for port placement in Cardio-Thoracic procedure. The average timing of all tasks was shorter, less errors and surgeon's discomfort was lesser operating with 60º manipulation angle.

Chapter-01

Title:

Evaluation of Various Port Positions for Minimally Access Cardiothoracic Procedures

CHAPTER I

Introduction

Overview of minimally invasive thoracic surgery

Video-assisted thoracoscopic surgery (VATS) refers to minimally invasive thoracic surgical (MITS) procedures used to diagnose or treat conditions of the chest (pulmonary, cardiac, mediastinal, chest wall). Most major procedures traditionally performed with open thoracotomy can be done using smaller incisions with video assistance. Robotic-assisted thoracic surgery (RATS), a related new technology, uses computers to help surgeon instrument control. The essential difference between VATS and RATS is that with VATS, the surgeon holds the instruments, whereas with RATS, the surgeon controls the instruments from the console and does not directly handle the instruments, but does directly control all aspects of the instruments' movement.

When patients are selected appropriately MITS provides safe, effective, and successful surgery. The indications have expanded as technology has improved. Continued outcome assessments are needed to ensure that MITS provides equivalent or improved outcomes compared with traditional open surgical methods. Quality of life assessments, morbidity rates, and recovery timelines also are important factors for comparison. Although few trials exist, many observational studies indicate that MITS has less perioperative morbidity and equivalent oncologic results compared with open operations. For special populations, such as frail and older adult patients, outcomes may be better. Generally, perioperative costs for minimally invasive procedures (both VATS and RATS) are higher because of costly equipments. However, overall costs may be lower due to shorter length of hospital stay and faster patient recovery.

THORACOSCOPIC SURGERY:

In the same manner in which laparoscopic techniques reduce the need for large abdominal incisions, minimally invasive thoracic surgeries (MITS) remove the need for thoracotomy that requires spreading of the ribs or long median sternotomy incision, large scar mark and prolonged post operative analgesia.

MITS uses a thoracoscope attached to a video camera to see inside the chest on monitor. The rod lens and the specially designed long shaft instruments necessary to perform the surgery are inserted between the ribs and into the chest cavity through single or multiple small incisions. The basic principles used in open thoracic surgery (exposure, traction, counter traction) govern MITS as well, but the surgeon's hands remain outside of the chest cavity (or, in the case of robotic surgery, at a separate console), to manipulate the instruments inside the chest.

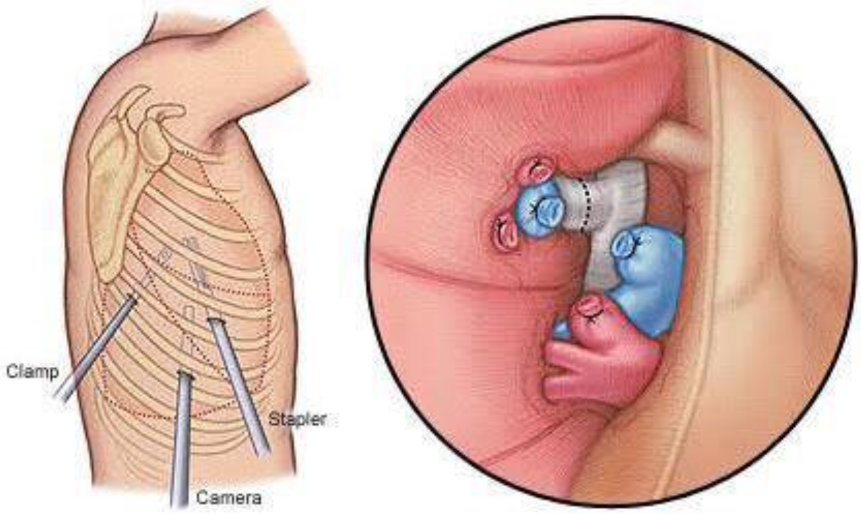


Figure-01: Sample diagram of VATS

Video Assisted Thoracic Surgery (VATS) and General Minimal Access Surgery started at the early of the 20th century. Although at first promising as a Diagnostic tool with few therapeutic indications, the succeeding decades diminished the progress of this explosive innovation. The principles and practice of VATS was firmly established as a separate discipline during the last 2- 3 decades and now a days all procedures to be done via minimal access.

The preoperative preparations for VATS as well as those for traditional open Thoracotomy are same with emphasis on evaluating Lung Functional reserve. Because of its minimal invasiveness, VATS has several advantages over thoracotomy. It has also less postoperative complications and earlier recovery. VATS has the short coming of prolonged learning curve because of the challenge in adapting to the use of long instruments, absent tactile feedback, different Chest geometry and the optics.

Long instruments including Thoracoscopic camera, fibre optic light source, gas insufflator, retractors, graspers, scissors, forceps, dissectors are passed through ports into the chest cavity via 1-2 cm skin incisions in Video Assisted Thoracic Surgery (VATS). There are ergonomic principles that leads the position and placement of these ports to help task performance and Surgeons Comfort.

The Baseball Diamond principle (BDP) as established for Laparoscopic procedures is also a conventional principle used in ports placement in VATS.[1,2] In BDP the Camera port and the target are placed at the opposing vertical angles of Diamond and the other 2 working instruments are placed perpendicular to that plane at the horizontal angles.

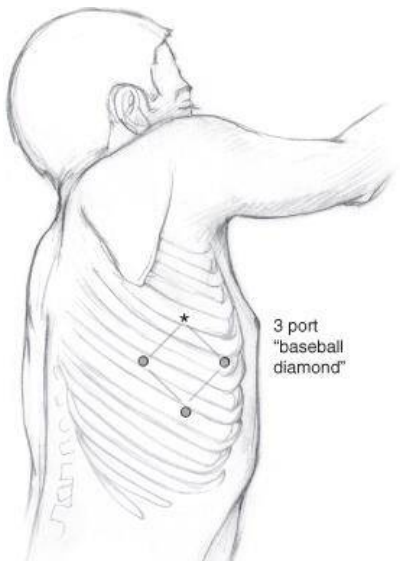


Figure-02: Diagram of a baseball port position

The triangle Target principle (TTP) is a new Principle. It has shown to be better in some situations. It is also popular with many Minimal Access Thoracic Surgeons. This procedure involves placing the camera port, one of the working instruments and the target at the angles of an equilateral triangle and the second working instrument placed close to the target.

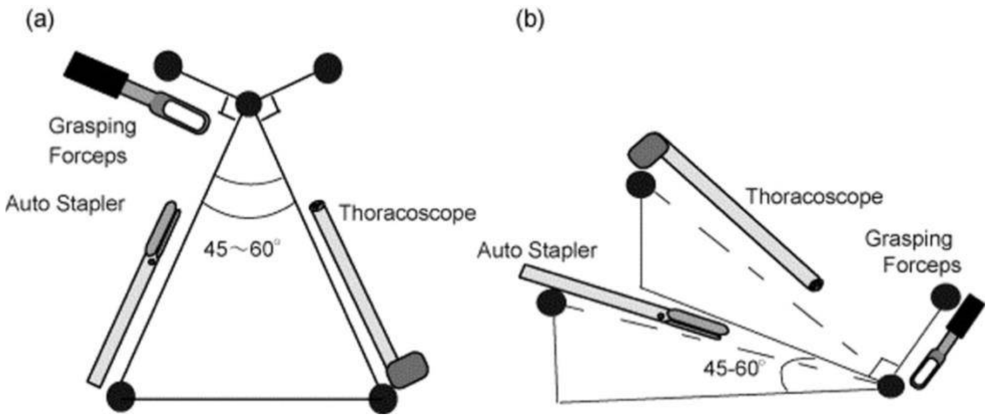


Figure-03: Triangle Target Principle

Using the Triangle Target Principle of port placement, most of the lung resections can be done safely. It is also need to assess the use of the TTP in various procedures in an attempt to identify the best possible site of Port placement and improve the efficiency of Video Assisted-Thoracic Surgery.

To demonstrate this, A Prospective Experimental Animal Study was carried out where 30 VATS procedures were performed by me using 30^0, 60^0 and 90^0 degree manipulation angles. (Different variety of 3 Thoracic and 2 Cardiac surgery were selected for this study).

The procedures are Thoracoscopic Lung Resection, Thymectomy, Internal Thoracic Artery Harvesting for endoscopic CABG, ASD closure and Oesophagectomy were done using Triangle Target Principle of port placement on 30 swine models.

Number of Procedure:

Six (6) procedures for Lung Resection, six (6) for Thymectomy, six (6) for Internal Thoracic Artery Harvesting for endoscopic CABG, six (6) for ASD closure and six (6) for Oesophagectomy were done on 30 adult healthy swine.

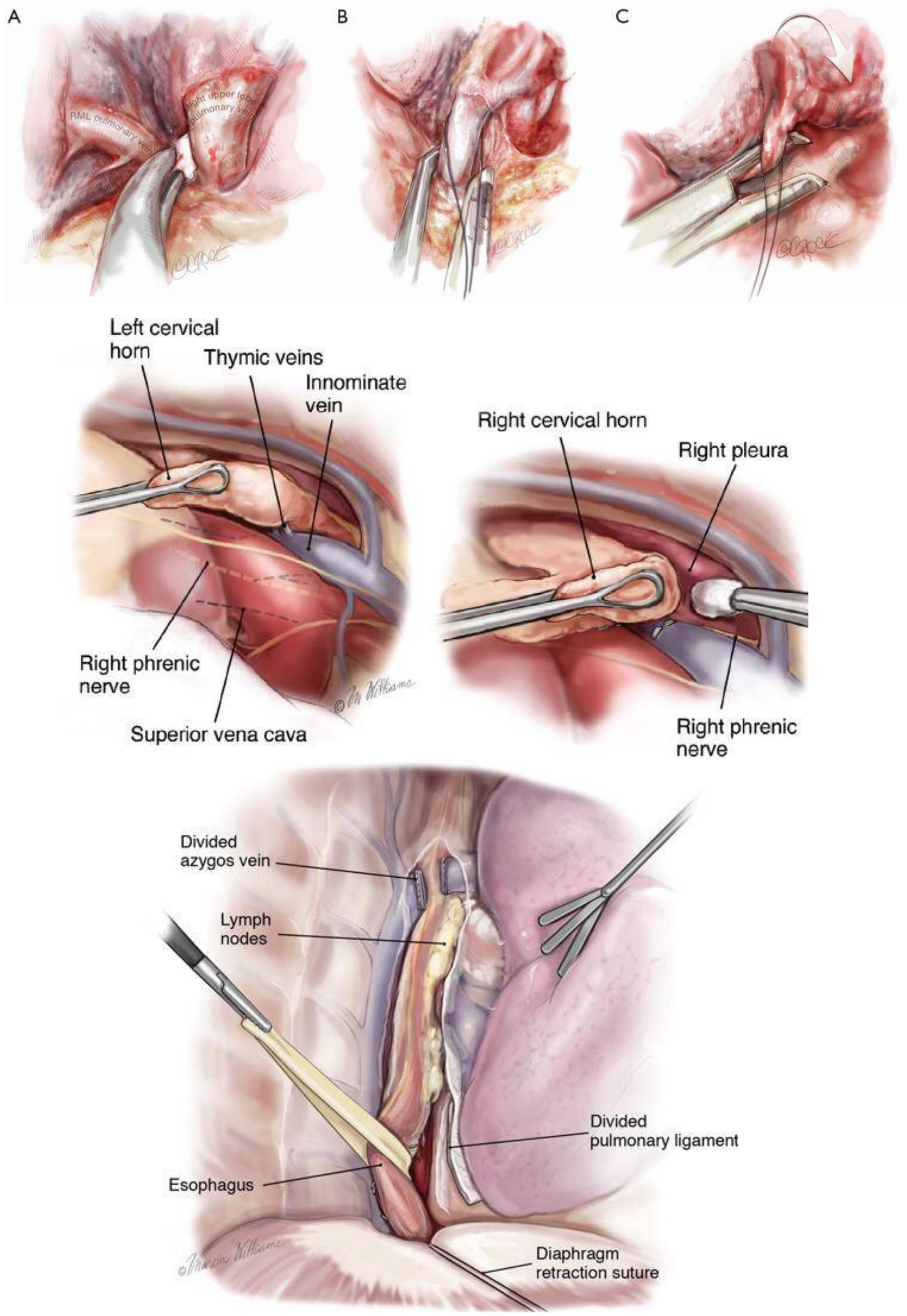


Figure-04: Thoracoscopic View for lobectomy,thymectomy & Oesophagectomy.

The measures of outcome used for the comparison are the Execution time, the Errors and Surgeon's Discomfort (a subjective measure). The aim is to find out which of the position for Port placement is better for cardiothoracic VATS in the Swine models. The result can be used to offer recommendations on the appropriate ports placement principles.

RATIONALE OF THE STUDY:

Video Assisted Minimal Invasive Cardiac Surgery has been introduced for long years ago. It has been developed profoundly in modern time with advance of science. Now a day it is preferred over traditional open thoracotomy, because VATS is better tolerated. It is associated with reduced length of hospital stay in the treatment of different types of cardiothoracic problems.

Compared to open Thoracotomy, VATS provides more access and better view of all areas of the Thoracic Cavity. Postoperative pain is associated with Open Thoracotomy, but it is greatly reduced in VATS due to avoidance of rib retraction. VATS facilitates earlier recovery with reduced morbidity as it induces less metabolic response to trauma. In VATS there is less scarring, lower risk of infection and bleeding. This allows earlier Respiratory Physiotherapy and mobilization.

Although the initial cost for VATS procedures seems to be more, the reduced morbidity, earlier mobilization and return to previous activities and work and the reduce man-hour loss for the patient as well as attendants cumulatively make VATS cheaper than Open Thoracotomy.

It is also superior to pleural drainage for pneumothorax and seems to have a complication profile comparable to that for thoracotomy. However, some doubts in its application in lobectomies. For this reason further studies are needed.

There are two principles regarding port placement for VATS, BDP and TTP. Three angles are used to perform the task in each principle. These manipulation angles are also to be evaluated for ideal position.

Moreover, while the world is advancing with this type of surgical procedure, Bangladesh is lacking producing least data. But many of Bangladeshi patients suffer from numerous surgical problems which can be easily solved by Minimal Access procedures. Skilled personnel in the field of Minimal Access Cardiothoracic Surgery should be produced.

This prospective experimental animal study was designed to find out a suitable manipulation angle for port position in TTP using 30, 60 and 90 degree angles regarding task performance time, error and comfort of surgeon.

HYPOTHESIS:

There is no perfect port position for Minimally Access Cardiothoracic Procedure.

RESEARCH QUESTION:

1. Is there any perfect port position for Minimally Access Cardiothoracic Procedure?
2. Which port position is comfortable for surgeon to perform the task in Minimally Access Cardiothoracic Procedure?

AIMS AND OBJECTIVES

GENERAL:

To evaluate and compare task performance at different port positions during Minimally Access Cardiothoracic Procedures in swine models

SPECIFIC:

1. To review the Literature on the principles of port placement in Video Assisted Thoracic Surgery (VATS)

2. To conduct VATS Lung Resection, Thymectomy, Internal Thoracic Artery Harvesting for Endoscopic CABG, ASD closure and Oesophagectomy through minimal access using the Triangle Target Principles of port placement in swine models.

3. To compare the Task performance (Execution time) by the application of this principles

4. To postulate on the translation of the findings to human subjects

5. To offer other recommendations based on the findings.

OUTCOME VARIABLES:

The Outcome measures are-

- The **Execution Time** in seconds (Port Access Time plus Actual Procedure Time),

- **Error rate** (Lung perforation, Myocardial Injury, injury to the great vessels, injury to the phrenic nerve, Oesophageal Perforation, Subdiaphragmatic primary Trocar entry for Oesophagectomy and Intercostal Vessels injury for port placement during ITA Harvesting) and

- **Surgeons Discomfort Level** as analysed by Visual Analogue System (VAS) ranging from 1-10 in increasing Discomfort pattern.

Chapter-02

LITERATURE REVIEW

Video-Assisted Thoracic Surgery (VATS) or Thoracoscopic surgery is a total Thoracoscopic approaches, where visualisation is dependent on video monitors, and rib spreading is avoided and one to four small (1-2 cm) incisions are required.[1-3]

VATS are performed by a thoracic Surgeon in the operating Room using single lung ventilation and various reusable and disposable instruments. This is different from Medical Thoracoscopy which is done by chest physicians under local anaesthesia or conscious sedation at the endoscopy suite or the operation theatre.

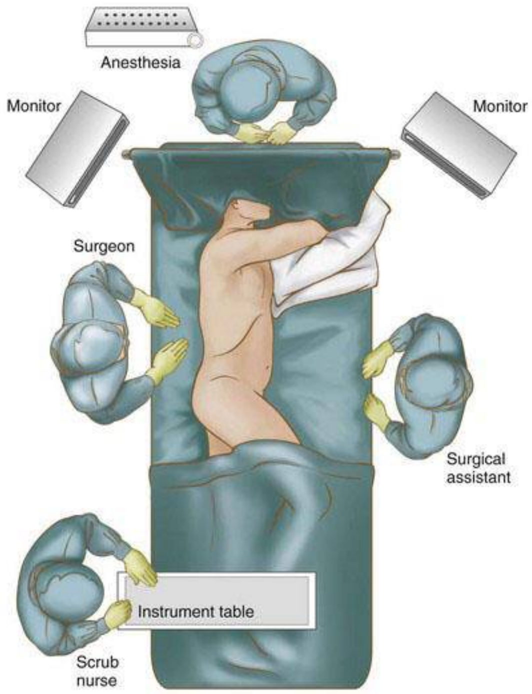


Figure-06: Standard patient position for VATS

2.1 THE PAST AND ADVANCEMENT OF VATS

Video-assisted thoracoscopic surgery (VATS) is a minimally invasive surgical technique. It is used to diagnose and treat problems in chest. The thoracoscope transmits images of the inside of chest onto a video monitor that guides the surgeon in performing the procedure.

The history of Minimally Invasive Surgery in the thorax is one of evolution, not revolution. The concept of video-assisted thoracic surgery

(VATS) to greatly reduce the trauma of chest operations was initiated over two decades ago. Since then, it has undergone a series of step-wise modifications and improvement.

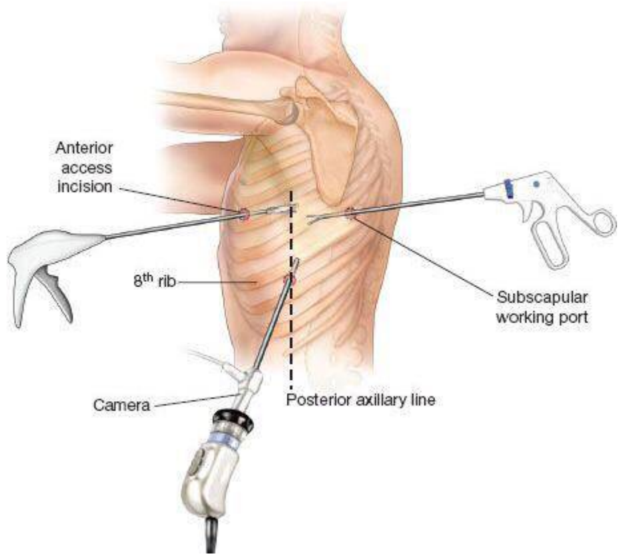


Figure-05: Access inside chest

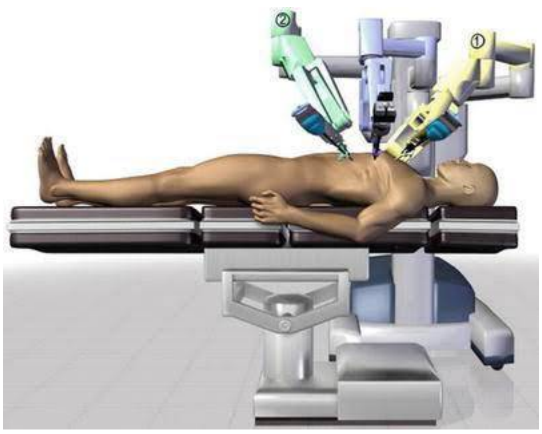
The history of VATS can be traced to the invention of the eye glasses in the 13th -14th century and the Telescope by Galileo Galilei in 1609. The 'Endoscope' concept was developed by Philipp Bozzini and he presented an instrument in 1804 and demonstrated its use in visualising the pharynx and nasal cavity in 1806 and later as a cystoscope. The term 'Endoscope' was invented by Antonin Jean De'sormeaux in 1853 which he presented at the French Imperial Academy of Medicine.

The development of light source and then the light bulb lead Gustave Trouve to use platinum filaments in the Endoscope as a light source but the resultant intense heat discouraged its use which prompted Julius Bruck to develop a cooling system around the filaments. Maximilian Nitze (1846-1906) modified and miniaturised the Bruck's cooling system and utilised the Galileo's concept to extend the field of view.

Possibly Francis Richard Cruise did the first Thoracoscopy as reported in the Dublin Quarterly Journal of Medical Science, issue 41, 1866 when Dr.Samuel Gordon caring for an 11 year old girl with an empyema asked Dr.Cruise to assist with his endoscopic skills.[4,5]

Hans Christian Jacobeus (1879—1937) a Swedish Internist is considered the Father of Thoracoscopy. The dual advantage of advancements in chest Medicine and Endoscopy provided him the opportunity to explore and establish the Practice of Thoracoscopy in 1910. The prevalence of pulmonary tuberculosis at the time and due to emergence of its vaccine failure lead to the search for other treatment options and artificial pneumothorax was introduced to fill the gap.

Jacobeus at first popularised Thoracoscopy as a diagnostic tool for Tuberculosis and cancer and later employed its therapeutic role for inducing artificial pneumothorax. He subsequently introduced Closed lntrapleural Pneumolysis (Jacobeus Operation) by thoracoscopically dividing pleural adhesions with Galvanocautery in 1913. The discovery of streptomycin for Tuberculosis treatment reduced the VATS enthusiasm and reduced it to a diagnostic tool for about half a century.
The use of Laparoscopic procedures led to a remarkable reappearance of VATS and VATS operations started flourishing in the 1905. Lewis and coworkers reported 100 consecutive Thoracoscopic procedures including 3 lobectomies in 1992.6 Since then VATS has shown significant advancements in the instruments design, reduced Ports and the introduction of Hybrid VATS which now culminates into the era of ROBOTIC Thoracic Surgery.[6,7]



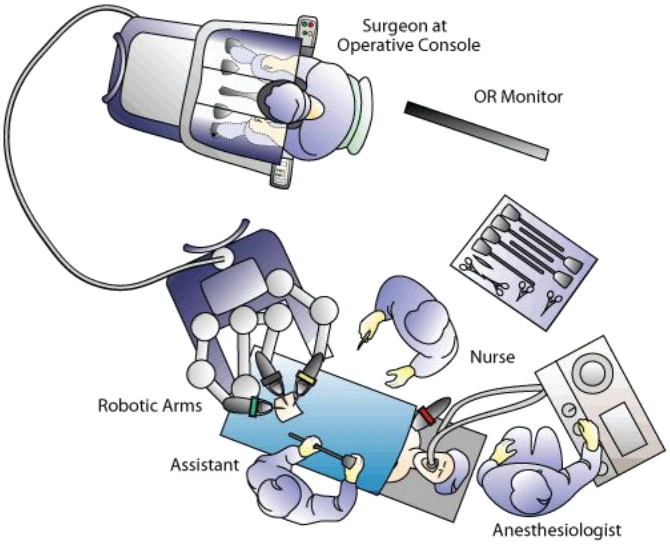


Figure-06: Robotic setup at Operation Theatre

2.2 INDICATIONS FOR VIDEO ASSISTED THORACOSCOPIC SURGERY (VATS)

The indications for VATS include practically all the indications for traditional open Thoracotomy. The diagnostic indications include all biopsies for Lung and other nodules, interstitial Lung Disease, Nodal staging for primary Thoracic tumours and staging of primary extra-thoracic Tumours. The diagnostic role of VATS in Chest Trauma is employed in lung laceration, Haemothorax and Diaphragmatic injury.

VATS is used in both diagnostic and therapeutic pleural, lung, and mediastinal surgery. Specific indications include the following:

- Stapled lung biopsy
- Lobectomy or pneumonectomy
- Resection of peripheral pulmonary nodule
- Evaluation of mediastinal tumors or adenopathy
- Pleural biopsy

- Bullectomy
- Treatment of recurrent pneumothorax
- Management of loculated empyema
- Pleurodesis of malignant effusions
- Repair of a bronchopleural fistula
- Chest trauma (mainly diaphragmatic injuries)
- Pericardial window
- Pericardiectomy
- Sympathectomy
- Truncal vagotomy

Although the use of thoracoscopy for pulmonary metastesectomy has been controversial, some authors have found it to be efficacious and safe.[8-10]

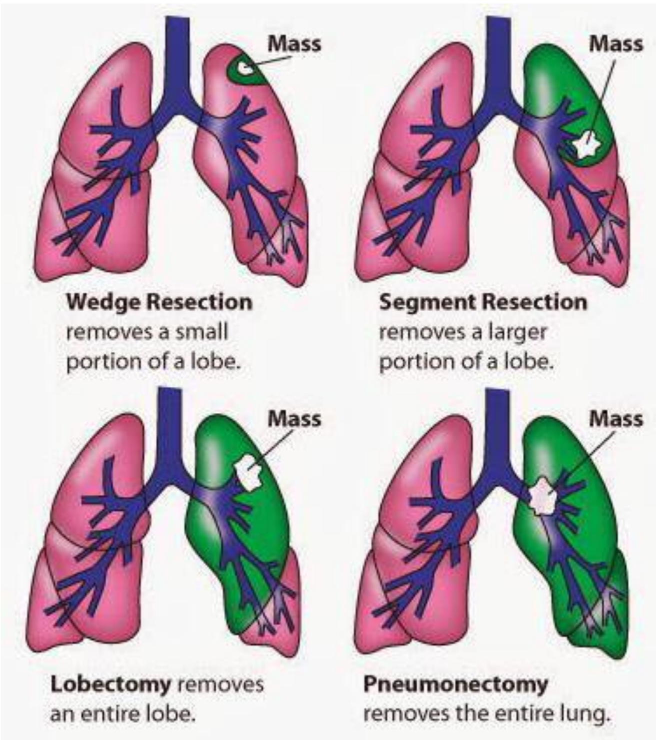


Figure-06: Various Lung Resection types

The therapeutic indications for VATS also include Pleural procedures (pleurodesis, resection of pleural masses), procedures for benign lung diseases like Blebs stapling and bulla excision for bullous Lung disease and Lung Volume Reduction Surgery for Chronic Obstructive Pulmonary Diseases as well as procedures for Malignant lung diseases such as Wedge Lung resection, Lobectomy, Pneumonectomy and Metastatectomy, non anatomical lung resection. Other indications are pericardiectomy, Heller's oesophageal cardiomyotomy, oesophageal resection for benign lesion, Oesophagectomy, and mediastinal procedures like Thymectomy, Pericardial Window, Excision of Cysts and Tumours, Thoracic Sympathectomy and thoracic duct ligation. Rib resection in sarcoma and first rib resection in Thoracic outlet syndrome are also indications.[3,8] It also includes various cardiac procedure like conduit harvesting for endoscopic Coronary artery bypass grafting, correction of congenital heart defects and valve repair or replacement, graft replacement of aortic aneurysms etc.

2.3 CONTRAINDICATIONS TO VIDEO ASSISTED THORACOSCOPIC SURGERY (VATS)

Most contraindications to VATS are now considered relative. They include marginal physiological respiratory reserve, severe adhesions, reduced working space due to high diaphragm in obesity and phrenic nerve paresis. Others may be considered absolute contraindications such as intolerance of single lung Ventilation, large Tumour size >6cm, anticipated sleeve resection, Hilar lymphadenopathy, chest wall and Mediastinal involvement.[3,8]

Absolute contraindications include the following:

- Markedly unstable or shocked patient
- Extensive adhesions obliterating the pleural space
- Prior talc pleurodesis

Relative contraindications include the following:

- Inability to tolerate single-lung ventilation
- Previous thoracotomies
- Extensive pleural diseases
- Coagulopathy
- Prior radiation treatment for thoracic malignancy; plan to resect

2.4 BENEFITS OF VATS OVER OPEN THORACOTOMY

VATS is better tolerated and associated with reduced length of hospital stay in the treatment of pneumothorax and minor resections. It is also superior to pleural drainage for pneumothorax and seems to have a complication profile comparable to that for thoracotomy. However, there is an uncertainty surrounding its application in lobectomies, and further studies are needed.

VATS provides more access and better view of all areas of the Thoracic Cavity when compared to open Thoracotomy. With the introduction of Minimal Invassive Surgery and magnified view for all, the proverb of Surgeons requiring the ’eyes of a hawk’ and the ‘hands of a lady' when embarking on open surgical procedures’ is no more a celebrated dictum.[9]

VATS induces less metabolic response to trauma and thus facilitates earlier recovery with reduced morbidity. The avoidance of rib retraction greatly reduces the postoperative pain associated with Open Thoracotomy and this allows earlier Respiratory Physiotherapy and mobilisation.

Although the initial cost for VATS procedures may be more, the reduced morbidity, earlier mobilisation and return to previous activities and work and the reduce man-hour loss for the patient and attendants cumulatively make VATS cheaper than Open Thoracotomy.

2.5 PROBLEMS OF VATS

The complications of VATS include Nerve injuries due to pressure from wrong positioning and Anaesthetic complications. Trocar complications during port placement may lead to Trocar Injury to intercostal vessels or internal Mammary Artery, instrument malfunction or breaking within the Thoracic cavity, intercostals nerve dysfunction due to tight leverage on the chest wall and Large Vessels injury.[10]

Prolonged Air Leak, Atelectasis, Pneumonia, chylothorax and arrhythmia such as atrial Fibrillation are some of the postoperative complications.[8]

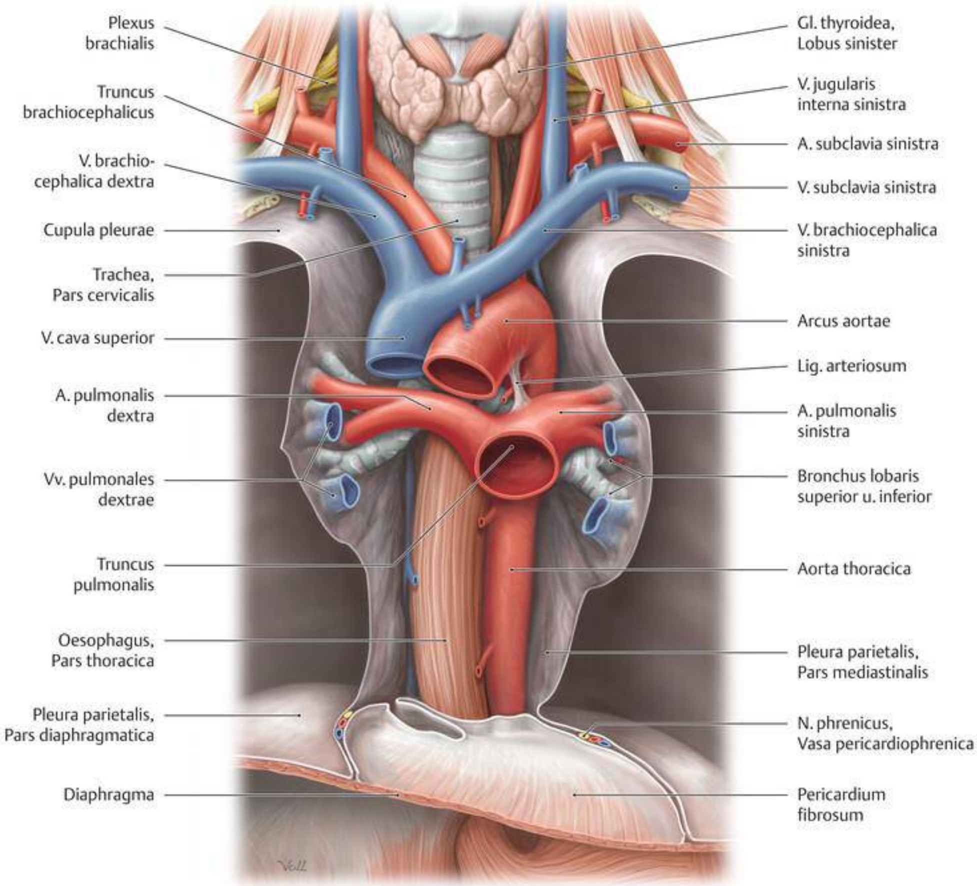


Figure-13: Important structures that might get injured in VATS

2.6 PRINCIPLES OF VATS

Preoperative Preparation

This is similar to open Thoracotomy. The goal is to establish the operability of the patient and resectability of the lesions.[3] The patient's evaluation by the Surgeon who is experienced in General Thoracic Surgery is supreme. Exhaustive history including past medical history and smoking history should be taken followed by detailed clinical examination. Diagnostic imaging including Chest X-rays, CT Scans, Magnetic resonance imaging, PET Scans and pathologic investigations are then done.

The risk assessment involves the Pulmonary reserve evaluation by oximetry and Pulmonary function tests, Carbon Monoxide Lung Diffusion (DLCO), Quantitative Ventilation: Perfusion (V/Q) Scan and Maximum

Oxygen consumption (VOz—max). Further evaluation may require Haemodynamic Pulmonary Response Tests.

Obtaining a documented and informed consent and the possibility of conversion to Thoracotomy, use of preoperative Antibiotics where indicated, cessation of smoking and preoperative physiotherapy coaching are part of the armamentarium for better postoperative outcome.

2.7 ORGANISATION OF OPERATION THEATRE, WORKFORCES AND EQUIPMENT PLACEMENT

Equipment

Equipment for video-assisted thoracoscopic surgery (VATS) includes the following:

- 5- or 10-mm video thoracoscope, with a 0º or 30º lens and a three-chip charge-coupled device video camera
- Sponge-holding forceps
- Long-blade diathermy pen
- Endoscopic biopsy forceps (for simple pleural biopsy)
- Endoscopic staple-transection devices (for lung wedge resection)
- Rigid or flexible trocar cannula and/or sterile plastic bag
- Thoracotomy tray
- Chest tube drainage device with water seal
- Suction source and tubing
- Sterile gloves
- Sterile drapes
- Gauze squares

The equipments used for VATS include the Video System, the Insufflator set, Ports, reusable and Disposable instruments, Energy source for electrocautery and some rare instruments like Laser. Open Thoracotomy set must be readily available in the event of conversion. The positioning of the personnel and equipments for VATS needs to be planned and each placed appropriately to ensure unobstructed view for the Surgeon and the Assistants, anaesthetist access to the patient and Scrub nurse access to the Surgeon. Figure-07 shows a typical setup for VATS.[8]

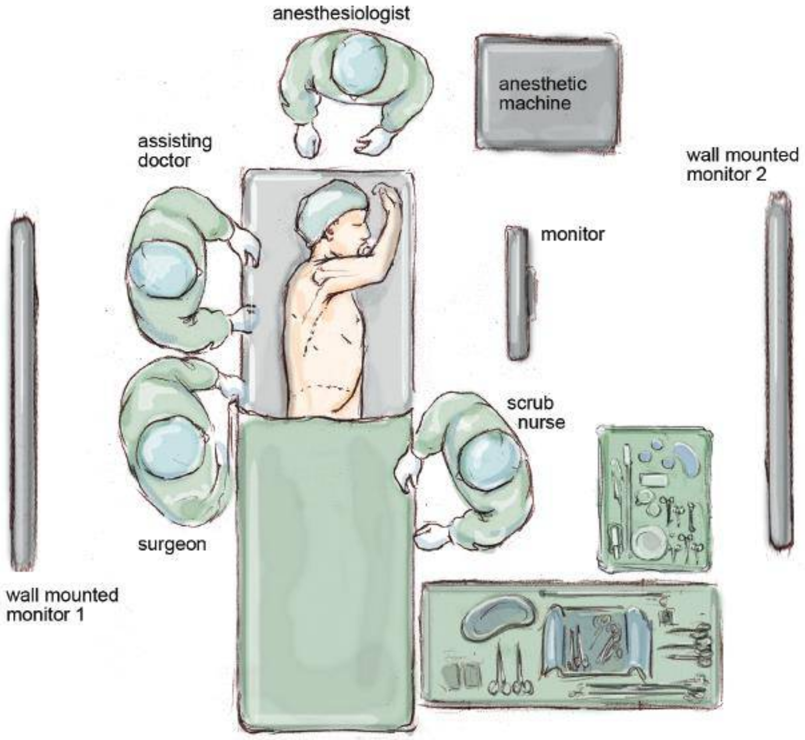


Figure-07: Theatre Setup for VATS

2.8 ANAESTHESIA AND PROCEDURES OF INTRAOPERATIVE MONITORING

In most VATS procedures general anaesthesia with Double—lumen Endo Tracheal tube is used to ensure collapse of the ipsilateral lung and provide more space in the thoracic cavity. Bronchial blockers can be used when Double-lumen tube is not available. Bronchoscopy instruments should be made available and used to ascertain tube Endotracheal tube placement. In some situations VATS can be done under Local Anaesthesia or conscious sedation.[11]

For treatment of pleural effusions and sympathectomy, single-lung ventilation with low tidal volumes is a better option and allows adequate visualization of the pleural space. Moreover, CO2 can be insufflated to facilitate partial collapse of the lung.

For pediatric patients, a single-lumen tube is used with the tip placed into the contralateral main stem bronchus.

For major lung resections, typed and crossmatched blood should be available. Two large-bore intravenous lines and an arterial line should be also placed.

Thoracoscopic evaluation of an awake, non-intubated, non-ventilated patient in an ambulatory setting under monitored anesthesia care has been described. [6] Irons et al, in a study of 73 patients who underwent elective minor VATS, found non-intubated general anesthesia with spontaneous ventilation via a supraglottic airway device to be a feasible alternative to intubated general anesthesia. [7]

Basic intra operative monitoring such as vital signs, Electrocardiogram (ECG) and pulse oximetry may suffice for basic VATS procedures. Advanced and prolonged procedures require more invasive monitoring including arterial line, central venous line, Urinary catheter, Core temperature etc.

2.9 POSITIONING OF PATIENT

Most procedures are done with the patient positioned in the lateral decubitus position. The bed is flexed to open the intercostal spaces wider. This decreases leverage of the instruments on the ribs with reduction in frequency of intercostal nerve compressions and postoperative pain. It also allows better manoeuvrability of the instruments. Some VATS procedures such as Thymectomy can be done in supine position with slight elevation of the ipsilateral shoulder.[3] The prone position is another option for other procedures.[12]

Alternatively, the patient can be positioned supine with a roll under his back to bump him or her up and provide access to the pleural space from a more anterior approach.

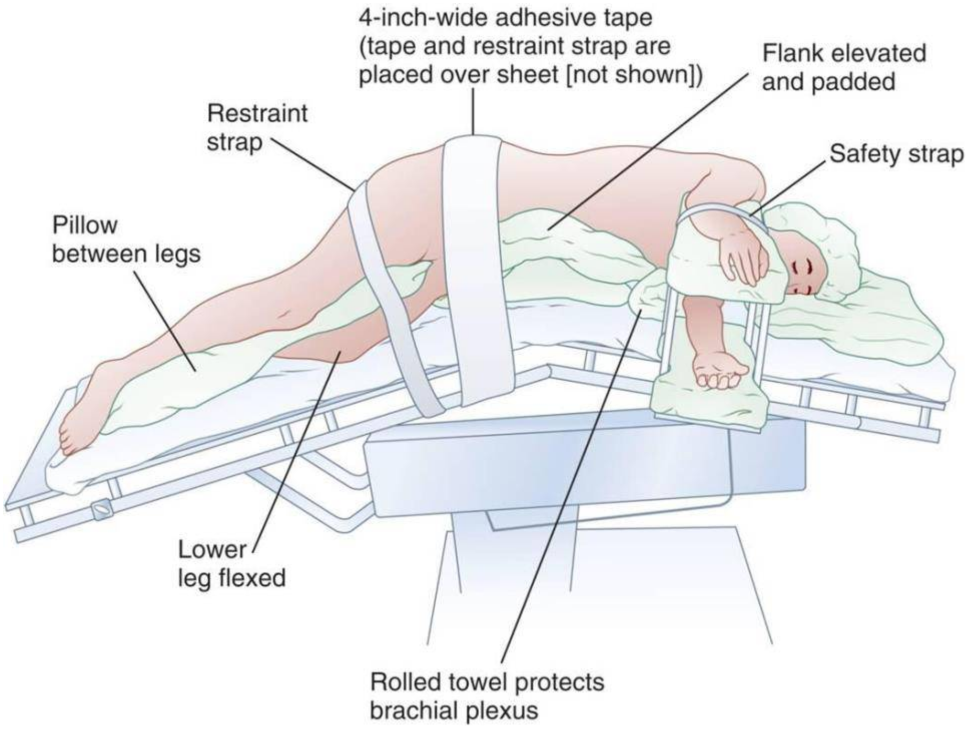


Figure-09: Standard patient position for VATS

The positions of the surgeon and assistant depend on the site of the pathology as suggested by preoperative imaging. The surgeon stands facing the site of the pathology, with the camera-holding assistant on the same side. The television monitor is positioned so that the surgeon, the site of pathology, and the monitor are aligned to allow the surgeon to look straight ahead when operating.

2.10 REMOVAL OF TISSUE SPECIMENS

VATS procedures which require excision of tissues either for Diagnosis or as a therapeutic excision require a route for retrieval of the tissue without spillage within the thoracic cavity or implantation along the Port pathway. This is very relevant in Cancer cases and also in infected cases. A Mini thoracotomy (4-6 cm) incision is done in VATS lung resections. The use of Endobags for tissue retrieval is employed. There are commercial bags but a simple one can be fashioned locally from hand globes.

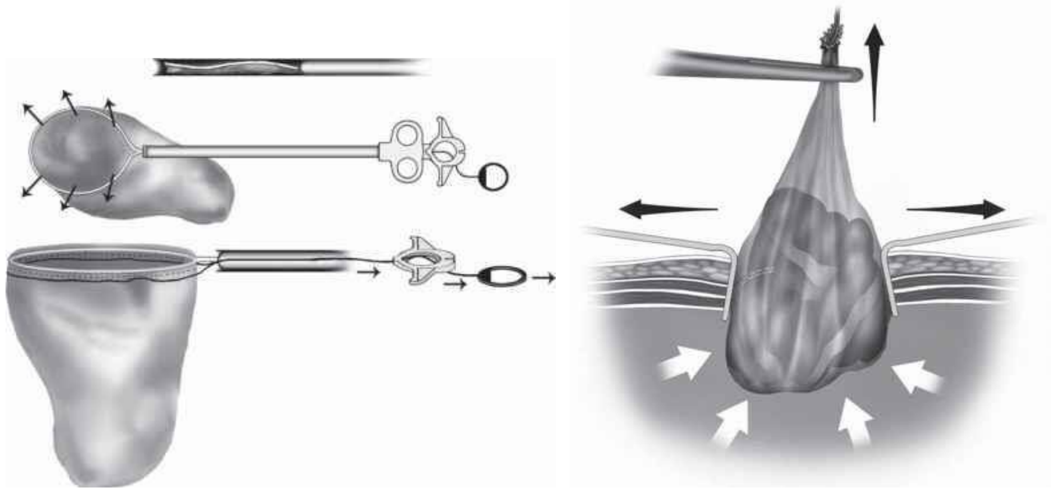


Figure-10: Endobags and technique for Specimen Retrieval.

2.11 PORT PLACEMENT IN MINIMAL ACCESS SURGERY (MAS):

ERGONOMIC PRINCIPLE FOR VATS:

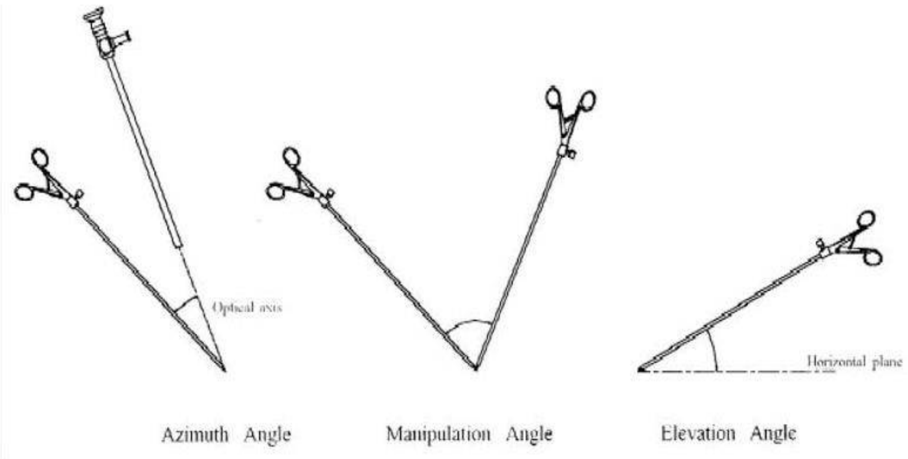
Ergonomics is "the scientific study of people at work, in terms of equipment design, workplace layout, the working environment, safety, productivity, and training". Ergonomics is based on anatomy, physiology, psychology, and engineering, combined in a systems approach.

There are Ergonomic Principles that govern the placement of Ports in Minimal Access Surgery. These facilitate better task performance and comfort to the surgeon which translates into better overall outcome.

These principles include:

- The Optical Trocar port is placed at the center so that the telescope will come to lie between the Working Instruments
- The instruments should act as type 1 lever with equal length inside and outside the Peritoneal or Thoracic cavity.

- The Manipulation angle between the 2 working instruments should optimally be 60° (elevation angles of 30° and Azithmus Angle of 15°- 45°)



- The Working instruments should not face or work against the Telescope as this leads to production of Mirror image and difficult task execution with increased error rate
- Height of operating table should be adjusted between 64 and 77 cm above floor level since this discomfort and operative difficulty are lowest when instruments are positioned at elbow height. [49]
- Ergonomically, the best view for thoracoscopy / laparoscopy is with the monitor image at or within 25 optimal degrees below the horizontal plane of the eye. [50],[51] This leads to least neck strain according to the available studies.
- To facilitate smooth instrument manipulation along with adequate visualisation during thoracoscopy, usually trocars are placed in triangular fashion. This is termed as triangulation.
- The target organ should be 15-20 cm from the centre port used for placing the optical trocar. Generally, the two remaining trocars are placed in the same 15-20 cm arc at 5-7 cm on either side of the optical trocars. This allows the instruments to work at a 60°-90° angle [52]. If necessary, two more retracting ports can be placed in the same arc but more laterally so that instruments do not clash.

- If the angle between the target and instrument if too wide or obtuse, manipulation of curved instrument is very difficult. So most surgeons used to customise trocar position.
- Manasnayakorn et al.[53] have studied in animal models and have indicated that the best task efficiency and performance quality are obtained with an ideal manipulation angle between 45° and 60°. This can be achieved by correct placement of the ports. The 90 manipulation angle had the greatest muscle workload by the deltoid and trapezius of the extracorporeal and intracorporeal limbs and the extracorporeal dominant arm extensor and flexor groups. Manipulation angle ranging from 45° to 75° with equal azimuth angles is recommended. Manipulation angles below 45° or above 75° are accompanied by increased difficulty and degraded performance. Task efficiency was reported be better with equal azimuth angles than with unequal azimuth angles. Achieving equal azimuth angles may be difficult in many practical situations, but in principle, azimuth inequality should be avoided because it degrades task efficiency.
- There exists a direct correlation between the manipulation and the elevation angles. With a manipulation angle of 60°, the corresponding optimal elevation angle which yields the shortest execution time and optimal quality performance is 60°. Wide manipulation angles necessitate wide elevation angles for optimal performance and task efficiency. When a 30° manipulation angle is imposed by the anatomy or build of the patient, the elevation angle should be also 30° as this combination carries the shortest execution time. The best ergonomic layout for endoscopic surgery consists of a manipulation angle ranging from 45° to 75° with equal azimuth angles. [54],[55]
- The suggested position of arm is slightly abduction, retroversion and rotation inwards at shoulder level. The elbow should be bent at about 90°-120°. The surgeon has to remember that moving about and loosening up his hands intermittently is essential to

prevent the buildup of lactic acid and ward off fatigue. [56] Problems related to depth perception, vision and loss of peripheral visual fields can be reduced by using a 10-15X magnification on the optical system offered by the recording camera and the output to the display. This can make life easier while operating, especially when dealing with minute and intricate internal anatomy.

2.12 PORTS USING IN TRIANGLE TARGET PRINCIPLE (TTP)

The experience that BDP may pose difficulties in some VATS procedures led a search for an alternative principle to ensure better task performance. Sasaki and colleagues[14] pointed to the difficulty they experienced in treating thoracic lesions especially peripheral lung lesions using the BDP and they developed and introduced the Triangle Target Principle (TTP) to solve the difficulty. They also concluded that the application of TTP for Ports placement can be used to access and treat all thoracic lesions.

The TTP involves placing 3 Ports to make an equilateral triangle between the Optical port, the 15'' working Instrument and the target. A 3rd port (usually used for grasping forceps introduction) is placed close to the Target and hence called the Target Port. (Figure 12)

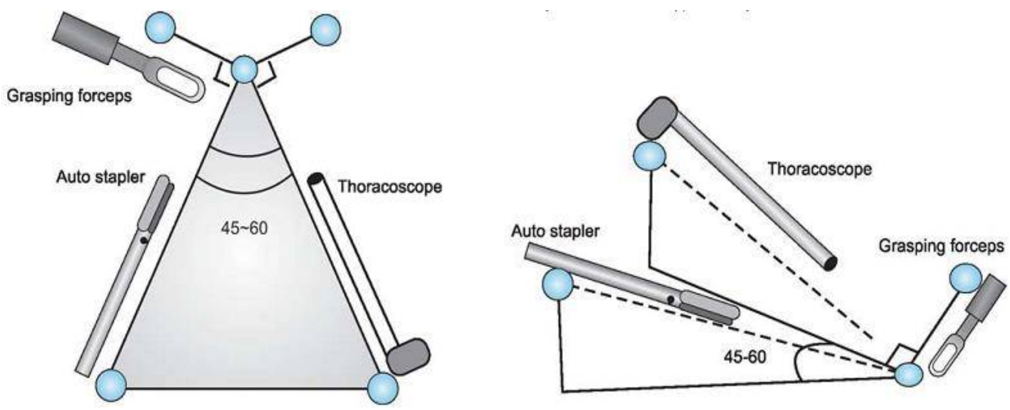


Figure-12: Ports using Triangle Target Principle

For lung tumours, the TTP is indicated in peripheral tumours which are not attached to the lateral chest wall and less than 3 cm in diameter.

Because of the different locations of the thoracic lesions, the TTP is modified based on that and 4 types of TTP were described. Figure-14 (a-d)

- **TYPE** 1: for lesions at the apical and anterior segments of the upper lobe and Superior Mediastinal lesions
- **TYPE** 2: for lesions of the Posterior segments of the Upper Lobe, the Lingular, Right Lateral segment of the middle lobe, 6 and 8 segments of the lower lobes and Upper posterior mediastinal lesions
- **TYPE** 3: for lesions of 9 and 10 segments of the Lower lobes, Lower Posterior Mediastinal lesions and Diaphragmatic lesions
- **TYPE** 4: for lesions of the medial segment of the middle lobe, pericardial lesions and Anterior Mediastinal lesions

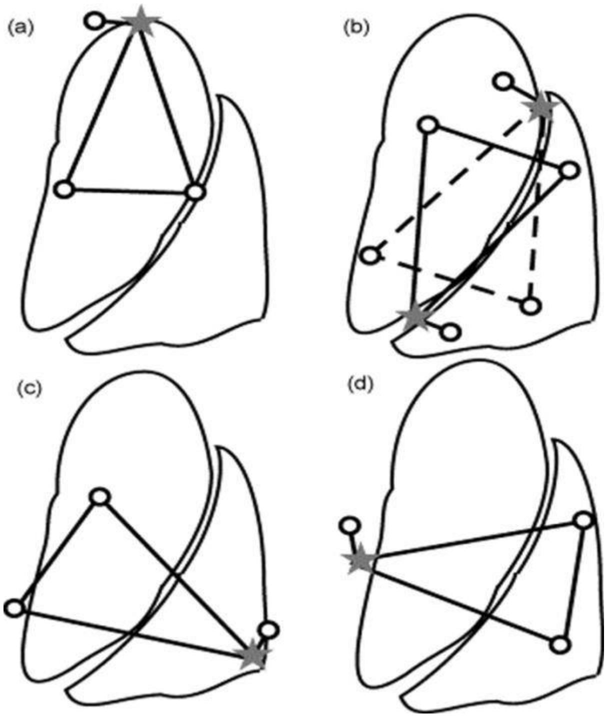


Figure-14: Classification of Triangle Target Principle based on lesion location

2.13 ADVANTAGES OF TTP

Sasaki and colleagues emphasized the advantages of TTP in relation to lung lesions as 89.4% of the patients who TTP Was applied in the study had Lung lesions. These include:

1. The possibility of grasping lung tissue near the Target lesion via the Target Port
2. Easy partial resection of Lung due to the grasping forceps and the stapler meeting at right angle which is the required angle for stapling.
3. Possibility of palpating a peripheral tumour via the Target Port
4. Ease in taking a needle biopsy via the Target Port

2.14 DRAWBACKS OF TTP

These are found mostly with Type 3 TTP and are-

1. Difficulty in determining the site of Trocar placement because proximity of 1st working Port and the Target Port to the Target leading to crowding and swording of Instruments.
2. Mirror imaging

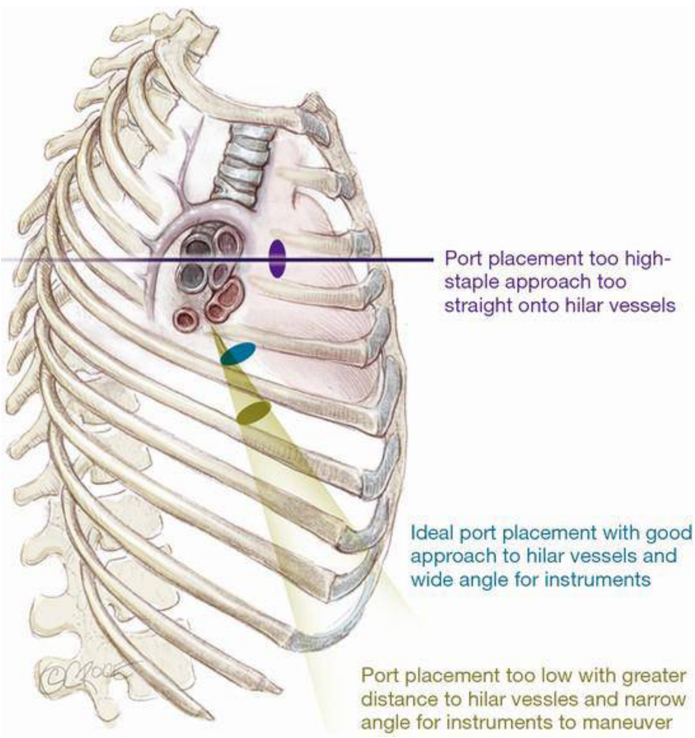


Figure-20: Port related difficulty in VATS

About 98% of their patients had successful Surgery without major complications and only 3 patients (1.9%) required modification of the TTP. The non-Pulmonary cases were 17 (10.6%) and 94.22% had successful surgery. Only one Pericardial Window (5.88%) required a Mini-thoracotomy. Thus from that study TTP was successful for both Lung lesions and non- Lung lesions.

Takao and Colleagues[15] reported using a similar TTP principle earlier but subsequently developed a fixed—style Principle for Ports Placement. For Right VATS, the Optical Port is placed at 4^{th} Intercostal space along the Anterior Axillary Line, 1^{st} working instrument at 6^{th} intercostal space along the mid-axillary line and the 2^{nd} working port at the 6^{th} intercostal space along the posterior axillary line.

For Left VATS, the Optical Port is placed at the 6^{th} intercostal space along posterior axillary line, the 1^{st} working instrument at the 6^{th} intercostal space along the mid-axillary line and the 2^{nd} working port at the 4^{th} intercostal space along the Anterior axillary line. The Ports can be shifted one intercostal space above or below depending on whether the lesion is in the Upper or Lower Chest.

Rocco[16] on the other hand compared principles of TTP with Uniportal VATS. He pointed to the Superiority of the Uniportal VATS which incorporates the TTP principles in addition to its other advantages. In response, Sasaki and colleagues argued and stressed that TTP is superior to Uniportal VATS in Mediastinal and Diaphragmatic lesions and Lower Lobe basal segmental lesions.

TTP is also employed during some laparoscopic procedures. An alternative Ports Placement in Laparoscopic Appendicectomy when cosmesis is a major concern use the TTP principles. The Optical Port is placed at the Umbilicus, the 1^{st} working port at the Left Iliac fossa and the Target port at the Right Iliac Fossa.

2.15 LUNG RESECTION:

Minimally invasive lung resection has replaced thoracotomy as the standard of care for early-stage lung cancer. The early pioneers of this technique have accomplished their goal of establishing a safe and predictable method for minimally invasive lung resection that allows patients a much faster recovery with equivalent oncologic effectiveness. Furthermore, the authors' assertion that minimally invasive anatomic segmentectomy may offer patients more accurate staging and, potentially, improved survival when compared with SABR is important to consider. A crucial point for the physician caring for lung cancer patients to be clear on is whether the thoracic surgeon is utilizing all the advantages of VATS resection: no rib spreading, no large incisions, thorough lymph node sampling, and complete anatomic dissection/division of the hilar structures. Finally, robotic-assisted lung resection is gaining momentum among thoracic surgeons because it allows the operating surgeon the convenience of performing a dissection that in many ways is similar to open surgery, yet that has the advantages of a minimally invasive approach. Hopefully, surgical robotics, along with VATS, will make it possible for the thoracic surgery community to offer minimally invasive lung resection to nearly all early-stage lung cancer patients.

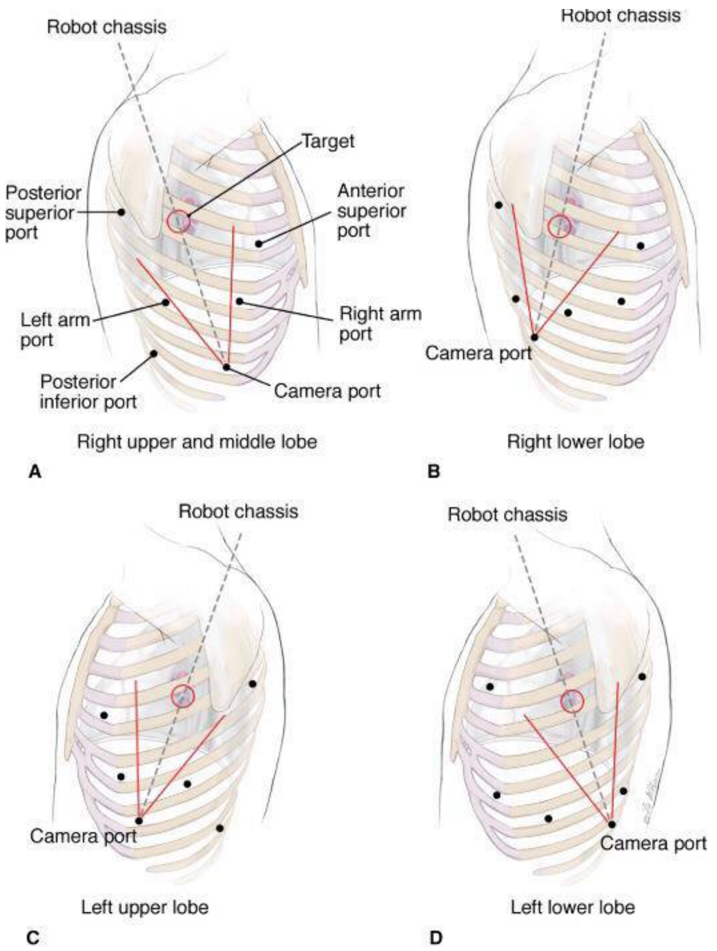


Figure-20: Robotic Port Placement for lung resection

Most of the thoracic surgery procedures now a days routinely performed by surgeons using a minimally invasive technique.

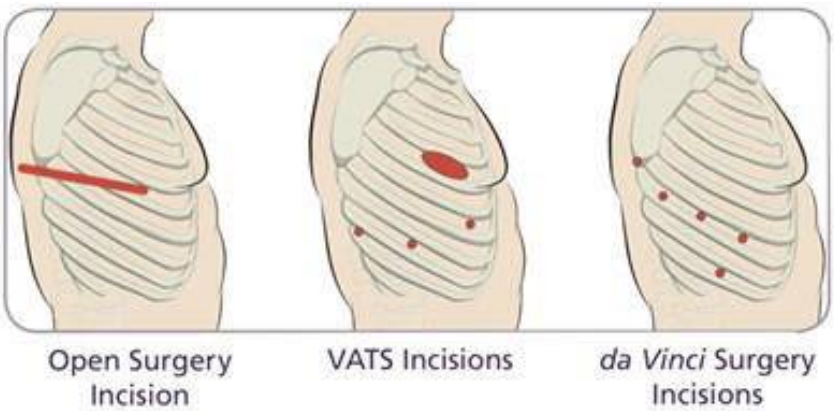


Figure-11: Different access incisions to enter in chest cavity

VIDEO-ASSISTED LOBECTOMY

Lobectomy (removal of a large section of the lung) is the most common surgery performed to treat lung cancer. Lobectomy has been traditionally performed during thoracotomy surgery. During thoracotomy surgery, an incision is made on the side of the chest between the ribs. The ribs are then spread apart so the surgeon can see into the chest cavity to remove the tumor or affected tissue.

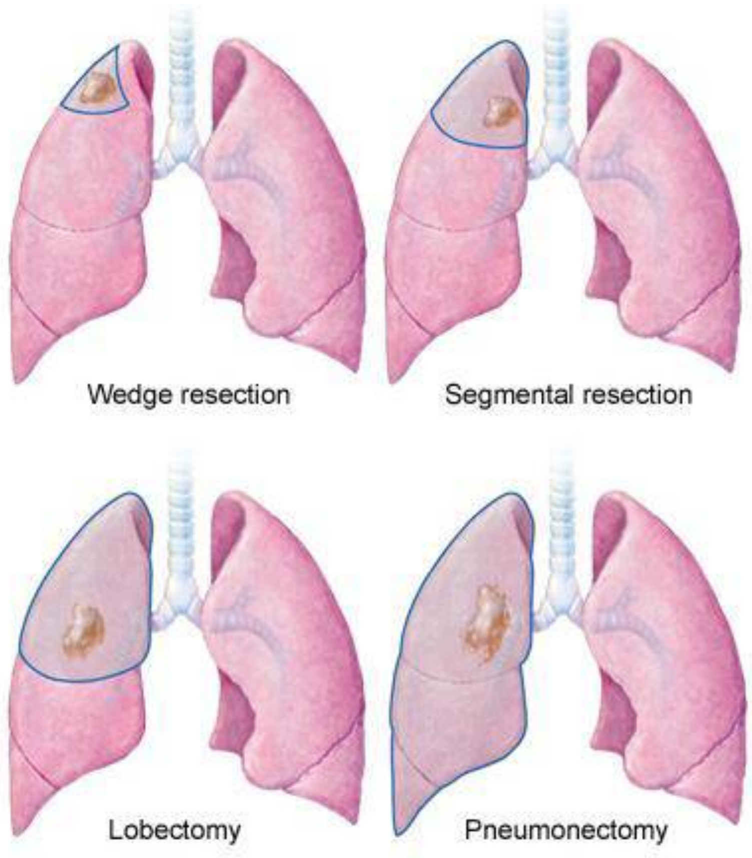


Figure : lung resection depending on location of pathology

Minimal access surgeons routinely perform lobectomy using a minimally invasive approach. During video-assisted lobectomy, three 1-inch incisions and one 3- to 4-inch incision are made to provide access to the chest cavity without spreading of the ribs. The patient experiences a more rapid recovery with less pain and a shorter hospital stay (usually 3 days) with video-assisted lobectomy as compared with traditional thoracotomy surgery. The surgical outcomes of video-assisted lobectomy are comparable to traditional lobectomy outcomes.

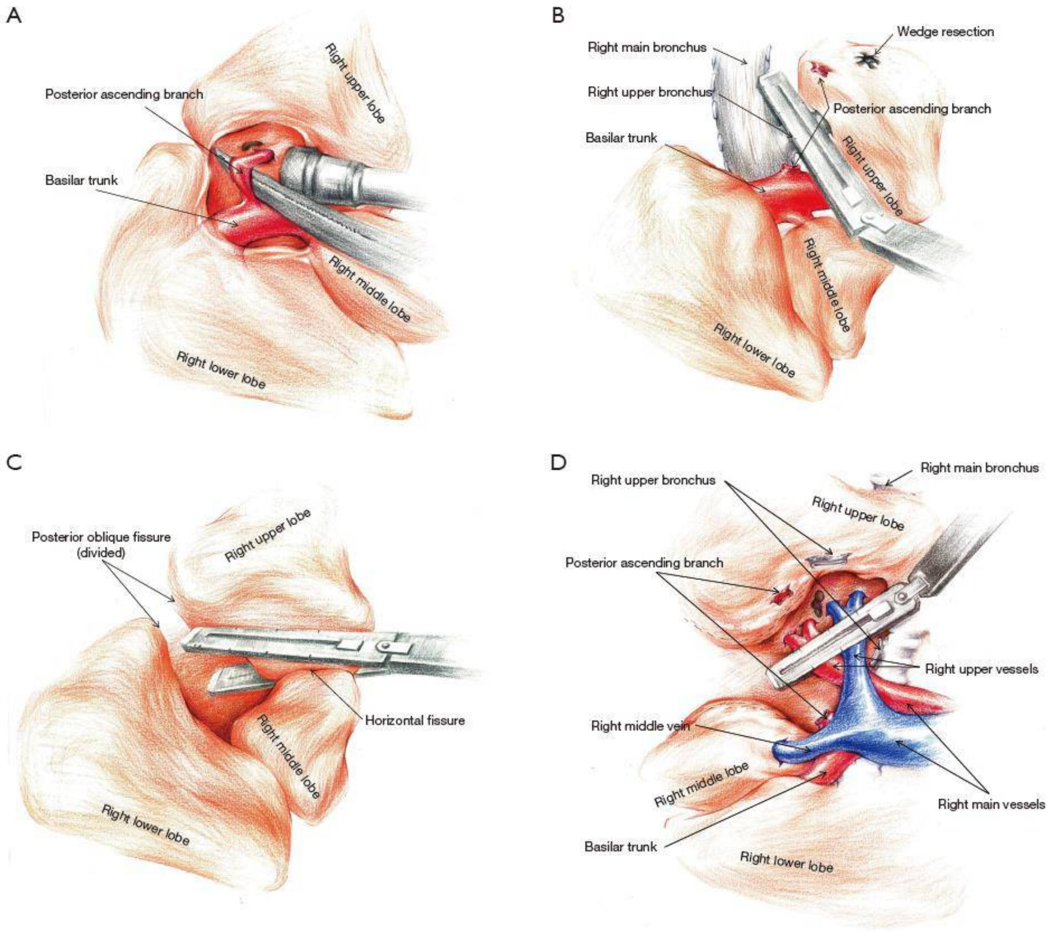


Figure-16: Procedural diagram of lobectomy

Although minimally invasive approaches are considered for every patient, in some cases, patients who have a large or more central tumor may not be candidates for video-assisted lobectomy.

Wedge Resection

A wedge resection is the surgical removal of a wedge-shaped portion of tissue from one, or both, lungs. A wedge resection is typically performed for the diagnosis or treatment of small lung nodules.

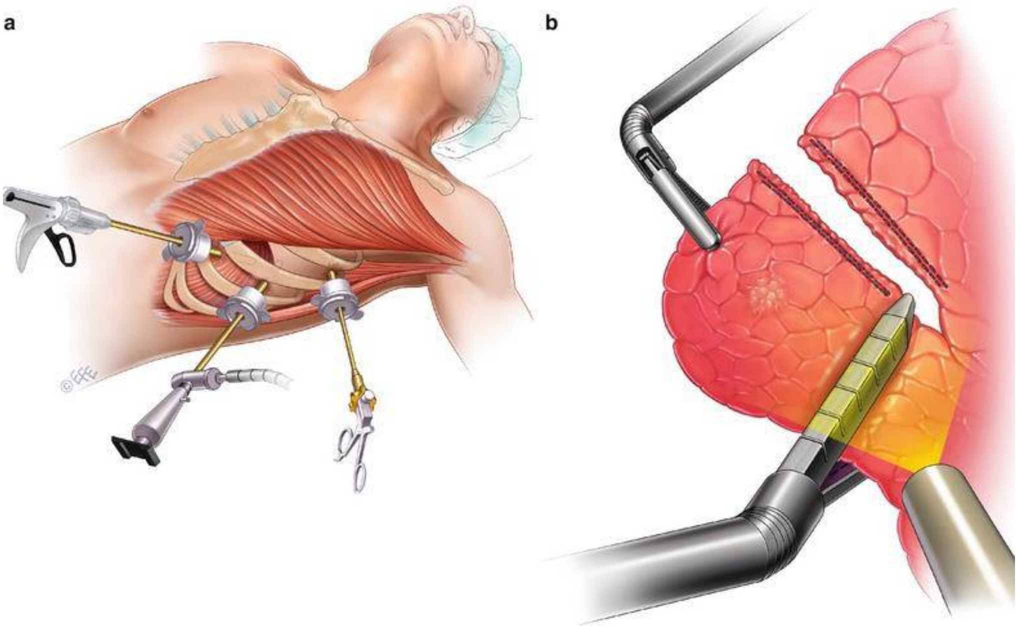


Figure-17: Wedge Resection

Lung Biopsy

A lung biopsy is a procedure in which a small sample of lung tissue is removed through a small incision between the ribs. The lung tissue is examined under a microscope by expert pathologists and may also be sent to a microbiological laboratory to be cultured. The lung tissue is examined for the presence of lung diseases such as infectious or interstitial lung disease.

Drainage of Pleural Effusions

A pleural effusion is the build-up of excess fluid between the layers of the pleura – the thin membrane that lines the outside of the lungs and the inside of the chest cavity. Normally, very little fluid is present in this space. The excess fluid is removed (drained) during a thoracoscopic procedure called thoracentesis and may be collected for analysis to indicate possible causes of pleural effusion such as infection, cancer, heart failure, cirrhosis, or kidney disease. Sterile talc or an antibiotic may be inserted at the time of surgery to prevent the recurrence of fluid build-up.

Stapling devices have been introduced for safety and to reduce the overall operative time in many surgical procedures. In hepatobiliary surgery, i.e. liver resection, several types of staplers are in use. While transection of hepatic vessels with vascular staplers is well established, their use in dissecting hepatic parenchyma has only been assessed recently. Its advantages were especially a low rate of biliary complications (i.e., bile fistulas, bilioma) and reduced bleeding. Recently it has been introduced in lung resection also. The success also observed in several cases. As expected, the operative time was decreased dramatically while both the complication rate in general and the overall costs for stapler were comparable with other techniques used in high-volume centers. Thus, endo-GIA vascular staplers can be safely used to dissect the hepatic as well as lung parenchyma in a routine clinical setting with low incidence of surgical complications.

2.7.3.3 THYMECTOMY

Thymectomy is most commonly indicated and performed for myasthenia gravis (MG), thymoma, and other anterior mediastinal tumors (1-6). While median sternotomy has long been the accepted standard approach, minimally invasive methods have emerged over recent decades including transcervical, video-assisted thoracoscopic (VATS), and robotic video-assisted thoracoscopic (R-VATS) approaches (7-11). While maintaining safety and surgical veracity remain the first priority, in appropriately selected patients, minimally invasive approaches aim to lower postoperative morbidity and improve post-operative quality of life. However, there remains debate regarding the indications, selection, and outcomes of patients undergoing these procedures versus open resections (12-31).

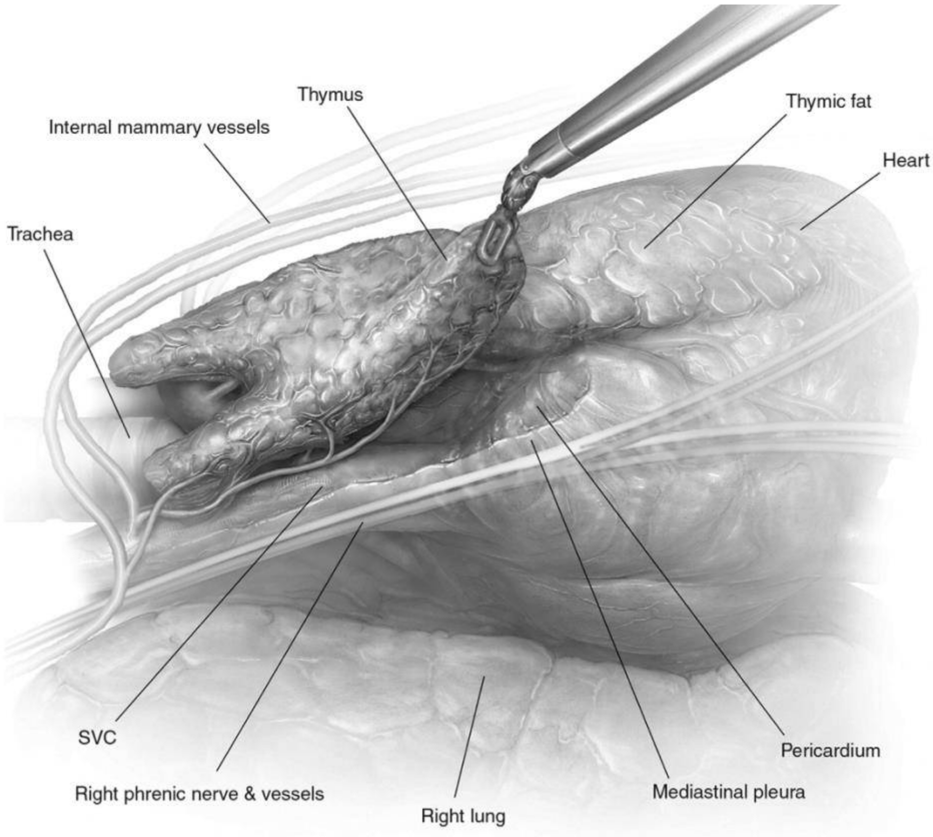
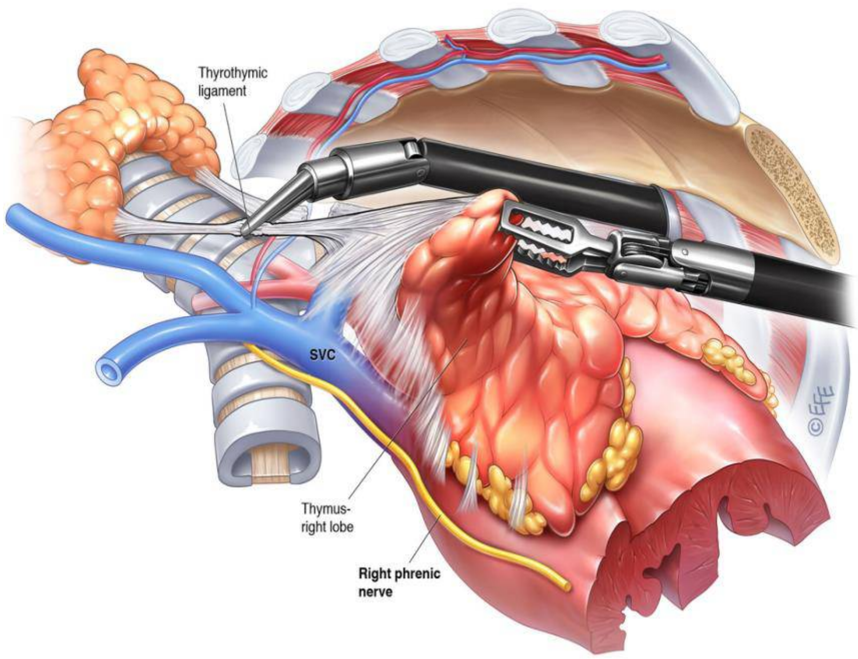


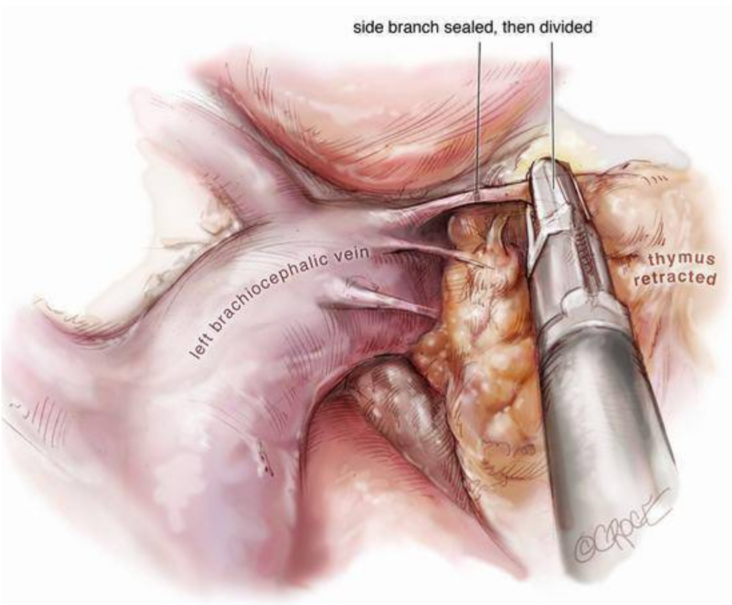
Figure-16: Structures around Thymus to noted during disection

Thymectomy is an acceptable therapy in the comprehensive care of myasthenia gravis (MG) and in undetermined lesions (not thought to be lymphoma) that are found within the anterior mediastinum by cross-sectional imaging (1-3). Primary epithelial thymic tumors are discovered in approximately 50% of all anterior mediastinal masses, of which thymoma is the most common (4,5). The efficacy of surgery in managing thymic diseases, including the ability to improve symptoms of inadequately controlled myasthenia, is contingent upon complete excision of all thymic and perithymic adipose tissue (6).

Video-assisted thoracoscopic surgery (VATS) and the da Vinci robotic system (Intuitive Surgical Inc., Sunnyvale, CA, USA) offer a minimally invasive approach to thymectomy with potentially less morbidity. However, controversy exists regarding the appropriateness of minimally invasive thymectomy (MIT) when employed for surgical resection of thymoma and other malignant neoplasms. Although evidence substantiating MIT as an effective treatment with less operative trauma, shorter length of hospital stay, fewer pulmonary complications and more satisfactory cosmetic results without compromising surgical outcomes is available, few studies have compared the two MIT approaches (7,8). More study is required to analyze patient and surgical outcomes in experience with VATS and robotic-assisted thymectomy.



In appropriately selected patients with MG, or with moderate to small sized thymoma, therapeutic outcomes of MIT are comparable to OT, and may result in shorter hospital length of stay, decreased blood loss, and potentially fewer post-operative complications. Right or left VATS approaches appear to be comparable in outcome and a matter of surgeon preference. While robotic assisted approaches may afford the surgeon improved control and visualization during the conduct of operation, clinical outcomes appear to be similar to VATS. Cost analyses remain indeterminate, with MIT likely incurring higher operational costs than OT, but with potentially overall lower cost due to decreased length of hospital stay. The impact of robotic assisted approaches on cost remain a significant unknown, with “common” wisdom suggesting higher costs due to the high capital costs of these platforms, but with few formal analyses investigating this assumption. Prospective, randomized, controlled trials will likely be necessary to better delineate the differential outcomes and costs between open and minimally invasive approaches in these patients.



MIT can be performed for both non-neoplastic and neoplastic thymic diseases with minimal morbidity and mortality. While gaining experience with the da Vinci robotic system (Intuitive Surgical, Inc., USA), still perform of VATS thymectomy should be more common at institutions.

Data suggest that currently VATS thymectomy is perform with greater surgical efficiency, less blood loss, less need for tube thoracostomy, and are able to discharge patients slightly earlier than robotic-assisted procedures. It has been estimated that 50 identical robotic cases are required to perform any specific robotic surgery with consistent operative time and predictable outcome. With this learning curve in mind, consideration of MIT should be pursued for all symptomatic MG patients with inadequate medical treatment and for all locoregional thymic neoplasms in patients who can tolerate single lung ventilation and in whom complete resection appears feasible.

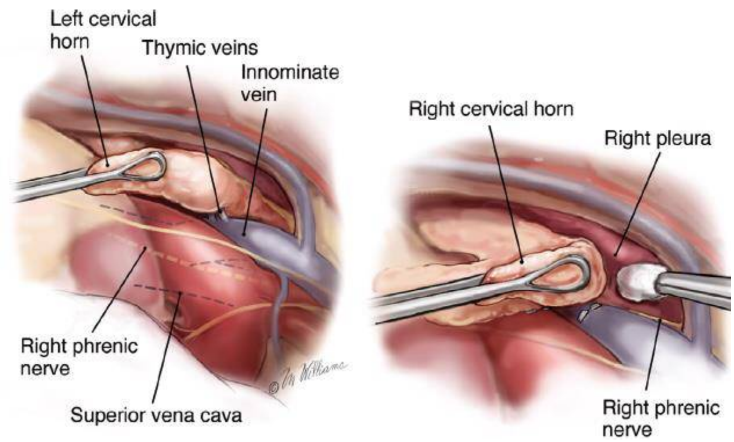


Figure: Dissection of thymus

PORT PLACEMENT IN VATS THYMECTOMY: TTP

Video-assisted thoracic surgery (VATS) for the management of non-thymomatous myasthenia gravis (MG) as well as the management of small thymomas and other benign thymic pathology has been gaining in acceptance and popularity as an alternative to the traditional median sternotomy approach. Access from the right chest is generally easier. Although VATS thymectomy has been described in several variations, current preference is a left sided VATS approach due to the exposure it provides in critical areas of dissection. The anesthetist places a double lumen tube to allow isolation of the required lung.

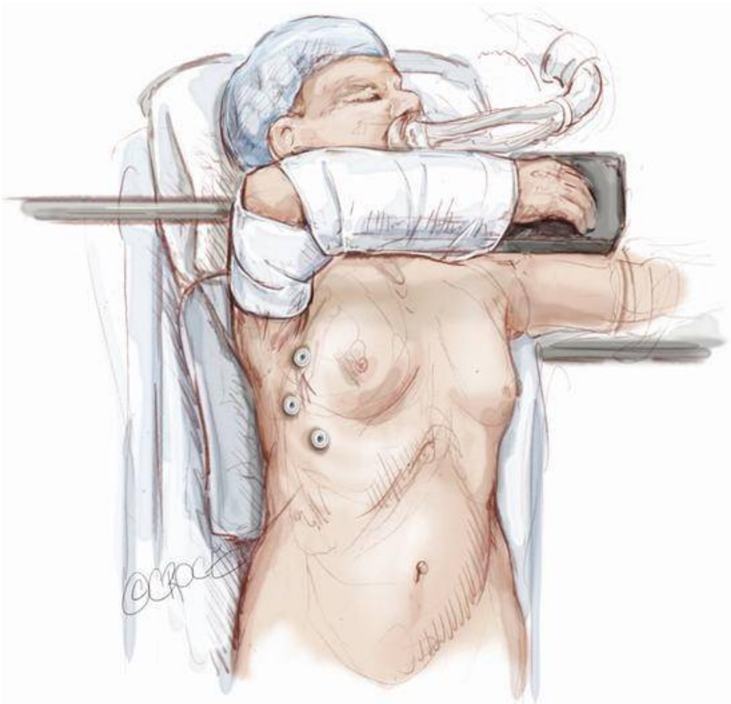


Figure 6A. Position for right VATS thymectomy.

The patient is placed with the chest elevated to an angle of around 30 degrees. This allows the plane between the sternum and thymus to be developed easily, while minimizing instrument clashes. The arm lies secured beside the chest.

The chest wall is prepared from the posterior axillary fold to beyond the sternum, and from the jugular notch to just below the xiphisternum. This leaves the entire sternum exposed, making quick conversion to sternotomy possible if needed.

Video-Assisted Thoracoscopic Thymectomy Using 5-Mm Ports and Carbon Dioxide Insufflation

Three 5-mm ports (Versaport, Covidien) along the lateral border of the breast gland are used. The first port is created with a 5-mm skin incision. A dissector is introduced using blunt dissection along the upper edge of the sixth intercostal space in the mid-axillary line in order to create a pneumothorax. A 5-mm port with a trocar is then introduced into the same incision and a 5-mm, 30-degree thoracoscope (Endoye, Olympus) is used for inspecting the thoracic cavity for potential adhesions and pathology. Carbon dioxide (CO_2) insufflation is installed using a pressure limit of 6–8 mmHg. Under thoracoscopic guidance, a second 5-mm port is bluntly introduced using a trocar into the anterior axillary line in the third intercostal space and a third 5-mm port placed in the midclavicular line into the sixth or seventh intercostal space. This latter incision is expanded at the end of procedure to 1–3 cm according to the size of the specimen to be resected.

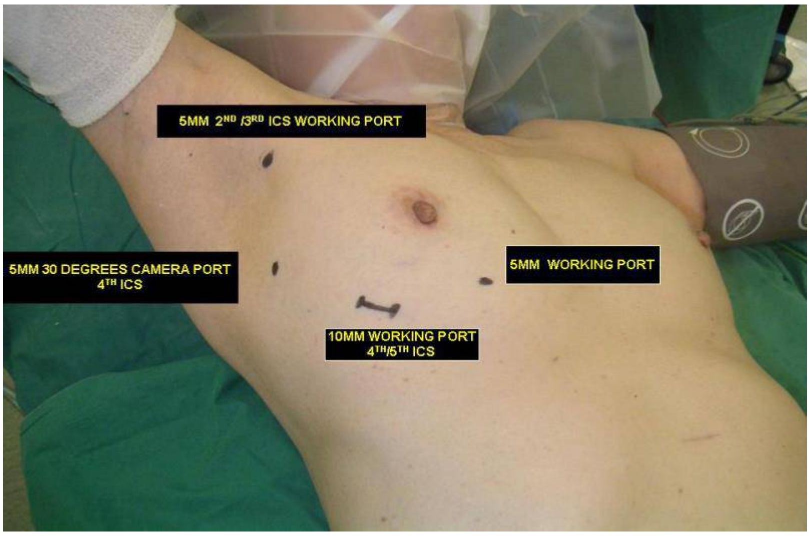


Figure 6B. Right VATS thymectomy incisions

Figure 6C. Left VATS thymectomy incisions

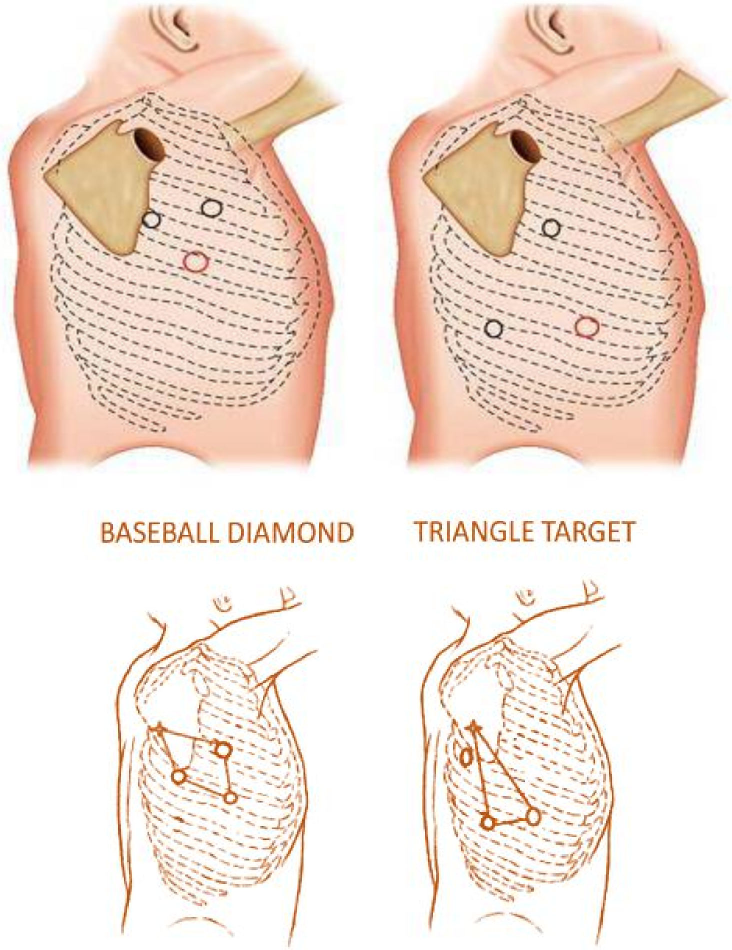


Figure 7: Ports placement in VATS Thymectomy using TTP

2.17 ATRIAL SEPTAL DEFECT

An atrial septal defect is an abnormal opening in the atrial septum. The atrial septum is the dividing wall between the two upper chambers of the heart. It can be a congenital (present at birth) heart defect, or it can result from the failure of normal postnatal closure of a hole that is present in the heart of every fetus.

Normally, oxygen-poor (blue) blood returns to the right atrium from the body, travels to the right ventricle, then is pumped into the lungs where it receives oxygen. Oxygen-rich (red) blood returns to the left atrium from the lungs, passes into the left ventricle, and then is pumped out to the body through the aorta.

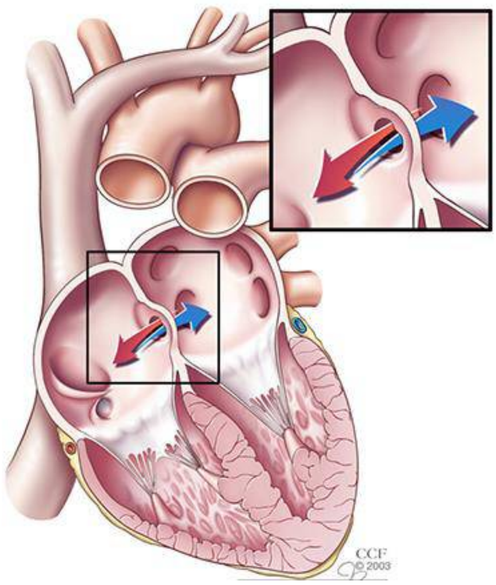


Figure-17: Schematic drawing showing the ASD

An atrial septal defect allows oxygen-rich (red) blood to pass from the left atrium, through the opening in the septum, and then mix with oxygen-poor (blue) blood in the right atrium.

Atrial septal defects occur in a small percentage of children born with congenital heart disease. For unknown reasons, girls have atrial septal defects twice as often as boys.

Types of atrial septal defects

There are four major types of atrial septal defects:

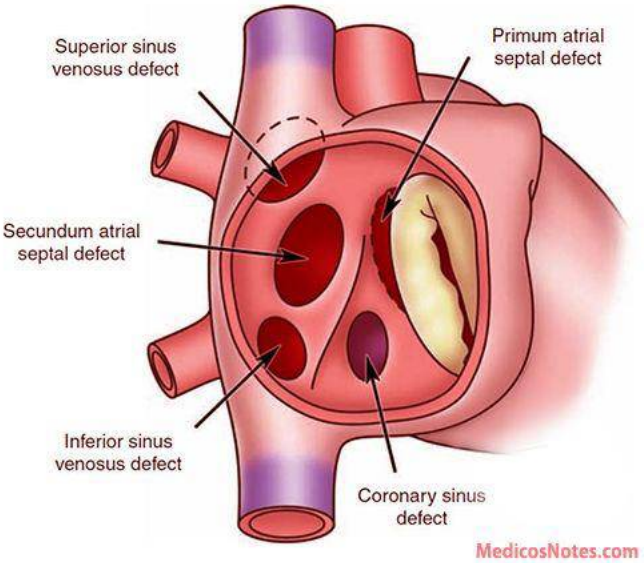


Figure-18: Schematic drawing showing the location of different types of ASD, the view is into an opened right atrium.
1: upper sinus venosus defect; 2: lower sinus venosus defect;
3: secundum defect; 4: defect involving coronary sinus;
5; primum defect.

- **Ostium secundum atrial septal defect:** This is the most common atrial septal defect, affecting over two-thirds of people with atrial septal defects. It is caused when a part of the atrial septum fails to close completely while the heart is developing. This causes an opening to develop in the center of the wall separating the two atria.
- **Ostium primum atrial septal defect:** This defect is part of atrioventricular canal defects, and is associated with a split (cleft) in one of the leaflets of the mitral valve.
- **Sinus venosus atrial septal defect:** This defect occurs at the superior vena cava and right atrium junction, in the area where the right pulmonary veins enter the heart. As a result, the drainage of one or more

of the pulmonary veins may be abnormal in that the pulmonary veins drain to the right atrium, rather than the left atrium.

- **Coronary sinus atrial septal defect:** This defect is located within the wall of the coronary sinus, where it passes behind the left atrium. The coronary sinus carries the blood flow from the heart's own vein, into the right atrium. It is the rarest of all atrial septal defects.

SYMPTOMS OF AN ATRIAL SEPTAL DEFECT

Many children have no symptoms and seem healthy. However, if the ASD is large, permitting a large amount of blood to pass through to the right side of the heart, the right atrium, right ventricle, and lungs will become overworked, and symptoms may be noted. Many children with ASD will have no symptoms. Some children, however, may have the following:

- Child tires easily when playing
- Fatigue
- Rapid breathing
- Shortness of breath
- Poor growth
- Frequent respiratory infections
- The symptoms of an atrial septal defect may resemble other medical conditions or heart problems.

TREATMENT OF ATRIAL SEPTAL DEFECT

Specific treatment for ASD will be determined based on:

- Child's age, overall health, and medical history
- Extent of the disease
- Child's tolerance for specific medications, procedures, or therapies
- Expectations for the course of the disease

Secundum atrial septal defects may close spontaneously as a child grows. Once an atrial septal defect is diagnosed, periodic checkup is needed to see whether it is closing on its own. Usually, an ASD will be repaired if it has not closed on its own by the time a child starts school. This is to prevent lung problems that will develop from long-time exposure to extra blood flow. The decision to close the ASD may also depend on the size of the defect. Atrial septal defects are typically repaired in childhood to prevent problems later in life.

Treatment may include:

- **Medical management:** Many children have no symptoms, and require no medications. However, in rare circumstances, children may need to take medications to help their heart work better, since the right side is under strain from the extra blood passing through the ASD. Medications may be prescribed, such as diuretics. Diuretics help the kidneys remove excess fluid from the body. This may be necessary because the body's water balance can be affected when the heart is not working as well as it could.
- **Device closure:** Device closure is frequently done for secundum ASD, depending on the size of the defect and the weight of the child. During the cardiac catheterization procedure, the child is sedated and a small, thin, flexible tube (catheter) is inserted into a blood vessel in the groin and guided to the inside of the heart. Once the catheter is in the heart, the cardiologist will pass a special device, called a septal occluder, into the open ASD, preventing blood from flowing through it.
- **Surgical repair:** Child's ASD may be repaired surgically in the operating room. The surgical repair is done under general anesthesia. The defect may be closed with stitches or a special patch.

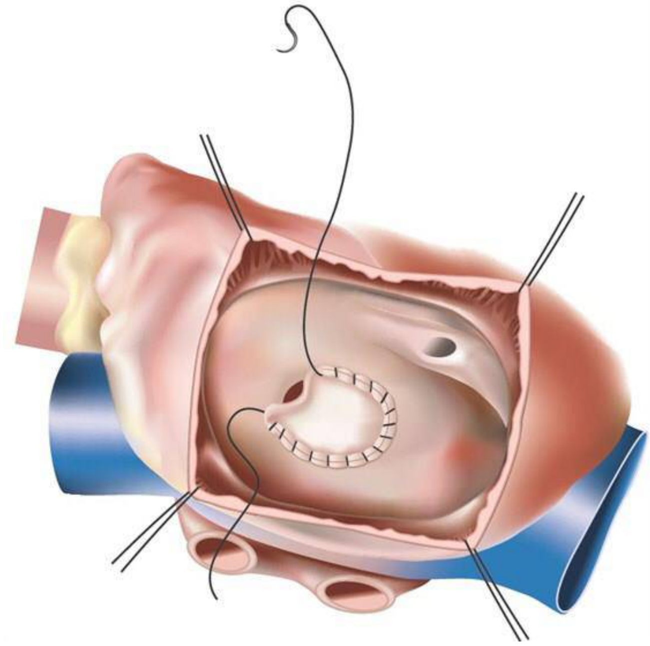


Figure: Surgical Repair of ASD

TOTALLY THORACOSCOPIC ASD CLOSURE:

Atrial septal defect (ASD) is one of the most common congenital cardiac defects. Many ASDs can now be closed with septal occluder devices through cardiac catheterization.[1] But large ASDs might not be suitable for transcatheter closure and require primary surgical repair.[2] Minimally invasive surgical approaches have been applied to repair ASDs to minimize surgical trauma and improve cosmetic results.[3, 4, 5, 6] In recent years, totally endoscopic techniques have also been developed for ASD closure.[6, 7, 8, 9, 10] Totally endoscopic procedures require the aid of computer and robotic technologies and are associated with excellent success rates in ASD closure and low complication rates.[4, 5, 6, 7, 8] Totally endoscopic repair of ASDs can be done through 3 small incisions in the right chest.

ANAESTHESIA:

After induction of general anesthesia, a left-sided double-lumen endotracheal tube placed to allow single-lung ventilation. The respiration rate to be set between 18 and 30 breaths/min, and the arterial oxygen saturation rate to be maintained at greater than 97%.

SURGICAL PROCEDURE (totally thoracoscopic technique):
Surgical closure can be done both on pump or off pump.

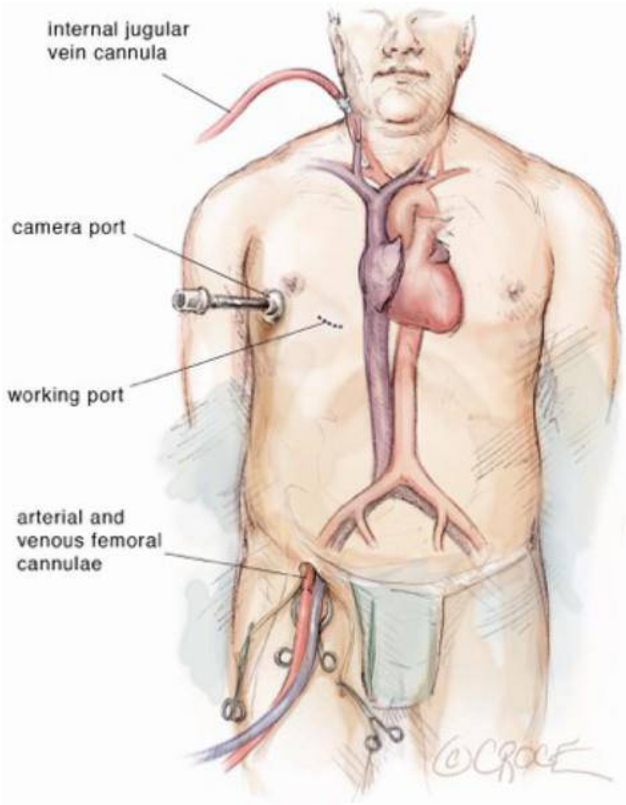


Figure : Femoral arterial and venous canulation for CPB

ON PUMP PROCEDURE: (on arrested heart)

The patient to be placed in the supine position with the right side of the body elevated to 15° to 20°. After systemic heparinization, the right femoral artery and vein to be accessed through an oblique incision along the inguinal crease, as previously reported by Bonaros and colleagues.10 A 24F/29F Carpentier double-lumen catheter (Medtronic, Inc) to be inserted through the right femoral vein into the inferior and superior vena cava. The bypass circuit to be completed by positioning a 17F or 21F catheter (Medtronic, Inc) in the abdominal aorta through the right femoral artery.

Three small incisions (ports) were made on the right side of the chest. Port 1 (1–1.5 cm) to be located in the fourth intercostal space on the right side of the sternum (Figure 1) for instrument like tissue forceps or suture needles. Port 2 (1–1.5 cm) for the entry of instruments, such as scissors, handled by the right hand of the operator and is located in the sixth intercostal space on a midclavicular line (Figure 1). Port 3 (1.5–2.0 cm) to be placed in the fifth intercostal space on the right midaxillary line for the placement of an endoscopic camera.

Entering to the chest, pericardiotomy done, 3 to 4 sutures are placed to suspend the pericardium. Caval snares to be placed in the superior and inferior vena cavae for total cardiopulmonary bypass (CPB). After CPB initiation and cooling to 32°C, the thoracoscopy is placed through port 2 to visualize the aortic root. An aortic crossclamp to be positioned on the ascending aorta (Figure 3). A needle then inserted through port 3 to the aortic root for the delivery of cold cardioplegic solution to achieve cardiac arrest.

The thoracoscopy then repositioned through port 3 to visualize right atrium. A tissue forceps and a scissors are entered through ports 1 and 2, respectively. After snaring of the superior and inferior vena cavae, the right atrium to be opened from a site parallel to the atrioventricular annulus, and 4 stay sutures placed on the incision to expose the atriam. The ASD can be closed with direct 4–0 Prolene sutures or in case large defect pericardial patch or PTFE can be used to repair with running Prolene sutures.

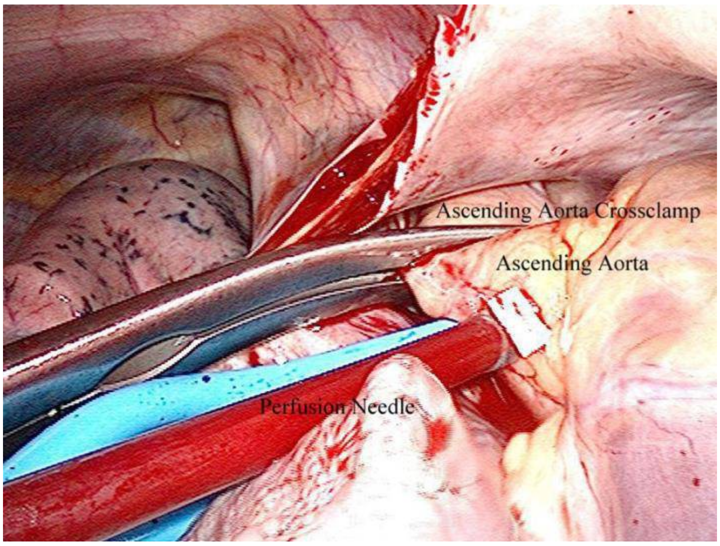


Figure 3. Ascending aortic crossclamp.

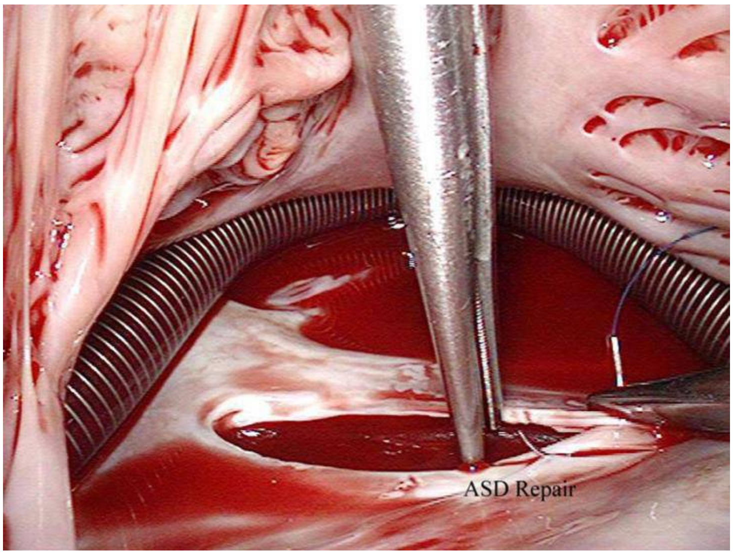


Figure 4. Repair of atrial septal defect (ASD).

After ASD closure, the aortic crossclamp to be released, patient rewarmed & weaned from CPB. Protamine sulfate (1:1) to be administered to counteract the actions of heparin. After adequate haemostasis all instruments to be removed from the chest, and a 24F chest tube to be inserted in the right pleural space through port 2 for drainage. Reconstruction of femoral artery and femoral vein to be done after removal of cannulas. The integrity of the ASD closure to be confirmed by means of transesophageal echocardiographic analysis.

ON BEATING HEART TECHNIQUE:

Under general anaesthesia, a single- or double-lumen endotracheal tube was placed to allow for single-lung or double-lung ventilation. Patients were positioned in the supine position with the right side of the body elevated to 15–20°. After systemic heparinization, a Carpentier double-lumen catheter (16F/20F, 20F/24F, 24F/29F or 30F/33F, Medtronic) was inserted through the right femoral vein into the inferior and superior vena cava. The bypass circuit completed by positioning a catheter (7F, 12F, 14F or 21F, Medtronic) in the abdominal aorta through the right femoral artery. On the right side of the chest, three 1–1.5 cm incisions were made in the fourth intercostal space on the right side of the sternum, in the sixth intercostal space on a mid-clavicular line and in the fifth intercostal space on the right mid-axilliary line, respectively. These incisions allow the entry of tissue forceps, or suture needles or scissors, and thoracoscopy.

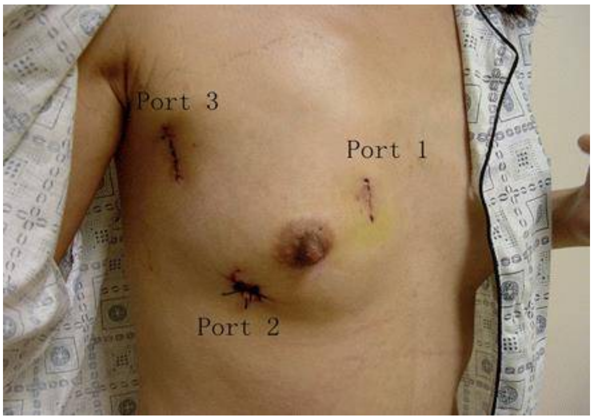


Figure : Location of the three ports on the right chest wall.

Pericardiotomy to be performed and caval snares to be placed in the superior and inferior vena cava to install total CPB. Core body temperature to be reduced to 32°C. Thoracoscopy inserted in to the chest through port 1 to visualize the aorta. A large perfusion needle then inserted into the root of the aorta through port 3 on the chest, and to be connected to the left heart suction tube to exhaust in left ventricle. The aorta has not cross-clamped, to be perfused with normothermic oxygenated blood throughout the procedure. The thoracoscopy then repositioned through port 3 to visualize the right atrium. Ports 1 and 2 to be used for the entries of scissors and tissue forceps, respectively. On the beating heart, right atriotomy done from a site parallel to the atrioventricular annulus, and a suction tube inserted in the coronary sinus ostium through port 1 to keep the operation field bloodless. The internal structures of atrium to be exposed and the ASD closed by direct 4-0 prolene sutures in small ASD. PTFE patch closure can be used to repair larger ASD using running prolene sutures. The right atrium subsequently closed with sutures, and the integrity of the ASD closure to be assessed by transoesophageal echocardiography. Left atrial and ventricular de-airing to be performed at the end of the ASD closure by aspiration of air from the left ventricle through the perfusion needle in the aortic root. After adequate haemostasis all instruments to be removed from the chest, and a 24F chest tube inserted in the right pleural space through one of the chest ports for drainage.

PERIOPERATIVE MANAGEMENT:

Like any surgical intervention, education and counselling on surgical techniques, possible outcomes, potential complications, and postoperative self-care measures. Lung function tests to be routinely performed. The lungs are inflated every 20 minutes during the operation.

After the operation, patients to be monitored in the intensive care unit overnight and received low-frequency, high-volume mechanical ventilation with a peak end-expiratory pressure of 3 to 5 cm H_2O. Bedside chest radiographic analysis to be routinely performed in the intensive care unit to exclude complications in the lungs. Mechanical ventilation to be ceased once the patient's hemodynamics and spontaneous respiration stabilized. Patients to be encouraged to perform respiratory exercises and have regular coughs. Chest physiotherapy is helpful to expel collected secretion from lungs. Frusemide (1 mg/kg/day, i.v.) with methylprednisolone (0.5 mg/kg/day, i.v., once daily) to be used in all patients to prevent pulmonary oedema. [10] Non-steroidal anti-inflammatory drugs to be prescribed to all patients for post-operative pain relief. For patients with severe pain not relieved by simple analgesics, opioid analgesics (intravenous fentanyl) to be provided.

Totally thoracoscopic ASD repair can successfully performed and patient can be discharged from the hospital 4 to 6 days after the operation. No patient underwent reoperation for bleeding.

The CPB and aortic crossclamp time is 50–100 minutes. Once the aortic clamp is removed, heart beat resumed spontaneously. But some time a 50-W DC shock through the chest wall is required to reboot the heart beat. Some patients required intravenous fentanyl (5–10 μg/kg/day) for 1 to 2 days after the operation for pain relief. The remainder can be treated with simple analgesics, mostly paracetamol. In all patients transesophageal echocardiographic analysis immediately after ASD repair showed complete closure with no residual shunt.

Sometime patient required blood transfusion, lung infection to be treated with antibiotics. patient might have atrial fibrillation but spontaneously returned to sinus rhythm 4 hours after the operation.

Usually there is no complications from the cannulation sites in the femoral vein or artery. Patients should be followed up for 2 to 9 months to see the signs of residual shunt on transthoracic echocardiographic analysis.

There have been several studies on endoscopic repair of congenital cardiac defects, such as ASD, VSD Initially, this robotically assisted endoscopic technology was used to maximize visualization of intracardiac structures by providing enhanced endoscopic camera control and to facilitate the manipulation of surgical instruments through limited thoracic incisions. Later, several authors reported ASD repair entirely through thoracoscopic port incisions, with a high success rate and very few complications and with no need for conversion to full sternotomy or minithoracotomy.[6, 7, 8, 9, 10] Totally endoscopic ASD repair minimized the degree of invasiveness, hastened postoperative recovery, and improved quality of life.

The currently used totally endoscopic techniques rely on a robotic surgical system, which might be a potential issue for some developing countries in which the high costs of these computerized systems could be ultimately passed on to patients.

Non-robotically assisted totally thoracoscopic closures of ASD on perfused beating hearts are feasible and safe. These procedures are associated with a shorter operation time and a shorter hospital stay than in surgeries on cardioplegic arrested hearts.

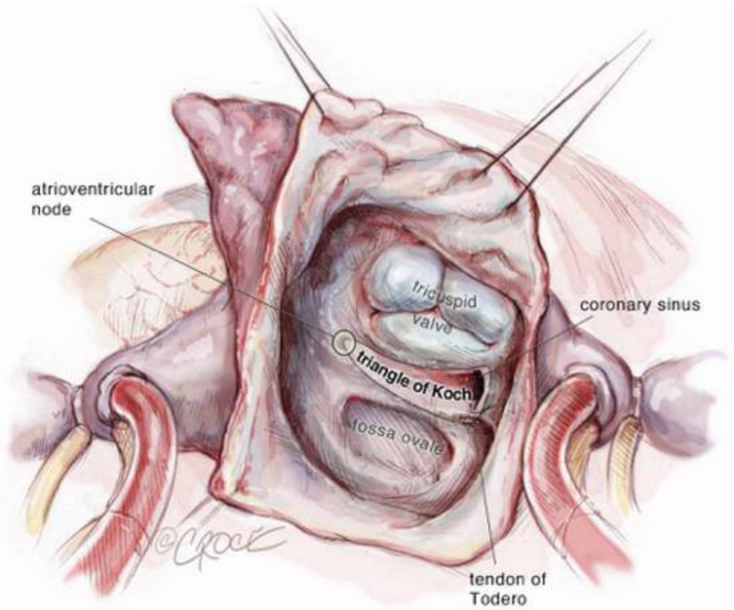
Cardiac surgeries involving CPB and cardioplegic arrest are associated with several pathophysiological processes that may contribute to myocardial ischaemia and tissue injuries. CPB is known to activate a systemic acute phase reaction of protease cascades and to stimulate platelets that result in tissue injuries [11]. Cardiac or other organ dysfunction may ensue in patients with an excessive inflammatory response or in those with limited functional reserve [11]. In addition, aortic cross-clamping and cardioplegic arrest is associated with myocardial ischaemia and reperfusion injuries. To avoid these potential disadvantages associated with CPB and cardioplegic arrest, cardiac surgeries on beating hearts have been developed for coronary bypass grafting or mitral valve repair [11–15].

Gao et al. [17] recently used a robotically assisted surgical system to perform totally endoscopic ASD repairs on beating hearts. They reported no operative deaths, strokes or other complications associated with the surgery on beating hearts [17].

Since early reports on endoscopic repair of congenital heart defects repair, the use of thoracoscopic techniques for ASD closure has been steadily increasing. Although robotically assisted endoscopic repairs are the most commonly used techniques to date, totally thoracoscopic closures without computerized surgery systems are emerging [18, 19]. Some clinical observations have shown that totally thoracoscopic repairs of cardiac defects on cardioplegic arrested hearts are associated with a reduced operation time and faster post-operative recovery in comparison with conventional surgery through a sternotomy [18, 19].

FACTS TO BE REMEMBERED:

Totally thoracoscopic ASD closures on beating hearts without cross-clamping the aorta in adults or in children is possible who have a body weight of 20 kg or above. For smaller children, this technique is impossible as Carpentier catheters were too large for the femoral vessels to establish CPB.



Compared with the surgeries on cardioplegic arrested hearts, the beating heart surgeries are associated with a shorter operation time, and a shorter intensive care or hospital stay. Post-operative mechanical ventilation may not required in 80% of the patients who received the beating-heart surgery, as they can safely extubated on the operation table. There was no statistically significant difference in the blood transfusion rate or in peri-operative complications between beating-heart and arrested-heart groups, but post-operative chest drainage volumes in the beating-heart group were lower than in the arrested-heart group.

In conclusion, non-robotically assisted totally thoracoscopic closure of an ASD can be safely performed on beating hearts without cross-clamping the aorta. These procedures are associated with a shorter duration of operation, and a shorter intensive care or hospital stay following the surgeries.

References

1
D.J. DiBardino, D.B. McElhinney, A.K. Kaz, J.E. Mayer Jr.
Analysis of the US Food and Drug Administration Manufacturer and User Facility Device Experience database for adverse events involving Amplatzer septal occluder devices and comparison with the Society of Thoracic Surgery congenital cardiac surgery database
J Thorac Cardiovasc Surg, 137 (2009), pp. 1334-1341
ArticleDownload PDFView Record in Scopus
2
E.H. Austin
Transcatheter closure of atrial septal defects
J Thorac Cardiovasc Surg, 125 (2003), pp. 85-86
View Record in Scopus
3
M.D. Black, R.M. Freedom
Minimally invasive repair of atrial septal defects
Ann Thorac Surg, 65 (1998), pp. 765-767
ArticleDownload PDFView Record in Scopus

4
N. Doll, T. Walther, V. Falk, C. Binner, J. Bucerius, M.A. Borger, et al.
Secundum ASD closure using a right lateral minithoracotomy five-year experience in 122 patients
Ann Thorac Surg, 75 (2003), pp. 1527-1531
View Record in Scopus
5
L. Torracca, G. Ismeno, O. Alfieri
Totally endoscopic computer-enhanced atrial septal defect closure in six patients
Ann Thorac Surg, 72 (2001), pp. 1354-1357
ArticleDownload PDFView Record in Scopus
6
N. Vistarini, M. Aiello, G. Mattiucci, A. Alloni, B. Cattadori, C. Tinelli, et al.
Port-access minimally invasive surgery for atrial septal defects: A 10-year single-center experience in 166 patients
J Thorac Cardiovasc Surg, 139 (2010), pp. 139-145
ArticleDownload PDFView Record in Scopus
7
G. Wimmer-Greinecker, S. Dogan, T. Aybek, M.F. Khan, S. Mierdl, C. Byhahn, et al.
Totally endoscopic atrial septal repair in adults with computer-enhanced telemanipulation
J Thorac Cardiovasc Surg, 126 (2003), pp. 465-468
ArticleDownload PDFCrossRefView Record in Scopus
8
M. Argenziano, M.C. Oz, T. Kohmoto, J. Morgan, J. Dimitui, L. Mongero, et al.
Totally endoscopic atrial septal defect repair with robotic assistance
Circulation, 108 (suppl 2) (2003), pp. 191-194
9
J.A. Morgan, J.C. Peacock, T. Kohmoto, M.J. Garrido, B.M. Schanzer, A.R. Kherani, et al.

Robotic techniques improve quality of life in patients undergoing atrial septal defect repair
Ann Thorac Surg, 77 (2004), pp. 1328-1333
ArticleDownload PDFView Record in Scopus
10
N. Bonaros, T. Schachner, A. Oehlinger, E. Ruetzler, C. Kolbitsch, W. Dichtl, et al.
Robotically assisted totally endoscopic atrial septal defect repair: insights from operative times, learning curves, and clinical outcome
Ann Thorac Surg, 82 (2006), pp. 687-693
ArticleDownload PDFView Record in Scopus
11 Murphy GJ, Ascione R, Angelini GD. Coronary artery bypass grafting on the beating heart: surgical revascularization for the next decade?, Eur Heart J , 2004, vol. 25 (pg. 2077-85)https://doi.org/10.1016/j.ehj.2004.09.022
Google ScholarCrossrefPubMed
12 Briffa N. Off pump coronary artery bypass: a passing fad or ready for prime time?, Eur Heart J , 2008, vol. 29 (pg. 1346-9)https://doi.org/10.1093/eurheartj/ehn128
Google ScholarCrossrefPubMed
13 Misare BD, Krukenkamp IB, Lazer ZP, Levitsky S. Recovery of postischemic contractile function is depressed by antegrade warm continuous blood cardioplegia, J Thorac Cardiovasc Surg , 1993, vol. 105 (pg. 37-44)
Google ScholarPubMed
14 Prifti E, Bonacchi M, Giunti G, Frati G, Leacche M, Bartolozzi F. Beating heart ischemic mitral valve repair and coronary revascularization in patients with impaired left ventricular function, J Cardiac Surg , 2003, vol. 18 (pg. 375-83)https://doi.org/10.1046/j.1540-8191.2003.t01-1-02044.x
Google ScholarCrossref
15 Thompson MJ, Behranwala A, Campanella C, Walker WS, Cameron EW. Immediate and long-term results of mitral prosthetic replacement using a right thoracotomy beating heart technique, Eur J

Cardiothorac Surg , 2003, vol. 24 (pg. 47-51)https://doi.org/10.1016/S1010-7940(03)00188-X
Google ScholarCrossrefPubMed
17 Gao C, Yang M, Wang G, Wang J, Xiao C, Wu Y, et al. Totally endoscopic robotic atrial septal defect repair on the beating heart, Heart Surg Forum , 2010, vol. 13 (pg. E155-8)https://doi.org/10.1532/HSF98.20091175
Google ScholarCrossrefPubMed
18 Ma ZS, Dong MF, Yin QY, Feng ZY, Wang LX. Totally thoracoscopic repair of atrial septal defect without robotic assistance: a single-center experience, J Thorac Cardiovasc Surg , 2011, vol. 141 (pg. 1380-3)https://doi.org/10.1016/j.jtcvs.2010.10.028
Google ScholarCrossrefPubMed
19 Ma ZS, Dong MF, Yin QY, Feng ZY, Wang LX. Totally thoracoscopic repair of ventricular septal defect: a short term clinical observation on safety and feasibility, J Thorac Cardiovasc Surg , 2011, vol. 142 (pg. 850-4)
Google ScholarCrossrefPubMed

2.9 Internal Thoracic Artery (ITA) Harvesting for Coronary Artery Bypass Graft (CABG)

In human anatomy, the internal thoracic artery (ITA), previously known as the internal mammary artery (a name still common among surgeons), is an artery that supplies the anterior chest wall and the breasts.

Internal mammary artery harvesting is an essential part of any coronary artery bypass operation. Totally endoscopic coronary artery bypass graft surgery has become reality in many centers as a safe and effective alternative to conventional surgery in selected patients. Internal mammary artery harvesting is the initial part of the procedure and should be performed equally safely if one wants to achieve excellence in patency rates for the bypass. We here describe the technique for mammary harvesting with the Da Vinci robotic system.

The internal mammary artery (IMA) has consolidated itself as the preferable graft for coronary artery bypass surgery (CABG). Classically harvested through a sternotomy it is one of the initial but essential steps in CABG surgery. Pediculated and skeletonized techniques were developed, the last one providing longer graft length and preserved blood supply for the sternum.

Inadequate flow and limited length can be reasons for not using the internal mammary artery graft for myocardial revascularization. Several methods have been described to obviate these limitations, but each has disadvantages that contraindicate their application on a routine basis. Herein we describe what to the best of our knowledge is a new surgical technique of harvesting the internal mammary artery graft wherein the endothoracic fascia is incised longitudinally along the artery. In our experience, this surgical maneuver enables an increase in hematic flow (average, 30.6%) and in length of the graft (average, 10%) with reduced risk of damaging the arterial intima. This technique also enables the surgeon to detect the presence of atheromatous plaques and of parietal hematomas of the internal mammary artery wall. Moreover, we have observed a drastic reduction in the incidence of arterial spasms after use of this technique.

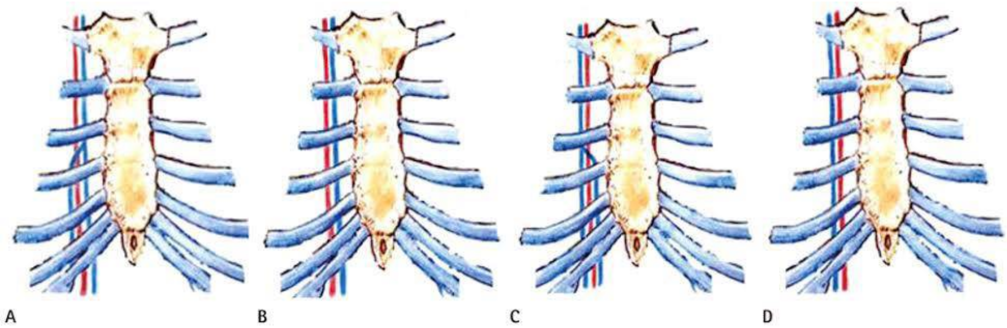
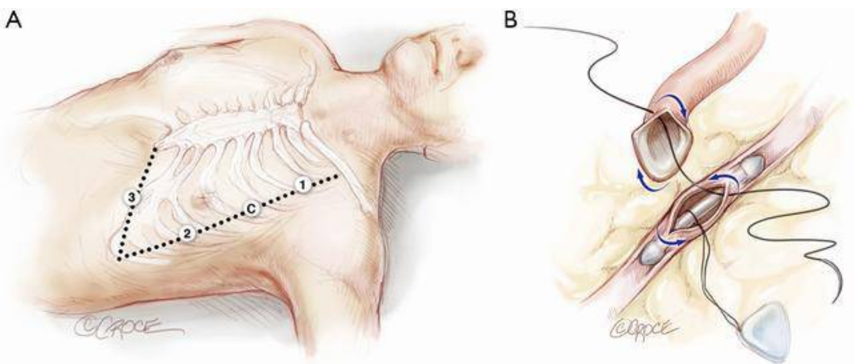
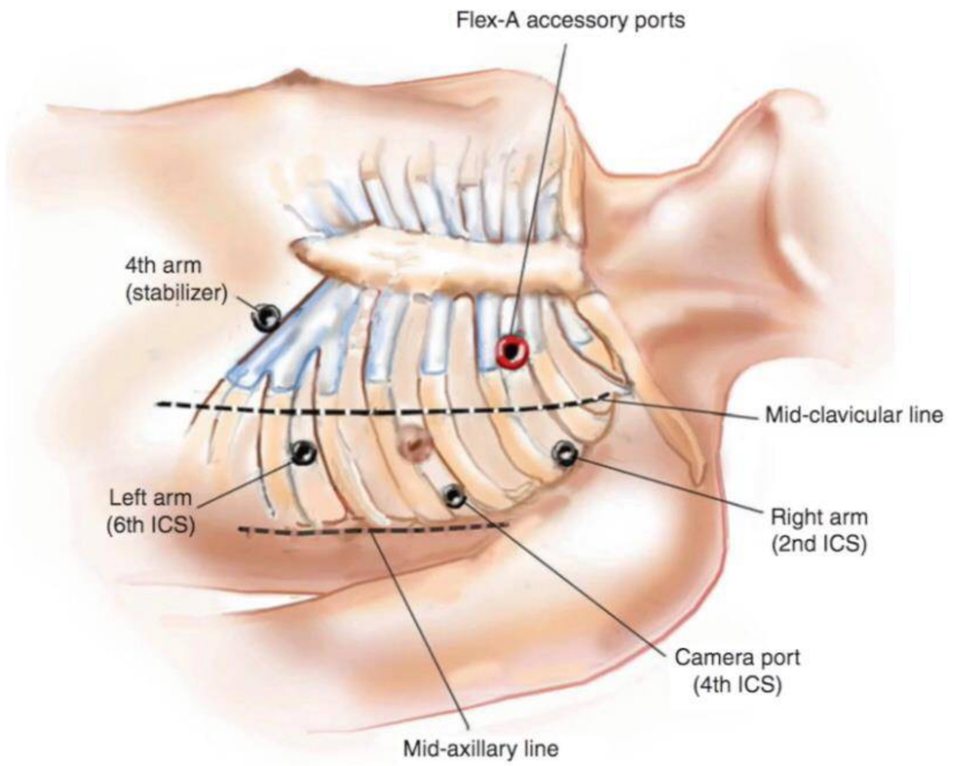


Figure : Mammary artery variation

The use of robotic assistance to perform totally endoscopic CABG has become an accepted option for surgical coronary artery revascularization. Again, the first step in this surgery is the process of IMA take down, which we will describe here.

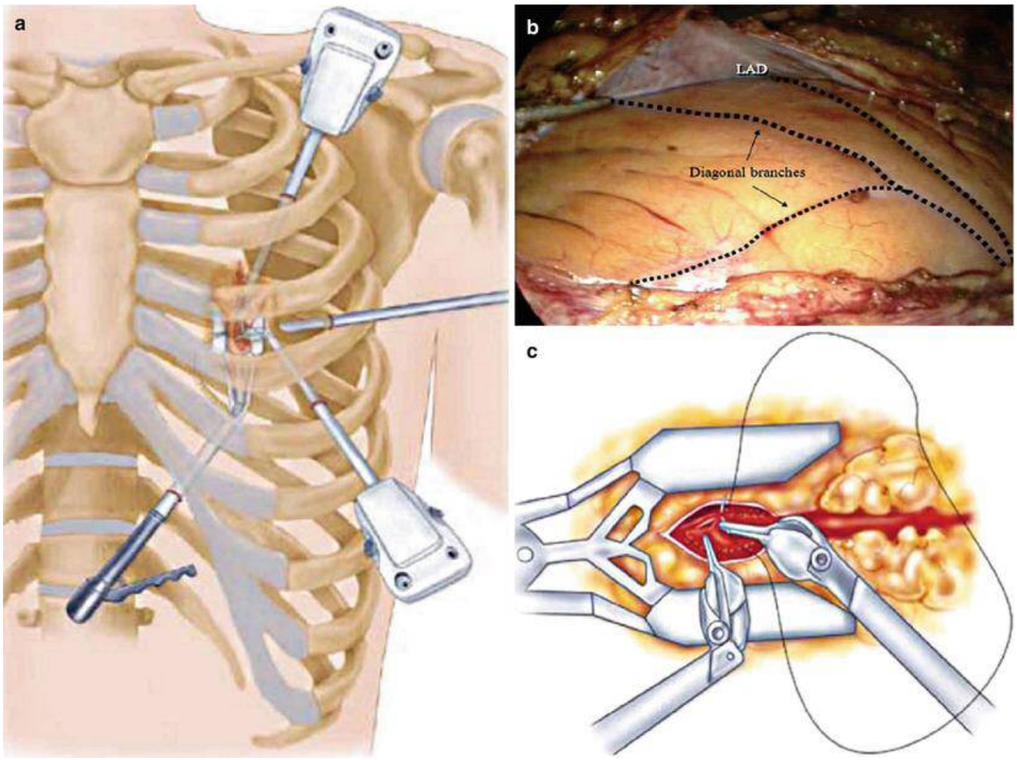


Anesthesia uses a double lumen endotracheal tube and places R2 defibrillator patches in the right infraclavicular region and the dorsal part of the left lower chest. The patient is placed in supine position with the left chest slightly elevated. Both arms are tucked to the chest and flank. During prepping and draping care has to be taken that the drapes do not reach beyond the posterior axillary line so as to have enough space for port placement or placement of a minithoracotomy.



The Da Vinci robotic patient cart (Intuitive Surgical, Inc.) which carries three or four robotic arms approaches the patient perpendicular from the right side. With the left lung deflated (using a dual tube endotracheal tube), a 12 mm camera port is initially inserted in the 5th intercostals space on the anterior axillary line. Carbon dioxide is insufflated to the chest (6-10 mmHg). The camera port hole can be predilated with an 8 mm instrument port. Port insertion has to be performed very gently and awareness of the presence of adhesions and the fact that the heart may be close to the chest wall is very important so as to avoid injury of intrathoracic structures. During this phase, the arterial blood pressure needs to be observed as insufflation may lead to hemodynamic compromise. In this case the insufflation pressure is lowered to a minimum.

The robotic camera is used to inspect the thoracic cavity for adhesions and orient the insertion of the other 2 ports. The right arm port (8 mm) is inserted in the 3rd intercostal space 3 cm anterior to the camera port, so avoid conflict between the robotic arm and the patients left shoulder. The left arm port (8 mm) is inserted in the 7th intercostal space 3 cm anterior to the level of the camera port. By doing so, we position the three arms in a flat triangle, which is a principle for any video assisted port procedure. For a rough orientation the surgeon can place the tip of his/her right third finger on the patient's jugulum and the tip of his/her left third finger on the xiphoid angle. Where the tips of the stretched out thumbs meet is the camera port insertion site. The instrument ports are placed four finger breaths apart from the camera port.



The robotic surgeon then performs an inspection of the left pleural space. For anatomic orientation he visualizes the left subclavian artery and the distal aortic arch. The pericardium and its covering fat pad first come into view. The left internal mammary artery (LIMA) can then be visualized beneath the endothoracic fascia. Harvesting starts where the surgeon sees the artery pulsating which is usually in its cranial part. A 30 degree camera is used "facing up". For most of the procedure the left robotic arm is equipped with EndoWrist fine tissue forceps (Intuitive Surgical, Inc.) and the right robotic arm with a EndoWrist spatula cautery

(Intuitive Surgical, Inc.), connected to low power monopolar energy (15W). The parietal pleura, fascia and muscles are then opened all along the lateral aspect of the artery (close to the camera). The LIMA is then carefully detached from the chest wall from distal to proximal end in a skeletonized fashion (Figure 1).

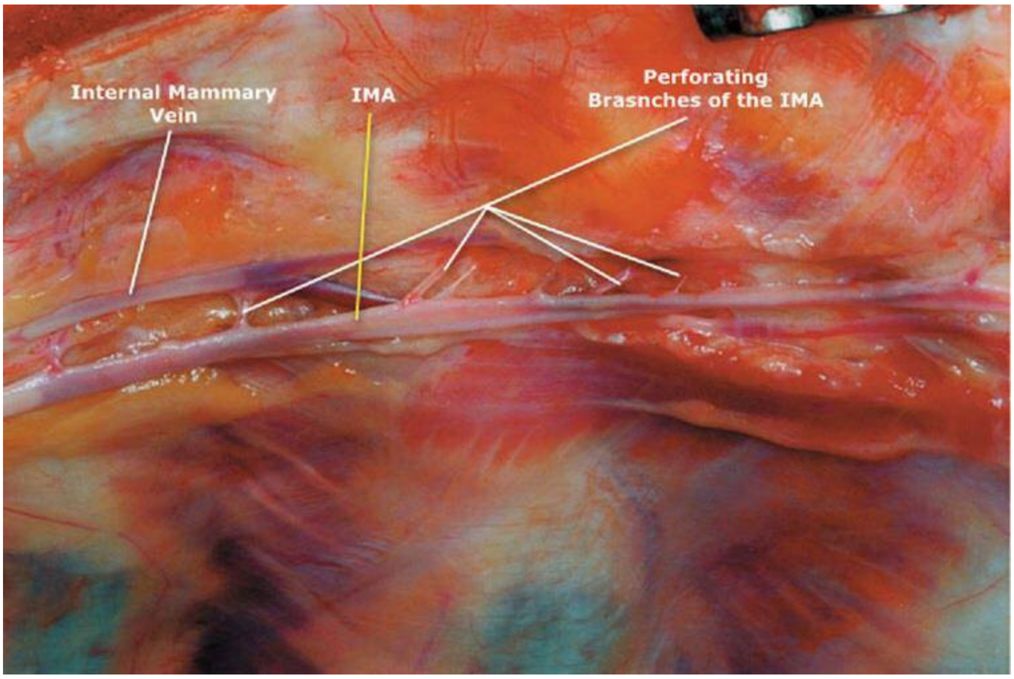
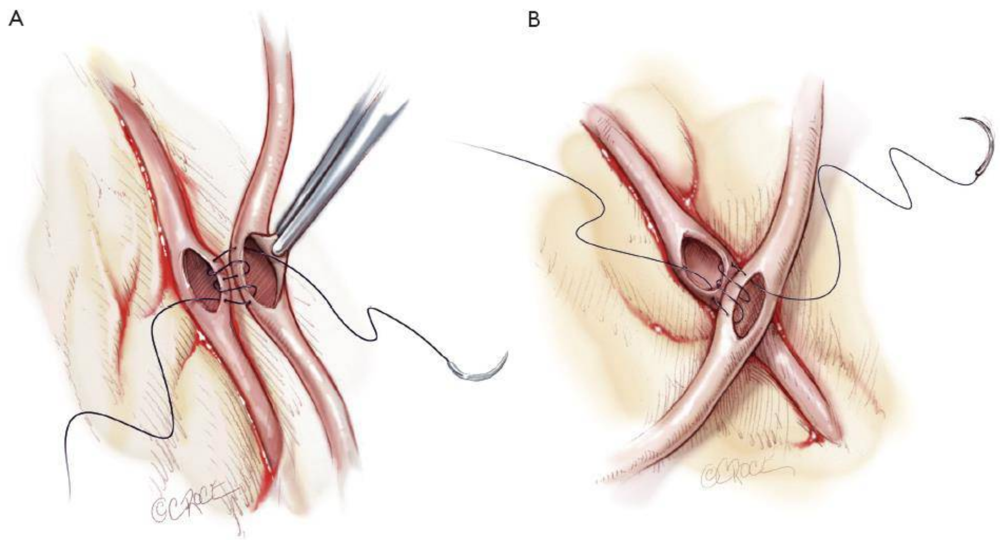
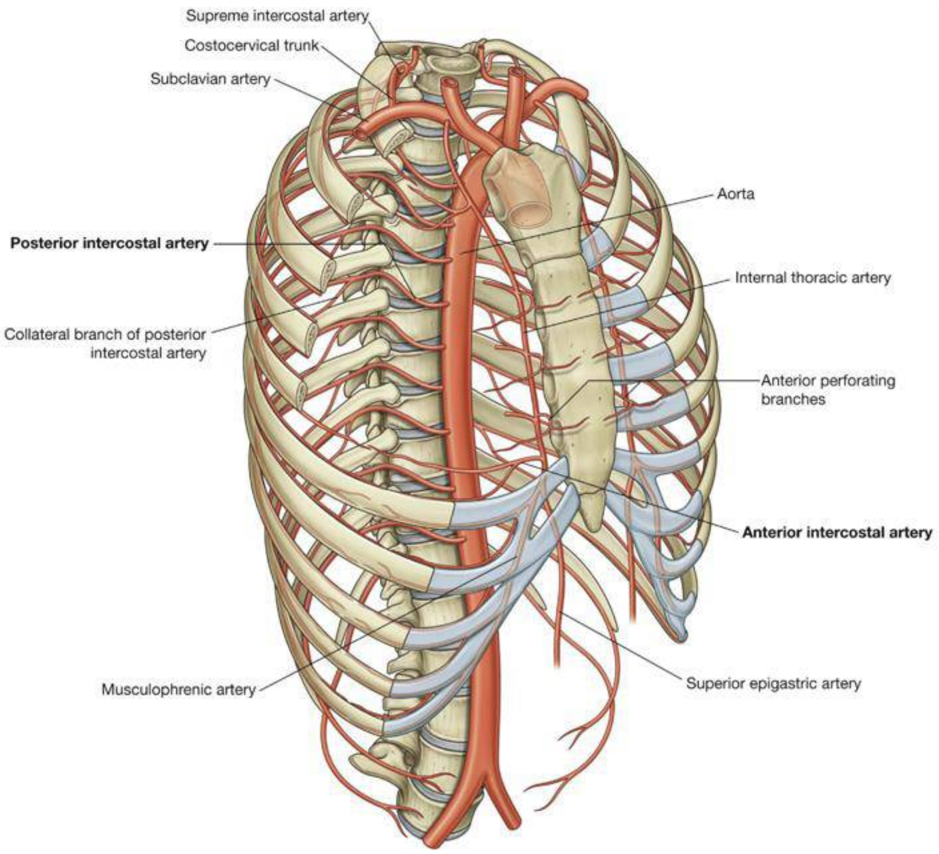


Figure: LIMA Hervesting

Dissection is performed using sweeping movements alongside the artery, part of the time without utilizing energy. The camera provides a 10 times magnification which lead to great visualization of the procedure, but also tends to overestimate the size of branches and the amount of bleeding. We tend to cauterize the small branches (far from the mammary and close to the chest wall) and clip the large ones (Figures 2 and 3). Although there is some bleeding from the transverse thoracic muscle and very small branches with this approach, these are always self limiting. When all the extension of the artery is free from the chest wall the patient is heparinized, and 2 clips are applied to the distal end. One clip is placed slightly proximal to the distal end and the vessel is divided using robotic Pott's scissors.



If bilateral IMAs are being planned, the right internal mammary artery (RIMA) should be dissected first. This is to avoid damage to an already harvested LIMA once the instruments go forward to the right side of the chest. To reach the RIMA, a dissection of the substernal plane is carried out all the way to the right pleura. The pericardium should not be opened at this time. The technique for RIMA takedown is overall similar to the LIMA. Harvesting of the very proximal part can at times be difficult. If the surgeon during harvesting feels difficulties reaching structures on the distal part of the IMA, ports should be checked for exact position from inside the chest. Ports can be pushed in for better reach and the right instrument port can be lifted into sternal direction. A full description of the rest of a totally endoscopic CABG can be found elsewhere [1].

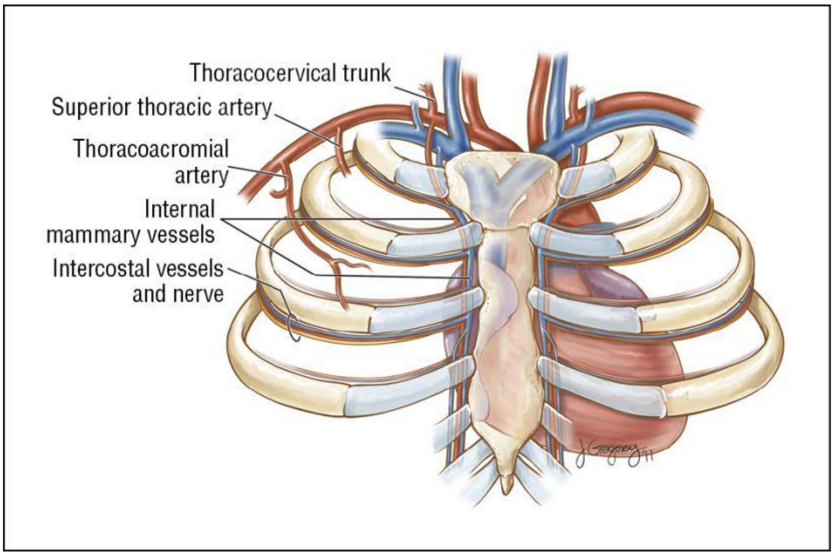


Regarding time to perform this procedure, an important learning curve has been observed. Oehlinger et al. [2] assessed the first 100 LIMAs harvested by the senior surgeon and noticed a decline in total time. The mean time for all cases was 48 minutes. While the first 10 cases required a mean of 140 minutes each, the last 10 cases required only 34 minutesd. More recently Yang et al. [3] reported on their first 200 harvested IMAs. Mean time for IMA harvesting was 35 minutes and a significant learning curve was observed: from 41 minutes in the first 30 cases to 29 minutes in the last 30 cases. In both studies the IMA was skeletonized.

A somewhat similar technique for mammary harvesting is described by Ishikawa et al termed "slide fascia technique" [4]. Instead of using a spatula for fascia opening the authors use a forceps connected to the monopolar energy.

Despite these excellent experiences with IMA harvesting, some investigators are trying to push the technique even more forward.

Ishikawa et al. [5] developed a tridimensional triangular hook to facilitate handling and traction of the mammary artery. This small instrument can be introduced in the chest through one of the 8 mm ports and goes around the IMA, held by regular robotic forceps. Experiments in dogs showed a decrease in total time of harvesting. Watanabe et al. [6] developed an electrical chest wall retractor to allow robotic mammary without the use of CO_2 insufflations. It is recognized that CO_2 pressures above 10 mmHg can lead to hemodynamic instability. Also some patients have a very small chest cavity space to allow for easy harvesting (obese patients, cardiomegaly). The authors present a device capable of raising the sternum up to 5-10 cm which avoids completely the use of CO_2.



In summary, robotic totally endoscopic IMA harvesting is feasible and safe. A learning curve phenomenon is clearly present. More than one technique is available. Further fine adjustments might improve time and ease of operation even further.

2.9.3 Endoscopic harvesting of the left internal mammary artery

Minimally invasive coronary artery bypass grafting via left anterior small thoracotomy is routinely performed on patients with single coronary artery disease, but recently has been expanded to a larger population as a part of a hybrid treatment in multivessel coronary artery disease. While the methods of internal mammary artery harvesting used in these operations can be different, the endoscopic method is more advantageous than operations performed by direct vision, and thus should be used as a technique of choice. In this article, we present detailed description of endoscopic mammary artery harvesting focusing on anatomical and technical aspects.

Minimally invasive direct coronary artery bypass (MIDCAB) grafting via an anterolateral thoracotomy was first introduced into clinical practice in 1967, thanks to the pioneering work by Dr. Kolesov (1). However, this novel approach was not widely adopted in the following years, given the degree of technical complexity and the poor quality of the anastomoses performed as a consequence of the inadequacy of the technological armamentarium.

During the past two decades, a revived interest in off-pump coronary artery surgery led to the introduction of a considerable number of tools such as heart stabilizers and shunts, which have consistently improved the quality of anastomoses being performed as well as the overall feasibility of the procedure. Despite considerable improvements in transcatheter techniques and the introduction of drug-eluting stents, a wide scientific consensus has confirmed an unparalleled patency rate of the left internal mammary artery (LIMA) compared to left anterior descending (LAD) coronary artery bypass graft. This fostered a renewed interest in the possibility to perform such operations via a minimally invasive approach, particularly through a left anterior small thoracotomy (2-5). Several reports have confirmed the safety and efficacy of such an approach, also in the long term (6-12). Moreover, the possibility of performing minimally invasive LIMA-LAD operations has been recently expanded to a larger population other than patients with single-vessel disease of the LAD, i.e., as a part of a hybrid treatment in multivessel coronary artery disease with the LAD being surgically grafted with a LIMA and the remaining vessels by means of a transcatheter technique (13-17). Finally, minimally invasive revascularization of the LAD has been proved to be a safe procedure with comparable results to conventional sternotomy procedures in terms of graft quality (18).

Surgical techniques

The endoscopic harvesting of the left internal thoracic artery (LITA) can be routinely performed by means of a simple and easily reproducible set-up:

Endoscopic camera: we routinely prefer a 10 mm, 30° angled endoscope (Karl Storz, Tuttlingen, Germany);

Trocars: reusable, stainless steel with CO_2 insufflation (Karl Storz, Tuttlingen, Germany); one 11 mm and two 6 mm are utilized;

Harmonic scalpel: either the curved or hook blade thoracoscopic device can be utilized (Ethicon Endosurgery, Cincinnati, OH).

The patient is positioned supine with a 30° rotated decubitus towards the right side, by means of a rolled towel, gel pads or inflatable mattress placed parallel to the spine beneath the left scapula. The left arm is elevated over the head of the patient. This position is of paramount importance since the degree of traction to the arm can create an excess of tension of the latissimus dorsi muscle and therefore influence the maneuverability of the superior trocar (utilized for the harmonic scalpel). Moreover, improper placement of the left upper limb can also lead to brachial plexus palsy. Finally, in all patients undergoing endoscopic atraumatic coronary artery bypass grafting (EACAB), external pads for emergency defibrillation are placed.

The routine trocar arrangement is achieved by placing one 6 mm trocar at the level of 3rd-4th intercostal space and the other 6 mm trocar at the 6th-7th intercostal space, on the medial-posterior axillary line. These trocars will be utilized for an endoscopic grasper and the harmonic scalpel, while the 11 mm trocar for the endoscopic camera will be positioned in 5th-6th intercostal space at the level of the anterior axillary line. The trocars' configuration should be adjusted according to the specific patient's chest anatomy. For example, the trocars for the grasper and the harmonic scalpel could be placed well apart from each other (e.g., on the 3rd and 7th intercostal spaces) in taller patients with a longer cephalad-caudal chest distance, but placed closer together in patients with smaller chest. Moreover, the presence of large breasts in women, the width of the ribs and intercostal spaces, and also potential cardiac enlargement may also affect the location of trocars and the minithoracotomy incision itself. It is important to place the skin incision for the trocars directly in the middle of corresponding intercostal space to avoid unnecessary pressure on the rib by the endoscopic instrument during dissection.

The intended incision for the mini-thoracotomy is performed through the 4th or 5th intercostal space based on the chest anatomy and heart orientation on X-ray.

After exclusion of the left lung, the first 11 mm trocar (for the endoscopic camera) is inserted and CO_2 insufflation is started. We routinely use a CO_2 flow of 3 L/min and a target pressure of 8 mmHg. If required, these settings can be adjusted and improved, albeit without jeopardizing the hemodynamic status of the patient due to an iatrogenic hypertensive pneumothorax, especially in patients with a decreased left ventricular ejection fraction.

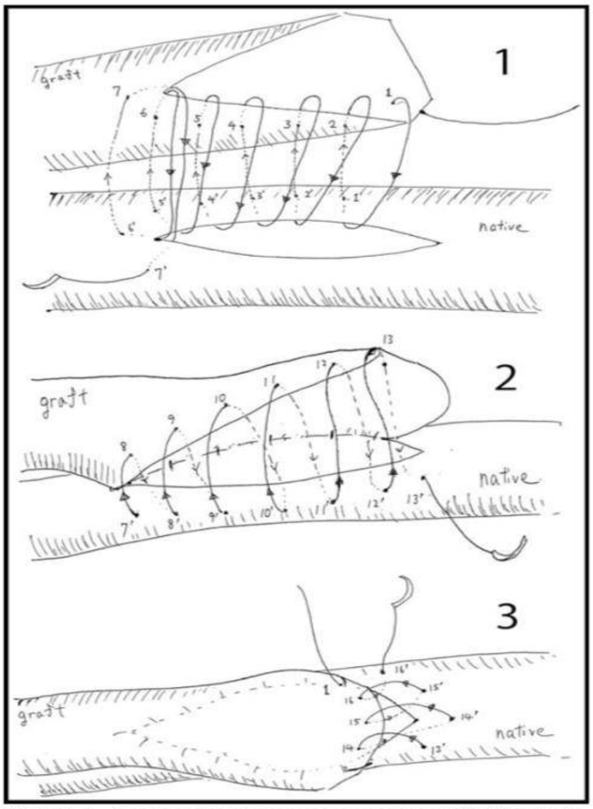


FIGURE 4. Anastomotic process. The anastomosis in this study was running fashion using 7-0 or 8-0 suture with a single needle. 1. The anastomosis started at the opposite side of the coronary artery toward the heel using parachute technique. 2. Sutured with the same needle to the near side and reached to the near side edge of the graft. 3. Advancing from the edge to the toe and ended by tied down at the opposite side. Between the 1 to 2 steps and 2 to 3 steps, we controlled the tension with a fine nerve hook.

After inserting the endoscopic camera, the course of the LIMA can be assessed. Usually, the LIMA is visualized close to the lateral left internal thoracic vein. In the presence of massive pleural adhesions, the thoracoscopic harvesting could be impossible, or at least extremely hazardous and time-consuming. Instead, limited adhesions can be easily dissected by means of the harmonic scalpel. In its proximal portion, the LIMA is lateral to the subclavian vein and is crossed by the phrenic nerve.

Once the overall visualization has been completed, the 6-mm trocars and endoscopic instruments are inserted. In case of poor LIMA visualization due to an excess of adipose tissue on the chest wall, this must be first dissected free from the endothoracic fascia. Routinely, the endothoracic fascia is longitudinally dissected along the internal mammary artery course first from the medial side and then on the lateral side, from the prominence of the first rib and distally down to the muscular part of the LIMA course. At this level (usually the 3rd-4th rib), the LIMA runs superficial to the transversus thoracic muscle and may not be directly visible, although its course can usually be drawn by observing the pulsation of the vessel itself. Therefore, we recommend at this level to leave a slightly larger margin (0.5-1 cm) of tissue from the expected course of the artery.

By retracting the prepared LIMA pedicle, a gentle spatulation with the harmonic scalpel allows for tissue separation and identification of the LIMA side branches, which are then sealed and divided by means of ultrasonic energy only. If enough time is allowed for tissue coagulation, vessel sealing can be safely accomplished and no additional maneuver (such as the use of endoscopic scissors) are required. Moreover, in our experience, the need for additional application of endoscopic clips was extremely rare.

In the occurrence of bleeding, the first recommendation is to avoid any attempt to coagulate in a “blind” fashion within a bloody area, as it may lead to inadvertent injury of the LIMA itself. Instead, the application of a gentle pressure for few minutes at the site of bleeding (by holding the pedicle against the chest wall) can significantly improve the endoscopic vision in the majority of cases.

Of note, a proper orientation of the endoscopic camera throughout the harvesting procedure is of utmost importance. In particular, the level of zoom should be minimal, so as to allow for a wide visualization of the LIMA site at all times. By the same token, an excessive zoom can lead to an improper endoscopic view of the artery and thereby lead to its injury.

In proximity to the first rib, it is often possible to find a larger amount of fat tissue, which can be safely dissected free by gently pulling the LIMA downward while coagulating the tissue close to the rib with a harmonic scalpel. At this site, it is important to avoid damage to neighboring anatomical structures such as the phrenic nerve and the subclavian artery.

When endoscopic LIMA harvesting is properly performed, the conduit should hang “freely” in an arc-like fashion as the procedure is being completed. The distal limit of LIMA harvesting can be individualized, but the LIMA should have enough length to avoid any potential stretching following the anastomosis to the LAD. Several options are available in order to assess proper LIMA length. Often, the pericardium is opened and the target vessel visualized so as to verify if the conduit yields enough length. Alternatively, another helpful maneuver is accomplished by inserting a transthoracic needle through the site of planned thoracotomy and assessing its position endoscopically in comparison with the distal end of the harvested LIMA. Finally, another option is to simply visualizing the distal end of the conduit in comparison with the apex of the heart. To ensure a proper LIMA length, division of the conduit endoscopically is avoided. Instead, completion of this maneuver after the minithoracotomy is preferred. Rarely, the LAD may have an intramuscular course thereby requiring a more distal anastomosis. In such instances, an extra-length of the LIMA is harvested under direct vision beyond the thoracotomy itself.

The technique of internal mammary artery harvesting can vary according to the revascularization approach utilized, i.e., either MIDCAB or

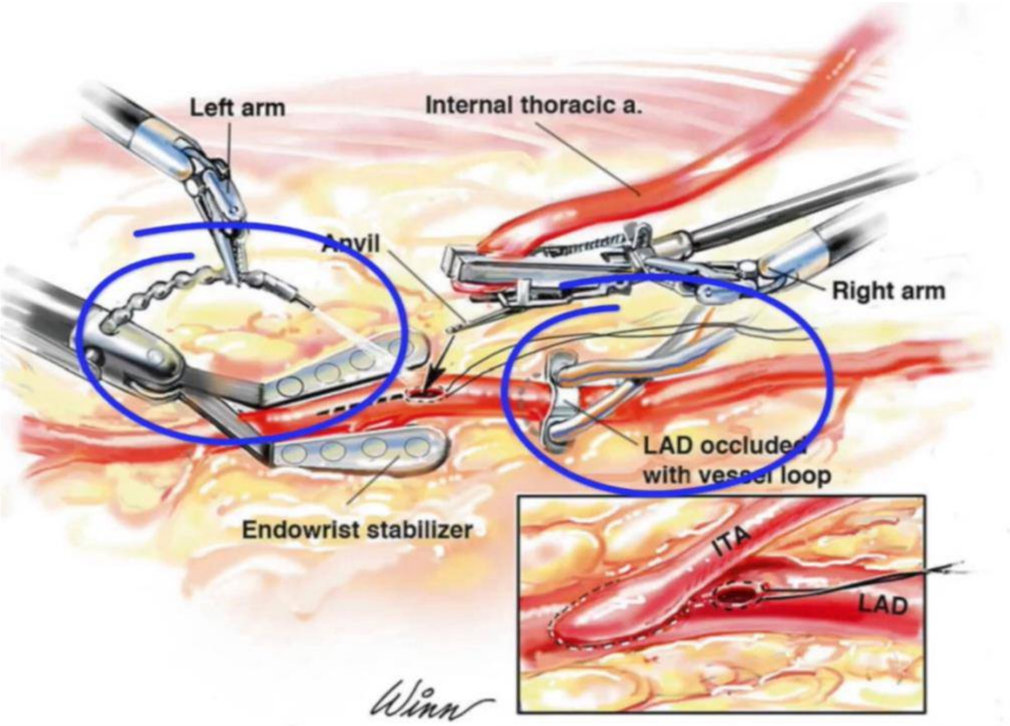
EACAB. In the former instance, the LIMA is harvested under direct vision through the left thoracotomy while in the latter, the procurement of the graft is achieved via a fully endoscopic approach, with each technique associated with potential advantages and drawbacks. Generally, the endoscopic approach allows for a full-length harvesting of the LIMA graft, in particular at the proximal level. In fact, LIMA harvesting under direct vision via the left thoracotomy can be cumbersome when dealing with the proximal portion of the graft, and it is potentially associated with a "steal syndrome" in relation to inadequate division of the proximal side branches.

An additional benefit of the endoscopic approach is related to the considerable reduction of postoperative pain when compared to the direct-vision approach (19). Indeed, endoscopic harvesting does not require such a consistent degree of ribs lifting and traction at the time of LITA preparation and may even allow for a more limited thoracotomy.

While we have experience with both techniques, we believe that endoscopic harvesting should be the technique of choice. We have previously demonstrated that the endoscopic approach does not jeopardize the quality of coronary anastomosis and late graft patency (20). In contrast, LIMA harvesting under direct vision was associated with a potentially higher risk of incomplete separation of the proximal side branches. Therefore, harvesting under direct vision is utilized only as a bailout strategy if the endoscopic approach fails.

The use of ultrasonic energy yields several advantages compared to the conventional diathermy and consistently facilitates endoscopic harvesting as previously reported (21-23). In our practice, we have used different kinds of endoscopic blades, including curved or hook blades. The curved blade is usually more comfortable and safer for preparation the thoracic artery, but the hook is more useful in coagulating and dividing the side branches. Although each type yields unique advantages and drawbacks, our preference is for the curved blade version of the harmonic scalpel.

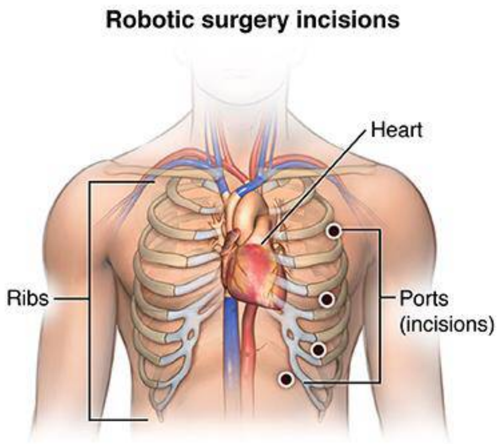
Appropriate patient selection is of utmost importance for safe and successful endoscopic harvesting of the LITA especially in early stages of the learning curve. Generally, obese patients (BMI >34) are not good candidates for minimally invasive artery bypass grafting and for thoracoscopic LITA preparation in particular. The presence of a large amount of adipose tissue in some instances may completely prevent a clear endoscopic visualization of the thoracic artery course. Still, endoscopic harvesting is also feasible in obese patients if the adipose tissue is generously removed from endothoracic fascia along the course of the artery itself. If such a maneuver is cumbersome, mammary harvesting under direct vision through the anterolateral thoracotomy is usually still doable.



Although endoscopic LIMA harvesting is routinely performed with a double-lumen endotracheal tube allowing for complete exposure of the left lung, this approach is potentially also feasible with a conventional intubation. During LIMA harvesting, the tube is advanced into the right bronchus therefore blocking the left one. Alternatively, another option is using a ventilation protocol with reduced tidal volumes and increased breathing rate per minute.

The position of the trocars has been widely debated in the past with several options available (23). We found that the set-up described above is reproducible in the majority of cases with minimal adjustments being required.

In our experience, endoscopic LIMA harvesting was feasible in over 95% of cases. Once the plateau phase of the learning curve has been reached, harvesting time usually ranges from 20 to 30 minutes and therefore does not impact the overall duration of the surgical procedure.



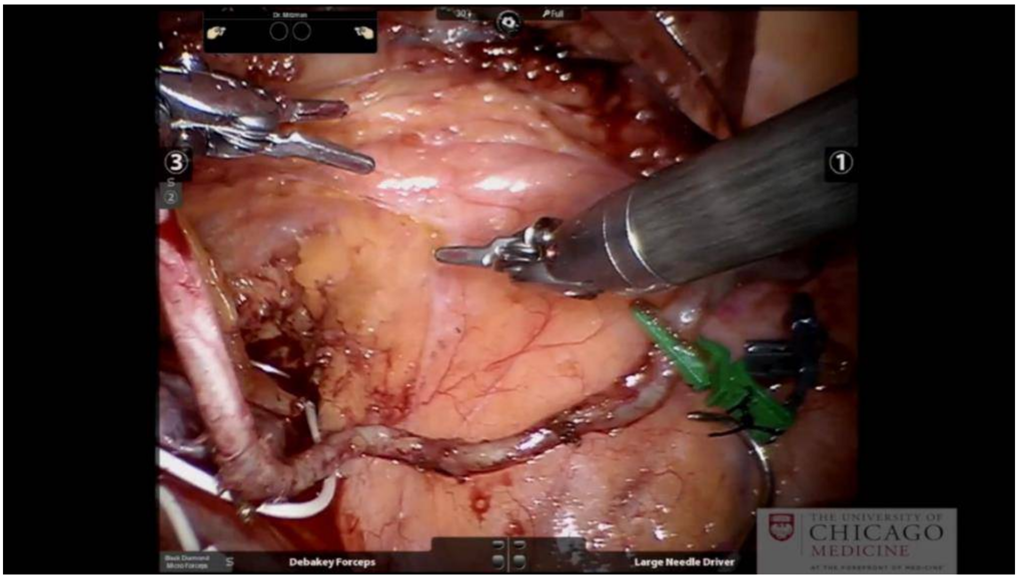
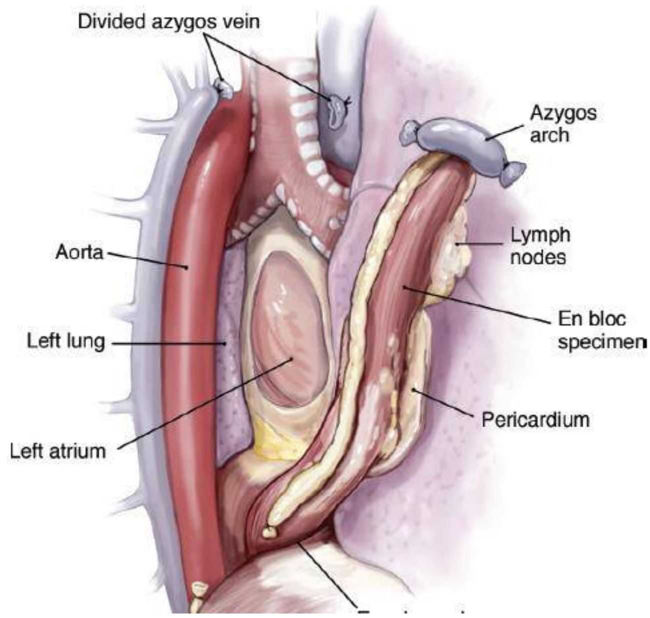


Figure-20:

2.7.3.2 OESOPHAGECTOMY

Minimally invasive techniques for esophageal resection have been reported to have acceptably reduced procedure-related morbidity without compromising disease-free survival rates. [12]

Luketich et al have an extensive reported experience; their initial series of 222 patients has grown to more than 1000. [22] In the initial series, mortality was 1.4% versus 5.5% for an open approach. [21, 23, 24] Furthermore, the survival curve at 19-month follow-up was comparable in the two groups. [21] In their 2012 report of 1011 patients who underwent MIE via either a modified McKeown minimally invasive approach or an MIE Ivor Lewis approach, the authors cited a 0.9% mortality for the MIE Ivor Lewis approach. [22]



In another analysis of 41 elderly patients over the age of 75 years who underwent minimally invasive esophagectomy, no operative deaths occurred, with a survival of 81% at 20 month follow-up. [25] These findings suggest that MIE can be safely performed in selected patients and even those considered high-risk that might not otherwise be considered for an open surgery.

Other outcome improvements seen with minimally invasive esophagectomy include decreased ICU and hospital length of stay, decreased blood loss, and operating times. In particular, Luketich et al reported a median ICU stay of 1 day and a total length of hospital stay of 7 days, compared with the average hospital stay of 16.6 days in the open approach. Operating room times in the same study averaged 306 minutes, whereas the average for an open procedure is 336

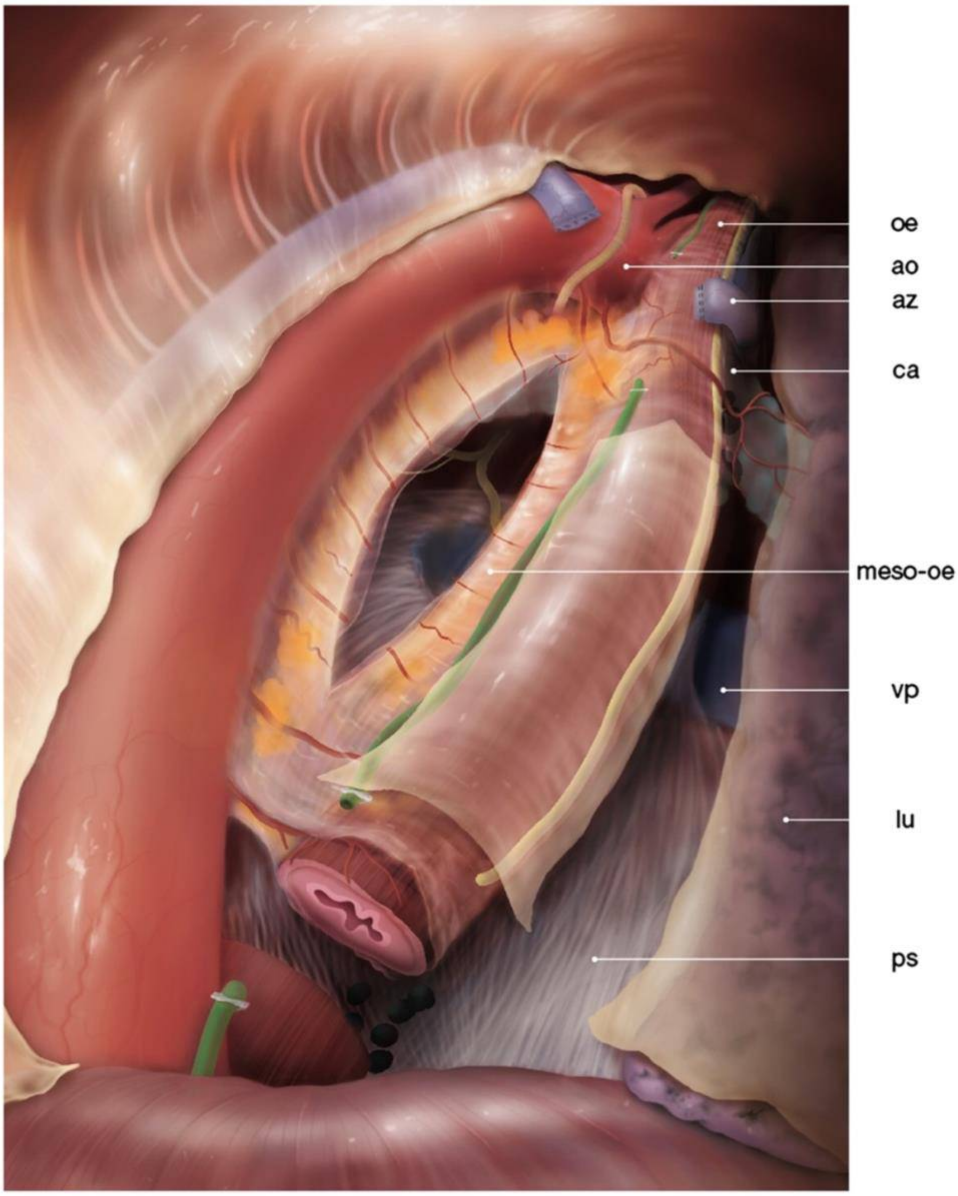


Illustration 1 Comprehensive concept of the oesophageal anatomy visualized from the prone position of the thorax. *ps* Pericard sac, *lu* right lung, *vp* right pulmonal vein, *ca*, carina and right bronchus *meso-oe* meso-oesophagus, *az* azygos vein; *ao* aorta, *oe* oesophagus

minutes. [21,23] Similar results can be seen in multiple other series as compared to open procedures (see the table below).

Complications and outcomes are significantly influenced by the volume of patients, because a large learning curve exists. High-volume centers tend to have more experience and, therefore, better outcomes than smaller-volume hospitals.

Wang et al carried out a propensity score-matched comparison of MIE and open esophagectomy with respect to outcomes, quality of life, and survival in patients with squamous cell carcinoma. [26] They found that MIE was associated with a shorter operating time (191 ± 47 minutes vs 211 ± 44 minutes), reduced blood loss (135 ± 74 mL vs 163 ± 84 mL), a similar lymph node harvest (24.1 ± 6.2 vs 24.3 ± 6.0), a shorter postoperative hospital stay (11 days vs 12 days), a lower rate of major complications (30.4% vs 36.9%), a lower rate of readmission to the intensive care unit (ICU; 5.6% vs 9.7%), and comparable perioperative mortality.

van der Sluis et al assessed the long-term oncologic results of robot-assisted minimally invasive thoracolaparoscopic esophagectomy (RAMIE) with two-field lymphadenectomy in 108 patients with potentially resectable esophageal cancer. [27] They found RAMIE to be oncologically effective and capable of providing good local control with a low percentage of local recurrence at long-term follow-up.

In a prospective phase II study (coordinated by the Eastern Cooperative Oncology Group) aimed at assessing the feasibility of MIE in a multi-institutional setting, Luketich et al reported the following results [28] :

The 30-day mortality in eligible patients who underwent MIE was 2.1%

The median ICU stay was 2 days

The median hospital stay was 9 days

Adverse events classified as grade 3 or higher included anastomotic leakage (8.6%), acute respiratory distress syndrome (ARDS; 5.7%), pneumonitis (3.8%), and atrial fibrillation (2.9%)

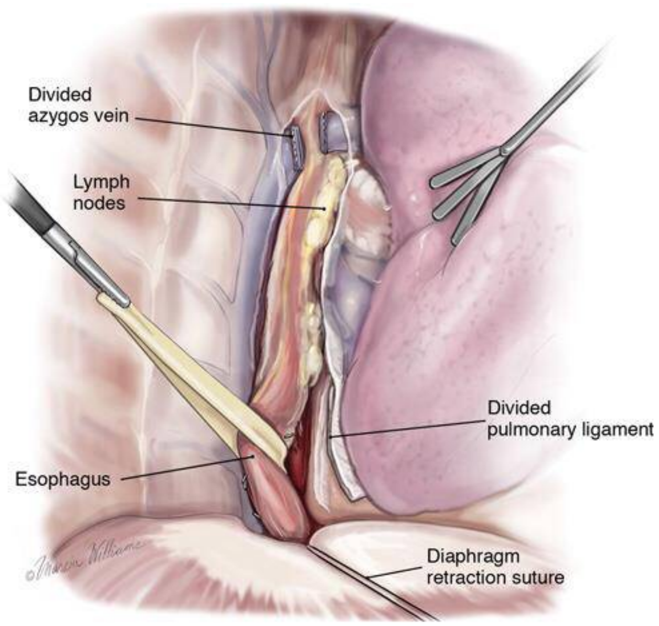
The estimated 3-year overall survival (median follow-up, 35.8 months) was 58.4%.

Locoregional recurrence occurred in only 7 patients (6.7%).

A global incidence of esophageal cancer has increased by 50% in the past two decades. Each year, around 482,300 people are diagnosed with esophageal cancer, and 84.3% die of the disease worldwide [1, 2]. At present, the primary method of treating patients with esophageal cancer has been surgery. However, the traditional open esophagectomy (OE) procedure has high complication rates resulting in significant morbidity and mortality [3, 4]. Various studies showed in-hospital mortality between 1.2 and 8.8% [4–7], even as high as 29% [8].

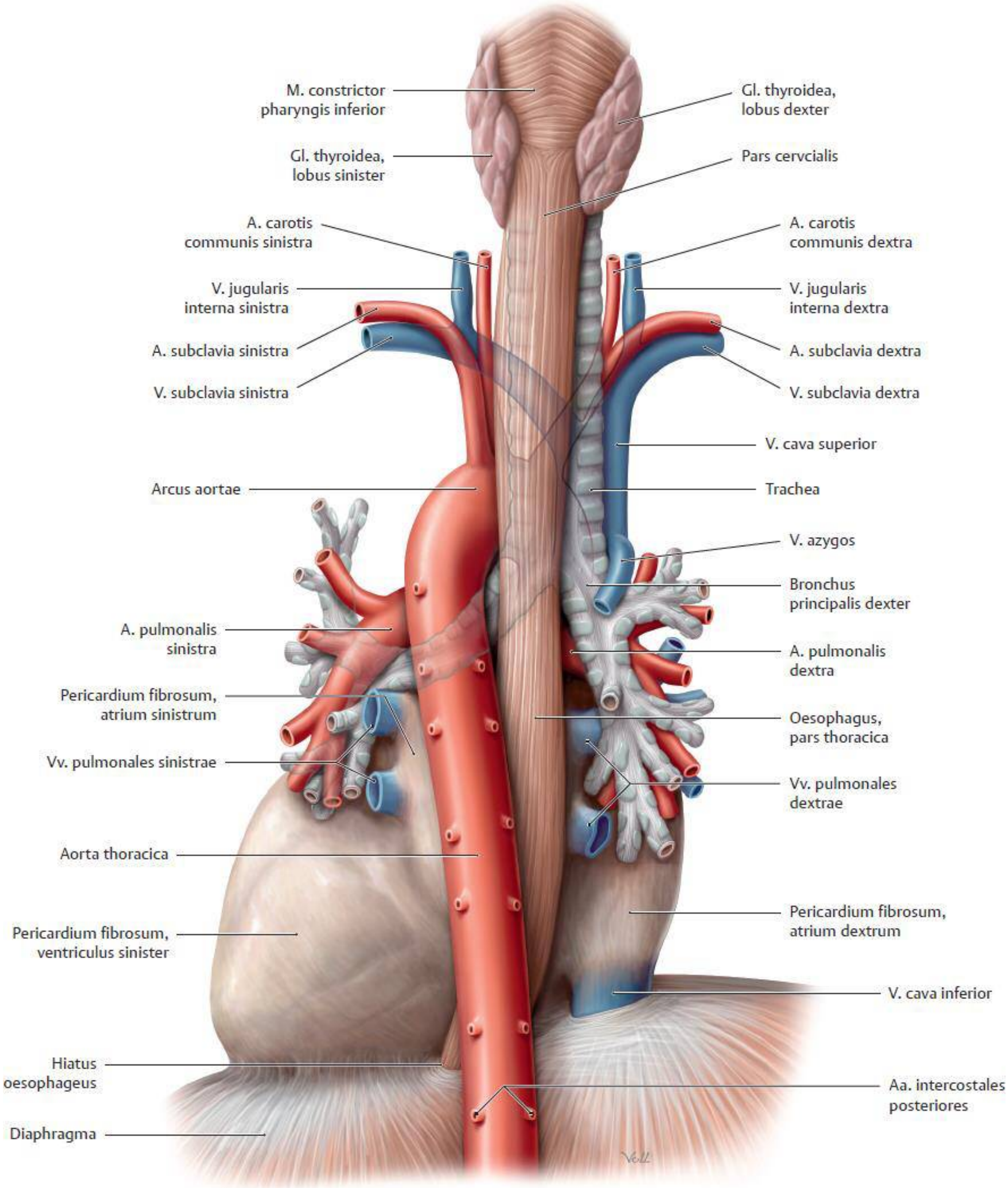
Minimally invasive oesophagectomy (MIO), which was first described in the 1990s [9, 10], was attributed to be superior in reducing postoperative outcomes, without compromising oncological outcomes and avoiding thoracotomy and laparotomy. The basis of minimally invasive techniques in esophageal surgery is to maintain the therapy effectiveness and quality of traditional operations, while reducing perioperative injury. Nevertheless, the real benefits of minimally invasive approach for esophagectomy are still controversial [11–13]. A number of meta-analyses and even randomized controlled trials demonstrated MIO to be superior in reducing risk of postoperative outcomes, but their results are not very consistent, especially on the issue of in-hospital mortality [14–30]. Furthermore, these studies ignored preoperative clinical data and other Chinese relevant literatures. We, therefore, performed a meta-analysis combining the relevant publications and comprehensively assess the superiority of MIO.

MIO is a feasible and a reliable surgical procedure and is superior to OE, with less perioperative complications and in-hospital mortality. However, due to certain limitations of this study, as aforementioned above, further large sample and RCT studies are needed to estimate the effect of MIO and establish the guidelines for future.



PORT PLACEMENT IN VATS OESOPHAGECTOMY: TTP

The patient is intubated with a double lumen endotracheal tube (ETT) for single lung ventilation and positioned in the left lateral decubitus position. Four thoracoscopic ports are introduced (Figure 7A). The camera port (10 mm) is placed at the seventh intercostal space, midaxillary line. A 10 mm port is placed at the eighth or ninth intercostal space 2 cm posterior to the posterior axillary line for the ultrasonic coagulating shears. Two additional ports are placed, one 5 mm posterior to the tip of the scapula and one 10 mm at the fourth intercostal space at the anterior axillary line for retraction and counter-traction during the esophageal dissection. Next, an 0 endostitch is placed in the central tendon of the diaphragm and brought out of the inferior, anterior chest wall through a 1-mm skin nick using the endo-close device. This traction suture allows downward retraction on the diaphragm without the need for a retractor and gives good exposure of the distal esophagus.



In the supine position, the double lumen ETT is exchanged to a single lumen tube, then 5 abdominal ports are placed on the anterior abdominal wall similar to the approach for a laparoscopic Nissen fundoplication: one cut-down 10 mm port in the right epigastrium and four 5 mm ports in the bilateral subcostal, left epigastrium and right flank locations (Figure 7B).

The triangle Target Principle requires placing the Optical Port at the 5th intercostal space along the midaxillary line, the 1st working port at the 7th intercostal space along the Posterior Axillary line and the Target port at the 9th intercostal space along the posterior axillary line. (Figure 7C)

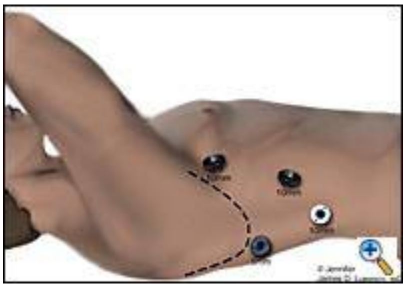


Figure 7A. Thoracoscopic port placement for MIE

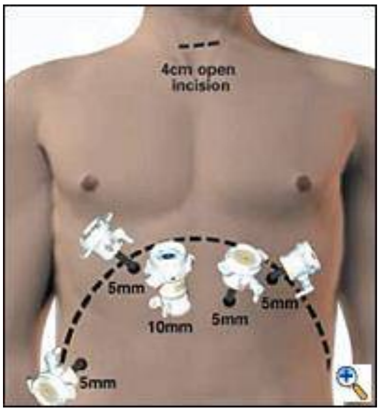


Figure 7B. Lap port placement for gastric mobilization in MIE

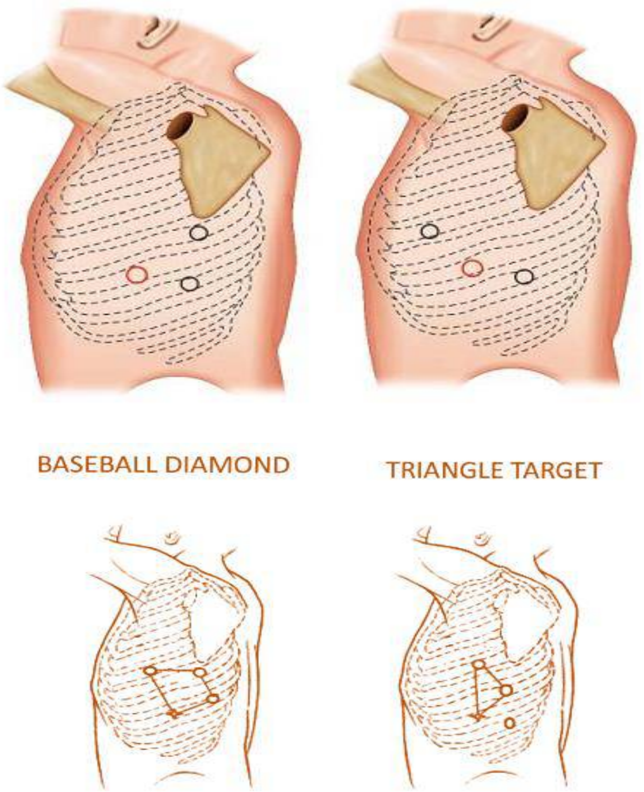


Figure 7C: Ports placement in VATS Oesophagectomy using TTP

Chapter- 03

CHAPTER III

METHODOLOGY

3.1 STUDY DESIGN

The study is a Prospective Experimental Study done in partial fulfillment for the award of Masters in Minimal Access Surgery (M.MAS) degree from Singhania University, Rajsthan, India.

3. 2 PLACE OF STUDY

The Study was conducted at the Institute of Minimal Access Surgery at the World Laparoscopy Hospital, Gurgaon, NCR Delhi, India under the supervision of Singhania University, Rajsthan, India.

Singhania University was established by the government of Rajasthan, under ordinance 6 of 2007. It is a UGC recognized university as per sec. 2f of the UGC act 1956. It is in Pacheri bari, Jhunjhunu in the northern indian state of Rajasthan.

The Department of Minimal Access Surgery was established under Professor R.K.Mishra at the World Laparoscopy Hospital to conduct Fellowships, Diploma and Master's degree in Minimal Access Surgery (F.MAS, D.MAS and M.MAS).[22]

The World laparoscopy Hospital (WLH) is a Premier Hospital for Laparoscopic treatment, Training and Research located in Gurgaon, Haryana, NCR Delhi. It was established in 2001 by Professor R.K.Mishra. It is recognised by the World Association of Laparoscopic Surgeons (WALS) and the Society of American Gastrointestinal and Endoscopic Surgeons (SAGES) and it is also ISO 9001-2008 certified.[23]

WLH conducts International Fellowships in Minimal Access Surgery, Laparoscopic, Thoracoscopic and Robotic Surgery, Diploma in Minimal Access Surgery and Hands-on Courses in Assisted Reproductive Technology, Upper and Lower Gastrointestinal Endoscopy, Arthroscopic Surgery and a Masters in Minimal Access Surgery (M.MAS) which is awarded by Singhania University, Rajasthan. So far about 7000 Surgeons and Gynaecologists have been trained at the WLH.

3.3 SAMPLE SIZE DETERMINATION

The Sample size was calculated using the formula n= Z^2 pq/d^2

Where n=Sample size z= constant at 95% confidence interval=1.96 P=prevalence=0.019[14] q= 1-p complementary probability=0.991 d= 0.05 precision

Thus n=1.96^2 x 0.019x 0.991/ 0.05^2 =28.93

Hence 30 VATS Procedures were done as the sample size.

3.4 DATA COLLECTION

Thirty (30) Video-Assisted Thoracic Surgery (VATS) procedures were conducted on swine models at the Institute of Minimal Access Surgery, World Laparoscopy Hospital, Gurgaon India over 6 months between 15/01/2018 and 15/10/2018.

The procedures are: 1. Thoracoscopic Lung Resection 2. Thoracoscopic Atrial Septal Defect closure 3. Thoracoscopic Thymectomy 4. Thoracoscopic Internal Thoracic Artery Harvesting for TECABG 5. Thoracoscopic Oesophagectomy.

The details of the procedures are 6 Lung Resection, 6 Atrial Septal Defect closure, 6 Thymectomy, 6 Internal Thoracic Artery Harvesting for TECABG and 6 Oesophagectomy on 30 Animals. Each procedure was done using the TTP principal. Thus 30 procedures were done using the TTP.

The Outcome measures are The **Execution Time** in seconds (Port Access Time plus Actual Procedure Time), **Error rate** (Lung perforation, Myocardial Injury, injury to the great vessels, injury to the phrenic nerve, Oesophageal Perforation, Subdiaphragmatic primary Trocar entry for Oesophagectomy and Intercostal **Vessels Bleeding** for port placement during ITA Harvesting) and **Surgeons Discomfort Level** as analysed by Visual Analogue System (VAS) ranging from 1-10 in increasing Discomfort pattern. These outcome measures recorded for each procedure were entered into a proforma. (Appendix I)

The procedures were done after the swine were given general Anaesthesia (Ketamine, Propofol, Diazepn-v, Midazolam and Tramadol). The ports were created using surgical scalpel and air insufflation of the chest cavity was done to collapse the ipsilateral Lung. The Optical trocar was inserted blindly while the Working Ports were inserted under vision. VATS Atrial Septal Defect closure either direct closure or pericardium/PTFE patch using grasper, scissors, retractor, arterial and venous cannula, hook disector, cardiopulmonary bypass circuit and Heart-Lung machine. VATS Oesophagectomy was done with the alternating use of scissors, monopolar hook diathermy and grasper for retracting the lower lobe of the left Lung. Monopolar hook diathermy, harmonic devices were also used to do Thymectomy. At the end of the procedure Euthanasia was conducted by giving high dose of Succinylcholine and the carcasses disposed appropriately as per regulation under the provisions of Section 15 of the Prevention of Cruelty to Animals Act, 1960 and the rules under the Act of 1998 and 2001.

3.5 METHODS OF DATA COLLECTION AND ANALYSIS

The data was recorded in a pre-constructed data collection sheet, cleaned and entered into a computer using SPSS version 16 for Windows. Analysis was done using statistical methods such as Mean and Chi-square. Results and manual calculation of Chi-square are presented in figures and tables.

3.6 ETHICAL CONSIDERATIONS

The research was an animal study which is strictly regulated in India under the provisions of Section 15 of the Prevention of Cruelty to Animals Act, 1960 and the rules under the Act of 1998 and 2001. This is enforced by the Committee for the Purpose of Control and Supervision of Experiments on Animals (CPCSEA).[24] In conducting this research, the operational guidelines for Observance of good Practices by the CPCSEA was strictly adhered to. Permission and approval for procurement of the Pigs from CPCSEA registered Animal breeding houses and conduct of the research was obtained. At the end of the experiments Euthanasia was induced and the Animals carcasses were disposed humanly according to the provisions.

Chapter- 04

CHAPTER- IV

RESULT AND OBSERVATIONS:

A total of 30 procedures were done in this study. Triangle Port Placement (TTP) was used.

The details of the procedures are 6 (20%) Lung Resection, 6 (20%) Atrial Septal Defect closure, 6 (20%) Thymectomy, 6 (20%) Internal Thoracic Artery Harvesting for TECABG and 6 (20%) Oesophagectomy on 30 animals through minimal access procedure.

It is to evaluate the Execution time (sum of the ports Access Time and the Actual Procedure Time), Error rates and the Surgeon's discomfort for each of the three angles of manipulation.

A. LUNG RESECTION

1. Timing for surgeon's suturing and knot tying

Table- 1.1A(a): Timing (in seconds) for surgeon's suturing and knot tying in Lung resection with manipulation angle 30^0	
Mean	311.8
Std. Deviation	±117.3
Minimum	279.0
Maximum	339.0

Timing (in seconds) for surgeon's suturing and knot tying in Lung resection with manipulation angle 30^0 is shown in Table 1.1A (a).
Mean time for suturing and knot tying for lung resection at 30^0 angle of manipulation is 311.8 (±117.3) seconds. Minimum and Maximum time required were 279.0 and 339.0 respectively.

Table- 1.1A (b): Timing for surgeon's suturing and knot tying in Lung resection with manipulation angle 30^0

Sl. No	Observed (O)	Expected (E)	(O-E)	(O-E)2	(O-E)2/E
1	306	311.83	-5.83	33.99	0.11
2	309	311.83	-2.83	8.01	0.03
3	320	311.83	8.17	66.75	0.21
4	278	311.83	-33.83	1144.47	3.67
5	319	311.83	7.17	51.41	0.16
6	339	311.83	27.17	738.21	2.37
	m=311.83				X^2=6.55
Average timing = 311.83 seconds					
P-value (30.141) > $\mathbf{X^2}$					

Timing for surgeon's suturing and knot tying in Lung resection for each case with manipulation angle 30^0 is shown in Table 1.1A (b).
Average timing is 311.83 seconds, X^2 value is 6.55 at which level p value is 30.141. So, $p > X^2$.

Table- 1.1B(a): Timing for surgeon's suturing and knot tying in Lung resection with manipulation angle 60^0	
Mean	304.33
Std. Deviation	±6.06
Minimum	294.00
Maximum	330.00

Timing (in seconds) for surgeon's suturing and knot tying in Lung resection with manipulation angle 60^0 is shown in Table 1.1B (a).
Mean time for suturing and knot tying for lung resection at 60^0 angle of manipulation is 304.33 (±6.06) seconds. Minimum and Maximum time required were 294.0 and 330.0 respectively.

Table- 1.1B (b): Timing for surgeon's suturing and knot tying in Lung resection with manipulation angle 60^0

Sl. No	Observed (O)	Expected (E)	(O-E)	(O-E)2	(O-E)2/E
1	300	304.33	-4.33	18.75	0.06
2	301	304.33	-3.33	11.09	0.04
3	294	304.33	-10.33	106.71	0.35
4	330	304.33	25.67	658.95	2.17
5	299	304.33	-5.33	28.41	0.09
6	302	304.33	-2.33	5.43	0.02
	m=304.33				X^2=2.73
Average timing = 304.33 seconds					
P-value (30.141) > $\mathbf{X^2}$					

Timing for surgeon's suturing and knot tying in Lung resection for each case with manipulation angle 60^0 is shown in Table 1.1B(b).
Average timing is 304.33 seconds, X^2 value is 2.73 at which level p value is 30.141. So, $p>X^2$.

Table- 1.1C(a): Timing for surgeon's suturing and knot tying in Lung resection with manipulation angle 90^0	
Mean	344.50
Std. Deviation	±1.21
Minimum	330.00
Maximum	400.00

Timing (in seconds) for surgeon's suturing and knot tying in Lung resection with manipulation angle 90^0 is shown in Table 1.1C(a).
Mean time for suturing and knot tying for lung resection at 90^0 angle of manipulation is 344.50 (±1.21) seconds. Minimum and Maximum time required were 330.0 and 400.0 respectively.

Table- 1.1C(b): Timing for surgeon's suturing and knot tying in Lung resection with manipulation angle 90^0

Sl. No	Observed (O)	Expected (E)	(O-E)	(O-E)2	(O-E)2/E
1	332	344.50	-12.50	156.25	0.45
2	330	344.50	-14.50	210.25	0.61
3	338	344.50	-6.50	42.25	0.12
4	332	344.50	-12.50	156.25	0.45
5	400	344.50	55.50	3080.25	8.94
6	335	344.50	-9.50	90.25	0.26
	m=344.50				X^2=10.84
Average timing = 344.50 seconds					
P-value (30.141) > $\mathbf{X^2}$					

Timing for surgeon's suturing and knot tying in Lung resection for each case with manipulation angle 90^0 is shown in Table 1.1C(b).
Average timing is 344.50 seconds, X^2 value is 10.84 at which level p value is 30.141. So, $p>X^2$.

Table- 1.1D: Average timing for surgeon's suturing and knot tying in Lung resection with manipulation

Manipulation angle	30^0	60^0	90^0
Average timing in seconds	311.83	304.33	344.50
$\mathbf{X^2}$	6.55	2.73	10.84

Average timing (mean time) in seconds for surgeon's suturing and knot tying in Lung resection at 30^0, 60^0 and 90^0 angle is 311.83, 304.33 and 344.50 respectively. X^2 values at those angles are 6.55, 2.73 and 10.84. The lowest time required is at 60^0 degree angle manipulation.

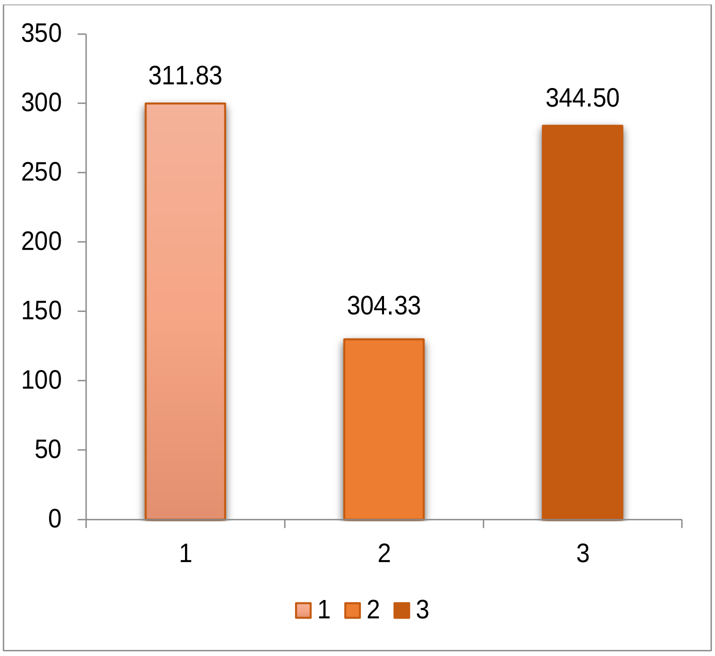


Fig-1: Average timing in seconds for surgeon's suturing and knot tying in Lung resection at 30^0, 60^0, 90^0 port position angles

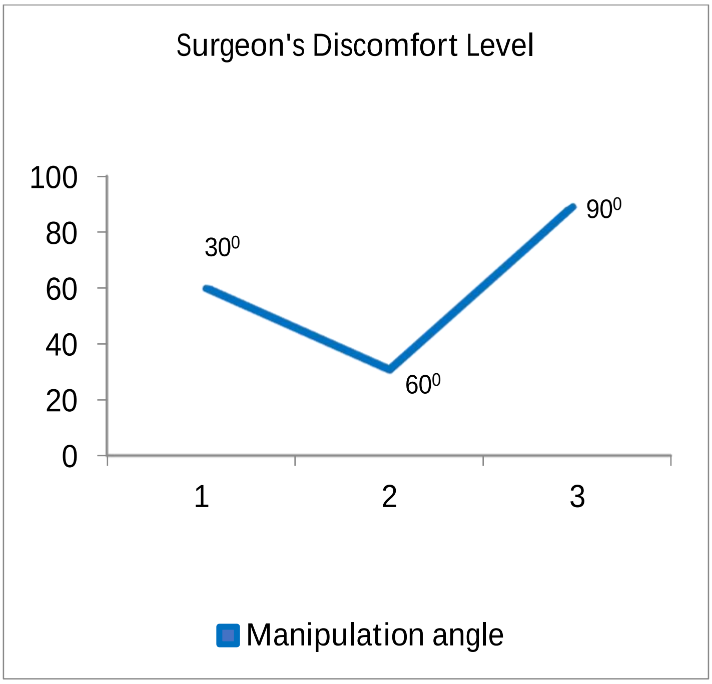


Fig-2: Surgeon's discomfort level for surgeon's suturing and knot tying in Lung resection at 30^0, 60^0, 90^0 port position angles

Readings of timing obtained while making a surgeon's suturing and knot tying in Lung resection in the dummy at different manipulation angles (30^0, 60^0, 90^0) are shown in above tables which were validated and average obtained by χ^2 tests. The average timing in seconds for 30º, 60º and 90º were 311.83, 304.33 and 344.50 respectively. All the readings were reproducible at p-value (30.144), 5% level of significance. It has demonstrated that the 60º angle has shorter operative time followed by 30^0 and then 90º.

2. Timing for surgeon's applying Endo GIA Stapler device (Linear) in Lung resection

Table- 1.2A(a): Timing for surgeon's applying Endo GIA Stapler device (Linear) in Lung resection with manipulation angle 30^0	
Mean	907.17
Std. Deviation	±8.24
Minimum	888.00
Maximum	923.00

Timing (in seconds) for surgeon's applying Endo GIA Stapler device (Linear) in Lung resection with manipulation angle 30^0 is shown in Table 1.2A(a).

Mean time for suturing and knot tying for lung resection at 30^0 angle of manipulation is 907.17 (±8.24) seconds. Minimum and Maximum time required were 888.0 and 923.0 respectively.

Table- 1.2A (b): Timing for surgeon's applying Endo GIA Stapler device (Linear) in Lung resection with manipulation angle 30^0

Sl no.	Observed(O)	Expected(E)	O-E	$(O-E)^2$	$\frac{(O-E)^2}{E}$
1	908	907.17	0.83	0.69	0.00
2	907	907.17	-0.17	0.03	0.00
3	888	907.17	-19.17	367.49	0.41
4	910	907.17	2.83	8.01	0.01
5	923	907.17	15.83	250.59	0.28
6	907	907.17	-0.17	0.03	0.00
	m=907.17				0.69
Average timing = 907.17 seconds					$\boldsymbol{X^2}$=0.69
P-value (30.142) > $\boldsymbol{X^2}$					

Timing for surgeon's applying Endo GIA Stapler device (Linear) in Lung resection for each case with manipulation angle 30^0 is shown in Table 1.2A(b).

Average timing is 907.17 seconds, X^2 value is 0.69 at which level p value is 30.142. So, $p>X^2$.

Table- 1.2B(a): Timing for surgeon's applying Endo GIA Stapler device (Linear) in Lung resection with manipulation angle 60^0	
Mean	835.00
Std. Deviation	±1.86
Minimum	822.00
Maximum	850.00

Timing (in seconds) for surgeon's applying Endo GIA Stapler device (Linear) in Lung resection with manipulation angle 60^0 is shown in Table 1.2B(a).

Mean time for suturing and knot tying for lung resection at 60^0 angle of manipulation is 835.00 (±1.86) seconds. Minimum and Maximum time required were 822.0 and 850.0 respectively.

Table- 1.2B(b): Timing for surgeon's applying Endo GIA Stapler device (Linear) in Lung resection with manipulation angle 60^0

Sl no.	Observed(O)	Expected(E)	O-E	(O-E)2	(O-E)2/E
1	832	835.00	-3.00	9.00	0.01
2	840	835.00	5.00	25.00	0.03
3	828	835.00	-7.00	49.00	0.06
4	838	835.00	3.00	9.00	0.01
5	850	835.00	15.00	225.00	0.27
6	822	835.00	-13.00	169.00	0.20
	m=835.00				X^2=0.58
Average timing = 835.00 seconds					
P-value (30.141) > X^2					

Timing for surgeon's applying Endo GIA Stapler device (Linear) in Lung resection for each case with manipulation angle 60^0 is shown in Table 1.2B(b).

Average timing is 835.00 seconds, X^2 value is 0.58 at which level p value is 30.141. So, p>X^2.

Table- 1.2C(a): Timing for surgeon's applying Endo GIA Stapler device (Linear) in Lung resection with manipulation angle 90^0	
Mean	988.5
Std. Deviation	±2.63
Minimum	978.00
Maximum	1012.00

Timing (in seconds) for surgeon's applying Endo GIA Stapler device (Linear) in Lung resection with manipulation angle 90^0 is shown in Table 1.1C(a).

Mean time for suturing and knot tying for lung resection at 90^0 angle of manipulation is 988.5 (±2.63) seconds. Minimum and Maximum time required were 978.0 and 1012.0 respectively.

Table- 1.2C(b): Timing for surgeon's applying Endo GIA Stapler device (Linear) in Lung resection with manipulation angle 90^0

Sl. No	Observed (O)	Expected (E)	(O-E)	(O-E)2	(O-E)2/E
1	987	988.50	-1.50	2.25	0.00
2	982	988.50	-6.50	42.25	0.04
3	1012	988.50	23.50	552.25	0.56
4	978	988.50	-10.50	110.25	0.11
5	984	988.50	-4.50	20.25	0.02
6	988	988.50	-0.50	0.25	0.00
	m=988.50				X^2=0.74
Average timing = 988.50 seconds					
P-value (30.141) > X^2					

Timing for surgeon's applying Endo GIA Stapler device (Linear) in Lung resection for each case with manipulation angle 90^0 is shown in Table 1.2C(b).

Average timing is 988.5 seconds, X^2 value is 0.74 at which level p value is 30.141. So, $p>X^2$.

Table- 1.2D: Average timing for surgeon's applying Endo GIA Stapler device (Linear) in Lung resection with manipulation

Manipulation angle	30^0	60^0	90^0
Average timing in seconds	907.17	856.83	988.50
X^2	0.69	3.94	0.74

Average timing (mean time) in seconds for surgeon's applying Endo GIA Stapler device (Linear) in Lung resection at 30^0, 60^0 and 90^0 angle is 907.17, 856.83 and 988.50 respectively. X^2 values at those angles are 0.69, 3.94 and 0.74. The lowest time required is at 60^0 degree angle manipulation.

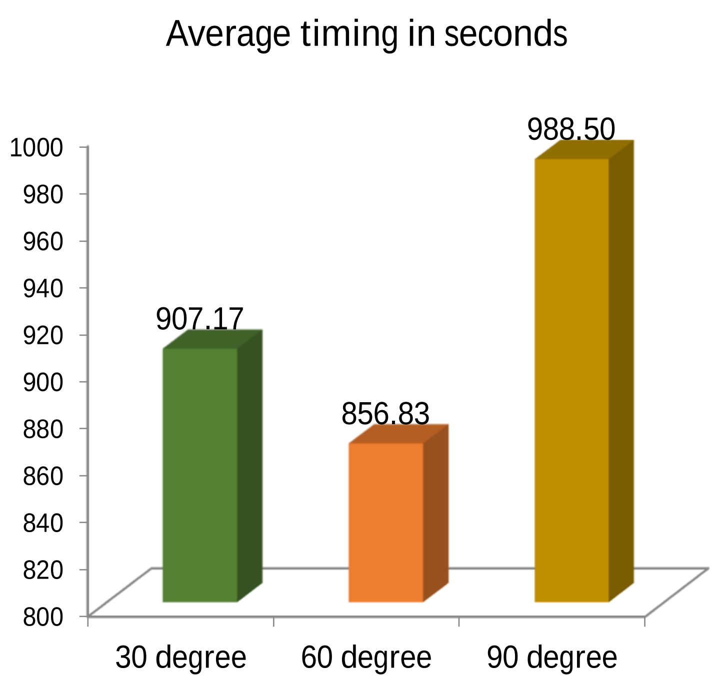


Fig- 1.2D: Average timing for surgeon's applying Endo GIA Stapler device (Linear) in Lung resection with manipulation angles

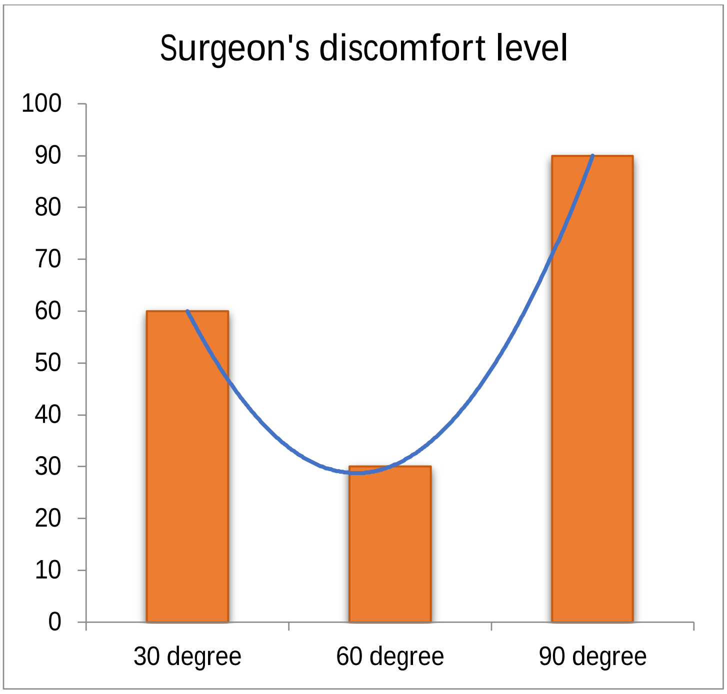


Fig- 1.2D: Surgeon's discomfort level for applying Endo GIA Stapler device (Linear) in Lung resection with manipulation angles

Readings of timing obtained while making a surgeon's applying Endo GIA Stapler device (Linear) in Lung resection in the dummy animals at different manipulation angles (30^0, 60^0, 90^0) are shown in Tables 1.2A to 1.2D which were validated and average obtained by χ^2 tests. The average timing in seconds for 30º, 60º and 90º were 907.17, 856.83 and 988.50 respectively. All the readings were reproducible at p-value (30.141), 5% level of significance. It has demonstrated that the 60º angle has shorter operative time followed by 30^0 and then 90º.

B. Atrial Septal Defect closure:

1. Timing for surgeon's suturing and knot tying in ASD closure

Table- 2.1A(a): Timing for surgeon's suturing and knot tying in ASD closure with manipulation angle 30^0	
Mean	221.23
Std. Deviation	±1.84
Minimum	199.00
Maximum	254.00

Timing (in seconds) for surgeon's suturing and knot tying in ASD closure with manipulation angle 30^0 is shown in Table 2.1A(a).

Mean time for suturing and knot tying for ASD closure at 30^0 angle of manipulation is 221.23 (±1.84) seconds. Minimum and Maximum time required were 199.0 and 250.0 respectively.

Table- 2.1A(b): Timing for surgeon's suturing and knot tying in ASD closure with manipulation angle 30^0

Sl no.	Observed(O)	Expected(E)	O-E	$(O\text{-}E)^2$	$\frac{(O\text{-}E)^2}{E}$
1	248	225.67	22.33	498.63	2.21
2	205	225.67	-20.67	427.25	1.89
3	211	225.67	-14.67	215.21	0.95
4	237	225.67	11.33	128.37	0.57
5	199	225.67	-26.67	711.29	3.15
6	254	225.67	28.33	802.59	3.56
	225.67				12.33
Average timing = 225.67 seconds					X^2=12.33
P-value (30.141) > X^2					

Timing for surgeon's suturing and knot tying in ASD closure for each case with manipulation angle 30^0 is shown in Table 2.1A(b).

Average timing is 221.20 seconds, X^2 value is 26.36 at which level p value is 30.141. So, $p>X^2$.

Table- 2.1B(a): Timing for surgeon's suturing and knot tying in ASD closure with manipulation angle 60^0	
Mean	128.67
Std. Deviation	±1.04
Minimum	115.00
Maximum	159.00

Timing (in seconds) for surgeon's suturing and knot tying in ASD closure with manipulation angle 60^0 is shown in Table 2.1B(a).

Mean time for suturing and knot tying for ASD closure at 60^0 angle of manipulation is 128.67 (±1.04) seconds. Minimum and Maximum time required were 115.0 and 159.0 respectively.

Table- 2.1B(b): Timing for surgeon's suturing and knot tying in with ASD closure manipulation angle 60^0

Sl no.	Observed(O)	Expected(E)	O-E	$(O-E)^2$	$\frac{(O-E)^2}{E}$
1	121	128.67	-7.67	58.83	0.46
2	132	128.67	3.33	11.09	0.09
3	117	128.67	-11.67	136.19	1.06
4	128	128.67	-0.67	0.45	0.00
5	159	128.67	30.33	919.91	7.15
6	115	128.67	-13.67	186.87	1.45
	m=128.67				X^2=10.21
Average timing = 132.37 seconds					
P-value (30.141) > $\mathbf{X^2}$					

Timing for surgeon's suturing and knot tying in ASD closure for each case with manipulation angle 60^0 is shown in Table 2.1B(b).

Average timing is 128.67 seconds, X^2 value is 10.21 at which level p value is 30.141. So, $p>X^2$.

Table- 2.1C(a): Timing for surgeon's suturing and knot tying in with ASD closure manipulation angle 90^0	
Mean	293.33
Std. Deviation	±1.78
Minimum	267.00
Maximum	327.00

Timing (in seconds) for surgeon's suturing and knot tying in ASD closure with manipulation angle 60^0 is shown in Table 2.1C(a).

Mean time for suturing and knot tying for ASD closure at 90^0 angle of manipulation is 293.33 (±1.78) seconds. Minimum and Maximum time required were 267.0 and 327.0 respectively.

Table- 2.1C(b): Timing for surgeon's suturing and knot tying in with ASD closure manipulation angle 90^0

Sl no.	Observed(O)	Expected(E)	O-E	$(O-E)^2$	$\frac{(O-E)^2}{E}$
1	294	293.33	0.67	0.45	0.00
2	327	293.33	33.67	1133.67	3.86
3	267	293.33	-26.33	693.27	2.36
4	271	293.33	-22.33	498.63	1.70
5	280	293.33	-13.33	177.69	0.61
6	321	293.33	27.67	765.63	2.61
	m=293.33				X^2=11.15
Average timing = 293.33 seconds					
P-value (30.141) > $\mathbf{X^2}$					

Timing for surgeon's suturing and knot tying in ASD closure for each case with manipulation angle 90^0 is shown in Table 2.1C (b).

Average timing is 293.33 seconds, X^2 value is 11.15 at which level p value is 30.141. So, $p>X^2$.

Table- 2.1D: Average timing for surgeon's suturing and knot tying in ASD closure with manipulation

Manipulation angle	30^0	60^0	90^0
Average timing in seconds	225.67	128.67	293.33
$\mathbf{X^2}$	12.33	10.21	11.15

Average timing (mean time) in seconds timing for surgeon's suturing and knot tying in ASD closure at 30^0, 60^0 and 90^0 angle is 225.67, 128.67 and 293.33 respectively. X^2 values at those angles are 12.33, 10.21 and 11.15. The lowest time required is at 60^0 degree angle manipulation.

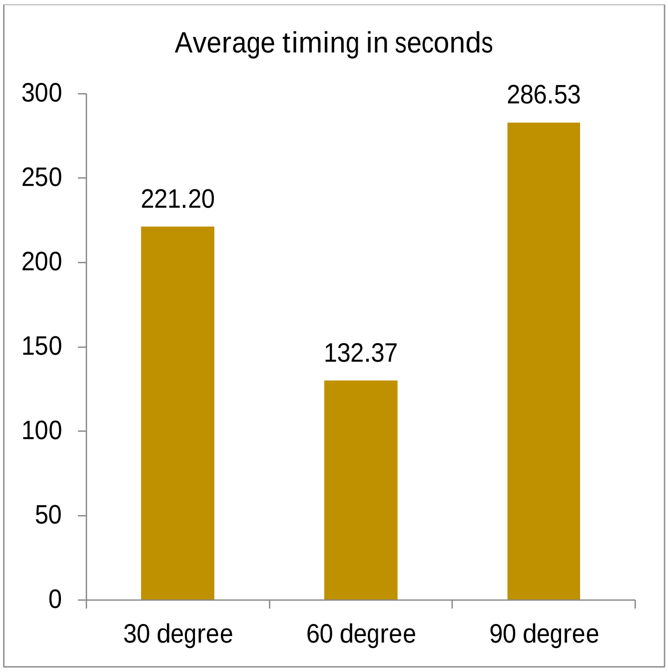


Fig- 2.1D: Average timing for surgeon's suturing and knot tying in ASD closure with manipulation angles

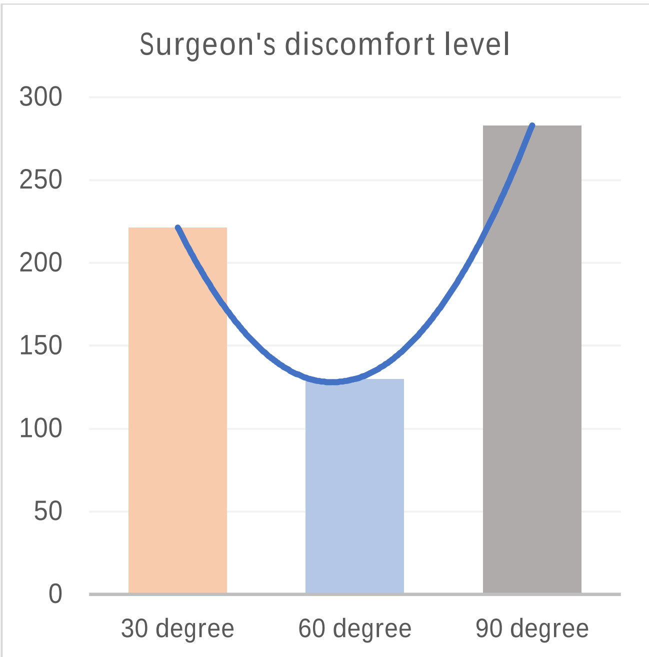


Fig- 2.1D: Surgeon's discomfort level for suturing and knot tying in ASD closure with manipulation angles

In the Tables 2A to 2D readings of timing taken to surgeon's suturing and knot tying in ASD closure in the swine at different manipulation angles are shown which were validated by χ^2 test and means obtained. The average timing in seconds for 30, 60 and 90 degrees were 225.67, 128.67 and 293.33 respectively. It has clearly demonstrated that the 60º angle has shorter operative time followed by 30º and then 90º, although, all the readings were reproducible at p-value (30.141), 5% level of significance.

2. Timing for surgeon's clipping in ASD closure

Table- 2.2A(a): Timing for surgeon's clipping in ASD closure with manipulation angle 30^0	
Mean	32.50
Std. Deviation	±3.44
Minimum	27.00
Maximum	39.00

Timing (in seconds) for surgeon's clipping in ASD closure with manipulation angle 30^0 is shown in Table 2.2A(a).

Mean time for suturing and knot tying for lung resection at 60^0 angle of manipulation is 32.50 (±3.44) seconds. Minimum and Maximum time required were 27.0 and 39.0 respectively.

Table- 2.2A(b): Timing for surgeon's clipping in ASD closure with manipulation angle 30^0

Sl. No	Observed (O)	Expected (E)	(O-E)	(O-E)2	(O-E)2/E
1	30	32.50	-2.50	6.25	0.19
2	32	32.50	-0.50	0.25	0.01
3	36	32.50	3.50	12.25	0.38
4	39	32.50	6.50	42.25	1.30
5	27	32.50	-5.50	30.25	0.93
6	31	32.50	-1.50	2.25	0.07
	m=32.50				χ2= 2.88
Average value= 32.50					
p value= 30.02 > χ2					

Timing for surgeon's clipping in ASD closure for each case with manipulation angle 30^0 is shown in Table 2.2A (b).

Average timing is 32.50 seconds, X^2 value is 2.88 at which level p value is 30.141. So, $p>X^2$.

Table- 2.2B(a): Timing for surgeon's clipping in ASD closure with manipulation angle 60^0	
Mean	31.00
Std. Deviation	±2.03
Minimum	27.00
Maximum	35.00

Timing (in seconds) for surgeon's clipping in ASD closure with manipulation angle 60^0 is shown in Table 2.2B (a).

Mean time for clipping in ASD closure at 60^0 angle of manipulation is 31.00 (±2.03) seconds. Minimum and Maximum time required were 27.0 and 35.0 respectively.

Table- 2.2B (b): Timing for surgeon's clipping in ASD closure with manipulation angle 60^0

Sl no.	Observed(O)	Expected(E)	O-E	$(O-E)^2$	$\frac{(O-E)^2}{E}$
1	30	31.00	-1.00	1.00	0.03
2	31	31.00	0.00	0.00	0.00
3	29	31.00	-2.00	4.00	0.13
4	35	31.00	4.00	16.00	0.52
5	27	31.00	-4.00	16.00	0.52
6	34	31.00	3.00	9.00	0.29
	m=31.00				X^2 =1.48
Average timing = 31.00 seconds					
P-value (30.141) > X^2					

Timing for surgeon's clipping in ASD closure for each case with manipulation angle 60^0 is shown in Table 2.2B (b).

Average timing is 31.00 seconds, X^2 value is 1.48 at which level p value is 30.141. So, $p>X^2$.

Table- 2.2C(a): Timing for surgeon's clipping in ASD closure with manipulation angle 90^0	
Mean	40.50
Std. Deviation	±2.09
Minimum	36.00
Maximum	45.00

Timing (in seconds) for surgeon's clipping in ASD closure with manipulation angle 90^0 is shown in Table 2.2C (a).

Mean time for clipping for ASD closure at 90^0 angle of manipulation is 40.50 (±2.09) seconds. Minimum and Maximum time required were 36.0 and 45.0 respectively.

Table- 2.2C(b): Timing for surgeon's clipping in ASD closure with manipulation angle 90^0

Sl no.	Observed(O)	Expected(E)	O-E	$(O-E)^2$	$\frac{(O-E)^2}{E}$
1	44	40.50	3.50	12.25	0.30
2	39	40.50	-1.50	2.25	0.06
3	41	40.50	0.50	0.25	0.01
4	36	40.50	-4.50	20.25	0.50
5	45	40.50	4.50	20.25	0.50
6	38	40.50	-2.50	6.25	0.15
	m=40.50				X^2 =1.52
Average timing = 40.50 seconds					
P-value (34.141) > X^2					

Timing for surgeon's clipping in ASD closure for each case with manipulation angle 90^0 is shown in Table 2.2C (b).

Average timing is 40.50 seconds, X^2 value is 1.52 at which level p value is 30.141. So, $p>X^2$.

Table- 2.2D: Average timing for surgeon's clipping in ASD closure with manipulation

Manipulation angle	30^0	60^0	90^0
Average timing in seconds	32.50	31.00	40.50
X^2	2.88	1.48	1.52

Average timing (mean time) in seconds for surgeon's clipping in ASD closure at 30^0, 60^0 and 90^0 angle is 32.50, 31.00 and 40.50 respectively. X^2 values at those angles are 2.88, 1.48 and 1.52. The lowest time required is at 60^0 degree angle manipulation.

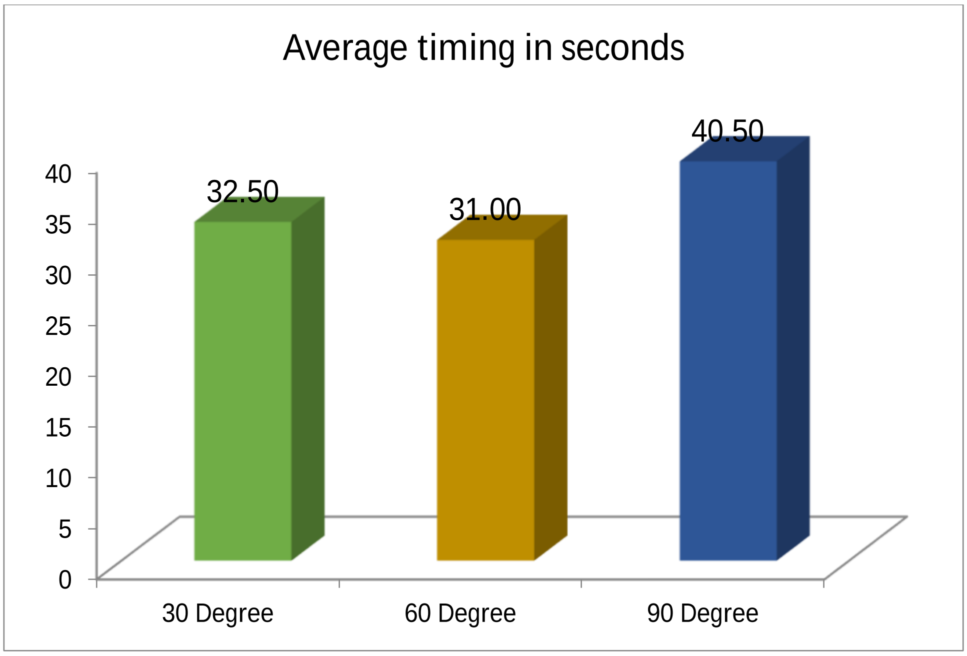


Fig- 2.2D: Average timing for surgeon's clipping in ASD closure with manipulation

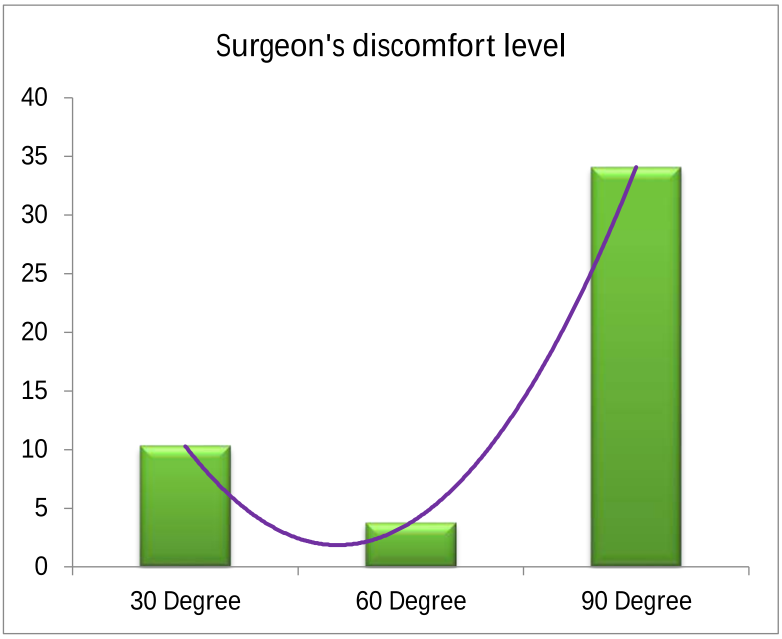


Fig- 2.2D: Surgeon's discomfort level for clipping in ASD closure with manipulation angles

Readings of timing obtained while making a surgeon's clipping in ASD closure in the pigs at different manipulation angles (30^0, 60^0, 90^0) are shown in Tables 2.2A to 2.2D which were validated and average obtained by χ^2 tests. The average timing in seconds for 30º, 60º and 90º were 32.50, 31.00 and 40.50 respectively. All the readings were reproducible at p-value (30.141), 5% level of significance. It has demonstrated that the 60º angle has shorter operative time followed by 30^0 and then 90º.

C. Thymectomy

1. Timing for surgeon's suturing and knot tying in Thymectomy

Table- 3.1A(a): Timing for surgeon's suturing and knot tying in Thymectomy with manipulation angle 30^0	
Mean	222.17
Std. Deviation	±1.80
Minimum	199.00
Maximum	254.00

Timing (in seconds) for surgeon's suturing and knot tying in thymectomy with manipulation angle 30^0 is shown in Table 3.1A (a).

Mean time for suturing and knot tying for thymectomy at 30^0 angle of manipulation is 222.17 (±1.80) seconds. Minimum and Maximum time required were 199.0 and 254.0 respectively.

Table- 3.1A(b): Timing for surgeon's suturing and knot tying in Thymectomy with manipulation angle 30^0

Sl no.	Observed(O)	Expected(E)	O-E	$(O-E)^2$	$\frac{(O-E)^2}{E}$
1	210	222.17	-12.17	148.11	0.67
2	232	222.17	9.83	96.63	0.43
3	214	222.17	-8.17	66.75	0.30
4	254	222.17	31.83	1013.15	4.56
5	224	222.17	1.83	3.35	0.02
6	199	222.17	-23.17	536.85	2.42
	m=222.17				X^2=8.39
Average timing = 222.17 seconds					
P-value (30.141) > $\mathbf{X^2}$					

Timing for surgeon's suturing and knot tying in thymectomy for each case with manipulation angle 30^0 is shown in Table 3.1A(b).

Average timing is 222.17 seconds, X^2 value is 8.39 at which level p value is 30.141. So, $p>X^2$.

Table- 3.1B(a): Timing for surgeon's suturing and knot tying in Thymectomy with manipulation angle 60^0	
Mean	138.17
Std. Deviation	±1.01
Minimum	115.00
Maximum	159.00

Timing (in seconds) for surgeon's suturing and knot tying in thymectomy with manipulation angle 60^0 is shown in Table 3.1B(a).

Mean time for suturing and knot tying for thymectomy at 60^0 angle of manipulation is 138.17 (±1.01) seconds. Minimum and Maximum time required were 115.0 and 159.0 respectively.

Table- 3.1B(b): Timing for surgeon's suturing and knot tying in Thymectomy with manipulation angle 60^0

Sl no.	Observed(O)	Expected(E)	O-E	$(O-E)^2$	$\frac{(O-E)^2}{E}$
1	132	138.17	-6.17	38.07	0.28
2	147	138.17	8.83	77.97	0.56
3	159	138.17	20.83	433.89	3.14
4	139	138.17	0.83	0.69	0.00
5	115	138.17	-23.17	536.85	3.89
6	137	138.17	-1.17	1.37	0.01
	m=138.17				
Average timing = 138.17 seconds					X^2=7.88
P-value (30.141) > $\mathbf{X^2}$					

Timing for surgeon's suturing and knot tying in thymectomy for each case with manipulation angle 60^0 is shown in Table 3.1B(b).

Average timing is 138.17 seconds, X^2 value is 7.88 at which level p value is 30.141. So, $p>X^2$.

Table- 3.1C(a): Timing for surgeon's suturing and knot tying in Thymectomy with manipulation angle 90^0	
Mean	282.83
Std. Deviation	±1.79
Minimum	262.00
Maximum	323.00

Timing (in seconds) for surgeon's suturing and knot tying in thymectomy with manipulation angle 90^0 is shown in Table 1.1B(a).

Mean time for suturing and knot tying for thymectomy at 90^0 angle of manipulation is 282.83 (±1.79) seconds. Minimum and Maximum time required were 262.0 and 323.0 respectively.

Table- 3.1C(b): Timing for surgeon's suturing and knot tying in Thymectomy with manipulation angle 90^0

Sl no.	Observed(O)	Expected(E)	O-E	$(O-E)^2$	$\frac{(O-E)^2}{E}$
1	274	282.83	-8.83	77.97	0.28
2	271	282.83	-11.83	139.95	0.49
3	262	282.83	-20.83	433.89	1.53
4	275	282.83	-7.83	61.31	0.22
5	292	282.83	9.17	84.09	0.30
6	323	282.83	40.17	1613.63	5.71
	m=282.83				X^2=8.52
Average timing = 282.83 seconds					
P-value (30.141) > $\mathbf{X^2}$					

Timing for surgeon's suturing and knot tying in thymectomy for each case with manipulation angle 90^0 is shown in Table 3.1C(b).

Average timing is 282.83 seconds, X^2 value is 8.52 at which level p value is 30.141. So, $p>X^2$.

Table- 3.1D: Average timing for surgeon's suturing and knot tying in Thymectomy with manipulation

Manipulation angle	30^0	60^0	90^0
Average timing in seconds	222.17	133.17	282.83
$\mathbf{X^2}$	8.39	7.88	8.52

Average timing (mean time) in seconds for surgeon's suturing and knot tying in Thymectomy at 30^0, 60^0 and 90^0 angle is 222.17, 133.17 and 282.83 respectively. X^2 values at those angles are 8.39, 7.88 and 8.52. The lowest time required is at 60^0 degree angle manipulation.

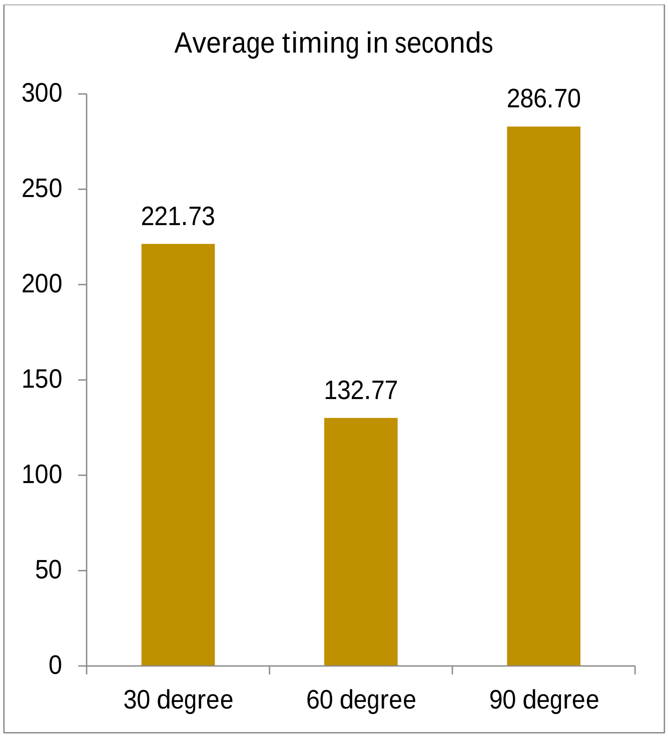


Fig- 3.1D: Average timing for surgeon's suturing and knot tying in Thymectomy with manipulation

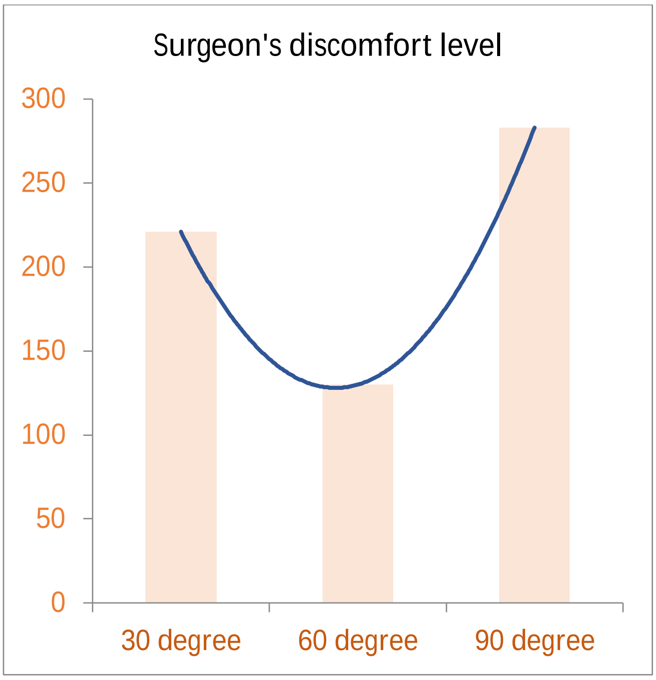


Fig- 3.1D: Surgeon's discomfort level for suturing and knot tying in Thymectomy with manipulation angles

Tables 3A to 3D showed readings of timing taken for suturing and knot tying in Thymectomy in the swine at different manipulation angles which were validated by χ^2 test and average obtained. The average timing in seconds for 30º, 60º and 90º were 222.17, 133.17 and 282.83 respectively. Only readings at 30^0 and 60º were reproducible at p-value (30.141), 5% level of significance but the χ^2 of readings at 90^0 was less than p-value, indicating nonreproducibility. These suggest that the 60º angle has shorter operative time than the 30º and 90º and above.

2. Timing for clipping in Thymectomy

Table- 3.2A(a): Timing for clipping in Thymectomy with manipulation angle 30^0	
Mean	33.00
Std. Deviation	±3.20
Minimum	28.00
Maximum	39.00

Timing (in seconds) for surgeon's clipping in Thymectomy with manipulation angle 30^0 is shown in Table 3.2A(a).

Mean time for clipping in Thymectomy at 30^0 angle of manipulation is 33.00 (±3.20) seconds. Minimum and Maximum time required were 28.0 and 39.0 respectively.

Table- 3.2A(b): Timing for clipping in Thymectomy with manipulation angle 30^0

Sl. No	Observed (O)	Expected (E)	(O-E)	(O-E)2	(O-E)2/E
1	30	33.00	-3.00	9.00	0.27
2	39	33.00	6.00	36.00	1.09
3	38	33.00	5.00	25.00	0.76
4	28	33.00	-5.00	25.00	0.76
5	32	33.00	-1.00	1.00	0.03
6	31	33.00	-2.00	4.00	0.12
	m=33.00				X^2=3.03
Expected value= 33.00					
p value= 30.141 > χ2					

Timing for surgeon's clipping in Thymectomy for each case with manipulation angle 30^0 is shown in Table 3.2A(b).

Average timing is 33.00 seconds, X^2 value is 3.03 at which level p value is 30.141. So, $p>X^2$.

Table- 3.2B(b): Timing for clipping in Thymectomy with manipulation angle 60^0	
Mean	32.33
Std. Deviation	±1.86
Minimum	29.00
Maximum	35.00

Timing (in seconds) for surgeon's clipping in Thymectomy with manipulation angle 60^0 is shown in Table 3.2B(b).

Mean time for clipping in Thymectomy at 60^0 angle of manipulation is 32.33 (±1.86) seconds. Minimum and Maximum time required were 29.0 and 35.0 respectively.

Table- 3.2B(b): Timing for clipping in Thymectomy with manipulation angle 60^0

Sl no.	Observed(O)	Expected(E)	O-E	$(O-E)^2$	$\frac{(O-E)^2}{E}$
1	32	32.33	-0.33	0.11	0.00
2	29	32.33	-3.33	11.09	0.34
3	34	32.33	1.67	2.79	0.09
4	35	32.33	2.67	7.13	0.22
5	34	32.33	1.67	2.79	0.09
6	30	32.33	-2.33	5.43	0.17
	m=32.33				X^2=0.91
Average timing = 32.33 seconds					
P-value (30.141) > X^2					

Timing for surgeon's suturing and knot tying in Lung resection for each case with manipulation angle 30^0 is shown in Table 3.2B (b).

Average timing is 32.33 seconds, X^2 value is 0.91 at which level p value is 30.141. So, p>X^2.

Table- 3.2C(a): Timing for clipping in Thymectomy with manipulation angle 90^0	
Mean	39.50
Std. Deviation	±2.15
Minimum	36.00
Maximum	45.00

Timing (in seconds) for surgeon's clipping in Thymectomy with manipulation angle 90^0 is shown in Table 3.2C(a).

Mean time for clipping in Thymectomy at 90^0 angle of manipulation is 39.50 (±2.15) seconds. Minimum and Maximum time required were 36.0 and 45.0 respectively.

Table- 3.2C(b): Timing for clipping in Thymectomy with manipulation angle 90^0

Sl no.	Observed(O)	Expected(E)	O-E	$(O-E)^2$	$\frac{(O-E)^2}{E}$
1	42	39.50	2.50	6.25	0.16
2	38	39.50	-1.50	2.25	0.06
3	39	39.50	-0.50	0.25	0.01
4	37	39.50	-2.50	6.25	0.16
5	36	39.50	-3.50	12.25	0.31
6	45	39.50	5.50	30.25	0.77
	m=39.50				X^2=1.46
Average timing = 39.50 seconds					
P-value (30.141) > X^2					

Timing for surgeon's clipping in Thymectomy for each case with manipulation angle 90^0 is shown in Table 3.2C(b).

Average timing is 39.50 seconds, X^2 value is 1.46 at which level p value is 30.141. So, $p>X^2$.

Table- 3.2D: Average timing for clipping in Thymectomy with manipulation

Manipulation angle	30^0	60^0	90^0
Average timing in seconds	33.00	32.33	39.50
X^2	3.03	0.91	1.46

Average timing (mean time) in seconds for clipping in Thymectomy at 30^0, 60^0 and 90^0 angle is 33.00, 32.33 and 39.50 respectively. X^2 value at those angles are 3.03, 0.91 and 1.46. The lowest time required is at 60^0 degree angle manipulation.

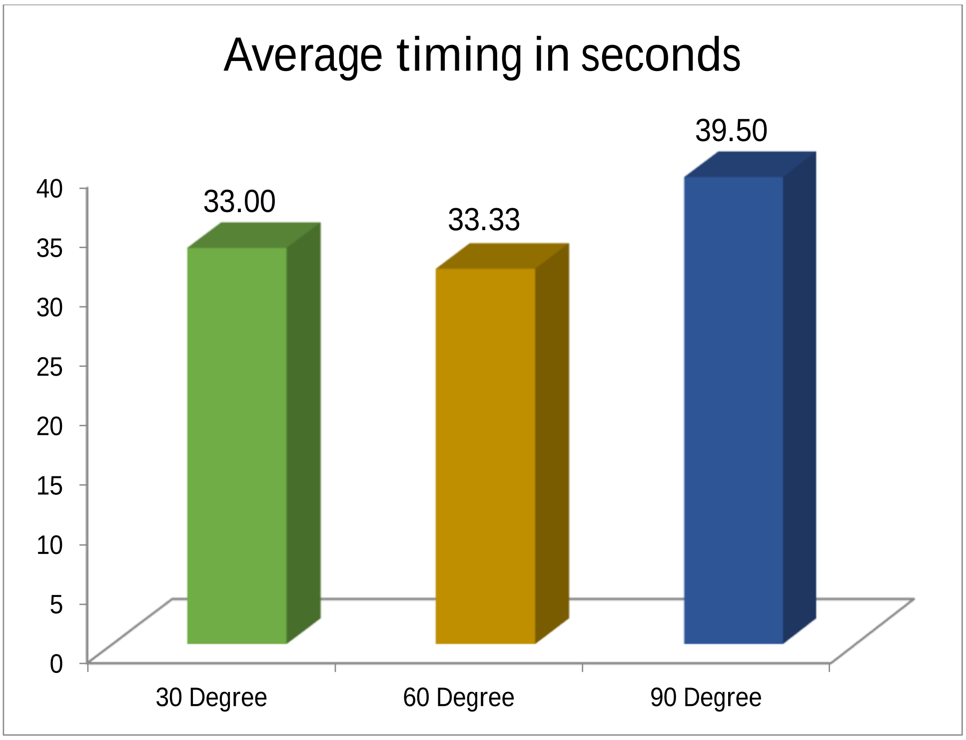


Fig- 3.2D: Average timing for clipping in Thymectomy with manipulation angles

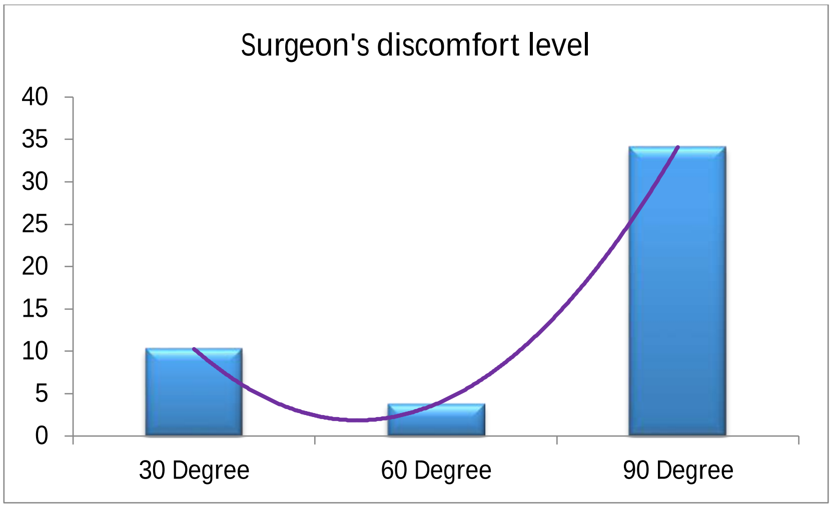


Fig- 3.2D: Surgeon's discomfort level for clipping in Thymectomy with manipulation angles

D. Internal Thoracic Artery (ITA) Harvesting for Coronary Artery Bypass Graft (CABG)

1. Timing for Electrosurgical device (Diathermy/Harmonic)

Table- 4.1A(a): Timing for Electrosurgical device (Diathermy/Harmonic) with manipulation angle 30^0	
Mean	34.17
Std. Deviation	±3.29
Minimum	28.00
Maximum	39.00

Timing (in seconds) for Electrosurgical device (Diathermy/Harmonic) in Internal Thoracic Artery (ITA) Harvesting for Coronary Artery Bypass Graft (CABG) with manipulation angle 30^0 is shown in Table 4.1A(a).

Mean time for Electrosurgical device (Diathermy/Harmonic) in Internal Thoracic Artery (ITA) Harvesting for Coronary Artery Bypass Graft (CABG) at 30^0 angle of manipulation is 34.17 (±3.29) seconds. Minimum and Maximum time required were 28.0 and 39.0 respectively.

Table- 4.1A(b): Timing for Electrosurgical device (Diathermy/Harmonic) with manipulation angle 30^0

Sl. No	Observed (O)	Expected (E)	(O-E)	(O-E)2	(O-E)2/E
1	31	34.17	-3.17	10.05	0.29
2	36	34.17	1.83	3.35	0.10
3	37	34.17	2.83	8.01	0.23
4	34	34.17	-0.17	0.03	0.00
5	39	34.17	4.83	23.33	0.68
6	28	34.17	-6.17	38.07	1.11
	m=34.17				X^2=2.42
Expected value= 34.17					
p value= 30.141 > χ2					

Timing for Electrosurgical device (Diathermy/Harmonic) in Internal Thoracic Artery (ITA) Harvesting for Coronary Artery Bypass Graft

(CABG) for each case with manipulation angle 30^0 is shown in Table- 4.1A(b).

Average timing is 34.17 seconds, X^2 value is 2.42 at which level p value is 30.141. So, $p>X^2$.

Table- 4.1B(a): Timing for Electrosurgical device (Diathermy/Harmonic) with manipulation angle 60^0	
Mean	31.83
Std. Deviation	±2.00
Minimum	28.00
Maximum	36.00

Timing (in seconds) for Electrosurgical device (Diathermy/Harmonic) with manipulation angle 60^0 is shown in Table- 4.1B(a).

Mean time for Electrosurgical device (Diathermy/Harmonic) at 60^0 angle of manipulation is 31.83 (±2.00) seconds. Minimum and Maximum time required were 28.0 and 36.0 respectively.

Table- 4.1B(b): Timing for Electrosurgical device (Diathermy/Harmonic) with manipulation angle 60^0

Sl no.	Observed(O)	Expected(E)	O-E	$(O-E)^2$	$\frac{(O-E)^2}{E}$
1	34	31.83	2.17	4.71	0.15
2	30	31.83	-1.83	3.35	0.11
3	32	31.83	0.17	0.03	0.00
4	28	31.83	-3.83	14.67	0.46
5	31	31.83	-0.83	0.69	0.02
6	36	31.83	4.17	17.39	0.55
	m=31.83				X^2=1.28
Average timing = 31.83 seconds					
P-value (30.17) > X^2					

Timing for Electrosurgical device (Diathermy/Harmonic) for each case with manipulation angle 60^0 is shown in Table- 4.1B(b).

Average timing is 31.83 seconds, X^2 value is 1.28 at which level p value is 30.141. So, $p>X^2$.

Table- 4.1C(a): Timing for Electrosurgical device (Diathermy/Harmonic) with manipulation angle 90^0	
Mean	40.33
Std. Deviation	±2.26
Minimum	36.00
Maximum	45.00

Timing (in seconds) for Electrosurgical device (Diathermy/Harmonic) with manipulation angle 90^0 is shown in Table- 4.1C(a).

Mean time for Electrosurgical device (Diathermy/Harmonic) at 90^0 angle of manipulation is 40.33 (±2.26) seconds. Minimum and Maximum time required were 36.0 and 45.0 respectively.

Table- 4.1C(b): Timing for Electrosurgical device (Diathermy/Harmonic) with manipulation angle 90^0

Sl no.	Observed(O)	Expected(E)	O-E	$(O-E)^2$	$\frac{(O-E)^2}{E}$
9	44	40.33	3.67	13.47	0.33
12	36	40.33	-4.33	18.75	0.46
23	40	40.33	-0.33	0.11	0.00
28	45	40.33	4.67	21.81	0.54
29	38	40.33	-2.33	5.43	0.13
30	39	40.33	-1.33	1.77	0.04
	m=40.33				X^2=1.52
Average timing = 40.33 seconds					
P-value (30.141) > X^2					

Timing for Electrosurgical device (Diathermy/Harmonic) for each case with manipulation angle 90^0 is shown in Table- 4.1C(b).

Average timing is 40.33 seconds, X^2 value is 1.52 at which level p value is 30.141. So, $p>X^2$.

Table- 4.1D: Average timing for Electrosurgical device (Diathermy/Harmonic) with manipulation

Manipulation angle	30^0	60^0	90^0
Average timing in seconds	34.17	31.83	40.33
X^2	2.42	1.28	1.52

Average timing (mean time) in seconds for Electrosurgical device (Diathermy/Harmonic) at 30^0, 60^0 and 90^0 angle is 34.17, 31.83 and 40.33 respectively. X^2 values at those angles are 1.42, 1.28 and 1.52. The lowest time required is at 60^0 degree angle manipulation.

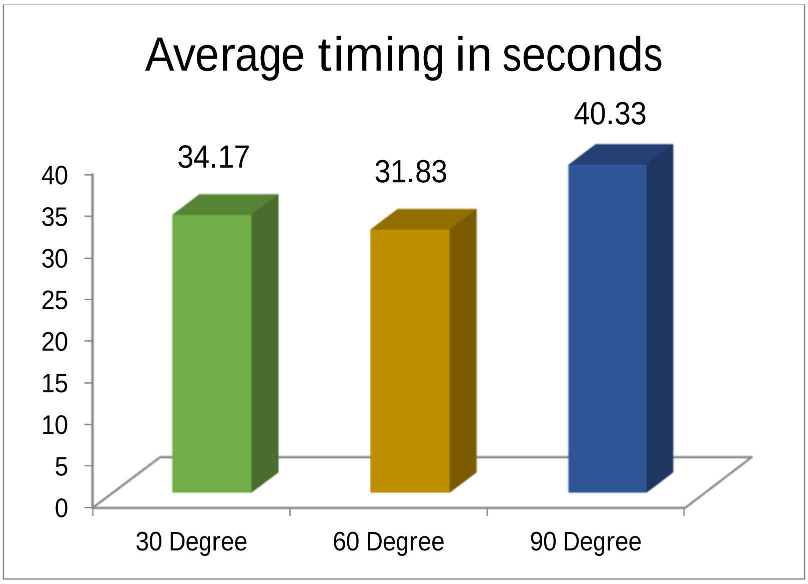


Fig- 4.1D: Average timing for Electrosurgical device (Diathermy/Harmonic) with manipulation angles

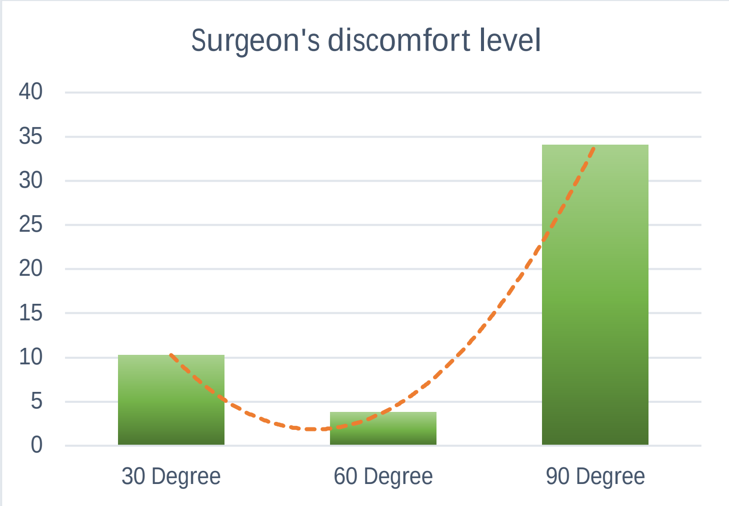


Fig- 4.1D: Surgeon's discomfort level for Electrosurgical device (Diathermy/Harmonic) with manipulation angles

In the tables 4A to 4D readings of timing taken Electrosurgical device (Diathermy/Harmonic) of the dummies at different manipulation angles is shown, which were validated by χ^2 test and average obtained. The average timing in seconds for 30º, 60º and 90º were 34.17, 31.83 and 40.33 respectively. Here it is observed that only the readings at 60º manipulation angle were reproducible at p-value (30.141), 5% level of significance which further support any port position that will provide working angle of 60º as the ideal.

2. Timing for grafting in Internal Thoracic Artery (ITA) Harvesting for Coronary Artery Bypass Graft (CABG)

Table- 4.2A(a): Timing for grafting with manipulation angle 30^0	
Mean	2110.83
Std. Deviation	±6.74
Minimum	2098.00
Maximum	2120.00

Timing (in seconds) for grafting in Internal Thoracic Artery (ITA) Harvesting for Coronary Artery Bypass Graft (CABG) with manipulation angle 30^0 is shown in Table 4.2A(a).

Mean time for grafting in Internal Thoracic Artery (ITA) Harvesting for Coronary Artery Bypass Graft (CABG) at 30^0 angle of manipulation is 2110.83 (±6.74) seconds. Minimum and Maximum time required were 2098.00 and 2120.00 respectively.

Table- 4.2A(b): Timing for grafting with manipulation angle 30^0

Sl. No	Observed (O)	Expected (E)	(O-E)	(O-E)2	(O-E)2/E
1	2109	2110.83	-1.83	3.35	0.00
2	2102	2110.83	-8.83	77.97	0.04
3	2118	2110.83	7.17	51.41	0.02
4	2098	2110.83	-12.83	164.61	0.08
5	2120	2110.83	9.17	84.09	0.04
6	2118	2110.83	7.17	51.41	0.02
	m=2110.83				X^2=0.21
Average timing = 2110.83 seconds					
P-value (30.141) > X^2					

Timing for grafting in Internal Thoracic Artery (ITA) Harvesting for Coronary Artery Bypass Graft (CABG) for each case with manipulation angle 30^0 is shown in Table 4.2A(b).

Average timing is 2110.83 seconds, X^2 value is 0.21 at which level p value is 30.141. So, $p>X^2$.

Table- 4.2B(a): Timing for grafting with manipulation angle 60^0	
Mean	2097.33
Std. Deviation	±3.83
Minimum	2088.00
Maximum	2109.00

Timing (in seconds) for grafting in Internal Thoracic Artery (ITA) Harvesting for Coronary Artery Bypass Graft (CABG) with manipulation angle 60^0 is shown in Table 4.2B(a).

Mean time for grafting in Internal Thoracic Artery (ITA) Harvesting for Coronary Artery Bypass Graft (CABG) at 60^0 angle of manipulation is 2097.33 (±3.83) seconds. Minimum and Maximum time required were 2088.0 and 2109.0 respectively.

Table- 4.2B(b): Timing for grafting with manipulation angle 60^0

Sl. No	Observed (O)	Expected (E)	(O-E)	(O-E)2	(O-E)2/E
1	2098	2097.33	0.67	0.45	0.00
2	2088	2097.33	-9.33	87.05	0.04
3	2099	2097.33	1.67	2.79	0.00
4	2096	2097.33	-1.33	1.77	0.00
5	2109	2097.33	11.67	136.19	0.06
6	2094	2097.33	-3.33	11.09	0.01
	m=2097.33				X^2=0.11
Average timing = 2097.33 seconds					
P-value (30.127) > X^2					

Timing for grafting in Internal Thoracic Artery (ITA) Harvesting for Coronary Artery Bypass Graft (CABG) for each case with manipulation angle 60^0 is shown in Table 4.2B(b).

Average timing is 2097.33 seconds, X^2 value is 0.11 at which level p value is 30.141. So, $p>X^2$.

Table- 4.2C(a): Timing for grafting with manipulation angle 90^0	
Mean	2146.17
Std. Deviation	±4.29
Minimum	2136.00
Maximum	2157.00

Timing (in seconds) for grafting in Internal Thoracic Artery (ITA) Harvesting for Coronary Artery Bypass Graft (CABG) with manipulation angle 90^0 is shown in Table 4.2C(a).

Mean time for grafting in Internal Thoracic Artery (ITA) Harvesting for Coronary Artery Bypass Graft (CABG) at 90^0 angle of manipulation is 2146.17 (±4.29) seconds. Minimum and Maximum time required were 2136.0 and 2157.0 respectively.

Table- 4.2C(b): Timing for grafting with manipulation angle 90^0

Sl. No	Observed (O)	Expected (E)	(O-E)	(O-E)2	(O-E)2/E
1	2157	2146.17	10.83	117.29	0.05
2	2147	2146.17	0.83	0.69	0.00
3	2150	2146.17	3.83	14.67	0.01
4	2136	2146.17	-10.17	103.43	0.05
5	2149	2146.17	2.83	8.01	0.00
6	2138	2146.17	-8.17	66.75	0.03
	m=2146.17				X^2=0.14
Average timing = 2146.17 seconds					
P-value (30.141) > X^2					

Timing for grafting in Internal Thoracic Artery (ITA) Harvesting for Coronary Artery Bypass Graft (CABG) for each case with manipulation angle 90^0 is shown in Table 4.2C(b).

Average timing is 2146.17 seconds, X^2 value is 0.14 at which level p value is 30.141. So, $p>X^2$.

Table- 4.2D: Average timing for grafting with manipulation angles

Manipulation angle	30^0	60^0	90^0
Average timing in seconds	2110.83	2097.33	2146.17
X2	0.21	0.11	0.14

Average timing (mean time) in seconds grafting in Internal Thoracic Artery (ITA) Harvesting for Coronary Artery Bypass Graft (CABG) at 30^0, 60^0 and 90^0 angle is 2110.83, 2097.33 and 2146.17 respectively. X^2 values at those angles are 0.21, 0.11 and 0.14. The lowest time required is at 60^0 degree angle manipulation.

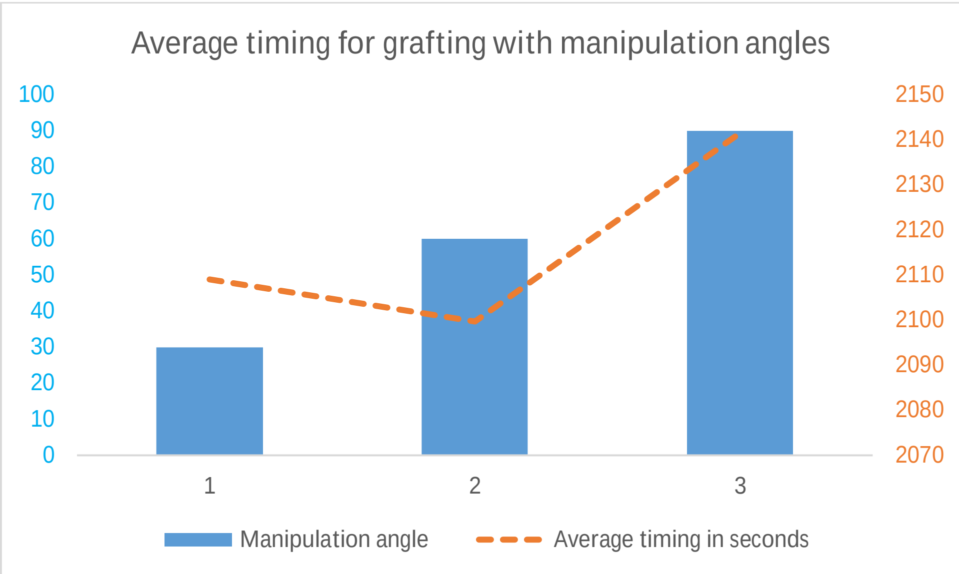


Fig- 4.2D: Average timing for grafting in Internal Thoracic Artery (ITA) Harvesting for Coronary Artery Bypass Graft (CABG)

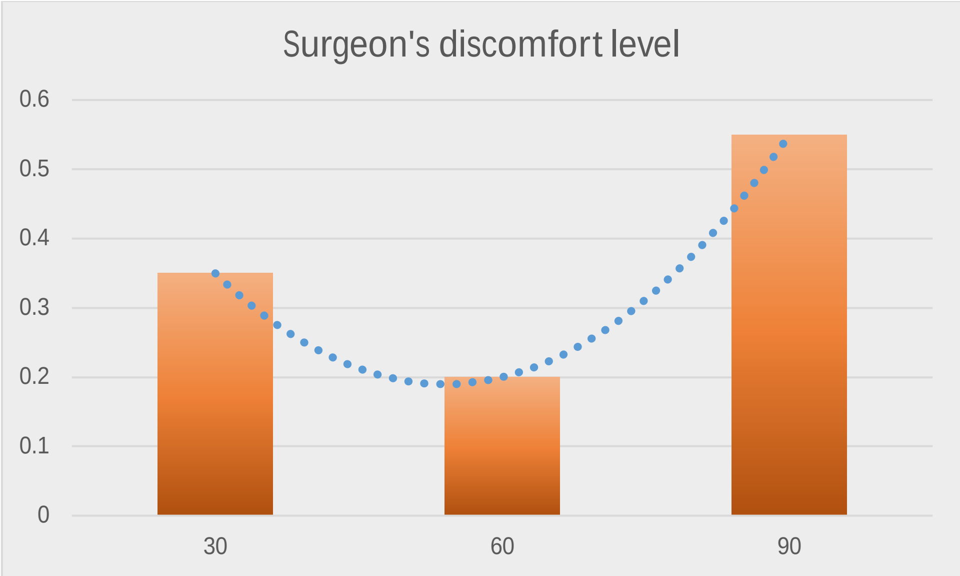


Fig- 4.2D: Surgeon's discomfort level for grafting in Internal Thoracic Artery (ITA) Harvesting for Coronary Artery Bypass Graft (CABG)

E. Oesophagectomy

1. Timing for surgeon's knot tying in Oesophagectomy

Table- 5.1A(a): Timing for surgeon's knot tying in Oesophagectomy with manipulation angle 30^0	
Mean	340.33
Std. Deviation	±5.14
Minimum	328.00
Maximum	354.00

Timing (in seconds) for surgeon's knot tying in Oesophagectomy with manipulation angle 30^0 is shown in Table 5.1A(a).

Mean time for knot tying for Oesophagectomy at 30^0 angle of manipulation is 340.33 (±5.14) seconds. Minimum and Maximum time required were 328.0 and 354.0 respectively.

Table- 5.1A(b): Timing for surgeon's knot tying in Oesophagectomy with manipulation angle 30^0

Sl. No	Observed (O)	Expected (E)	(O-E)	(O-E)2	(O-E)2/E
1	340	340.33	-0.33	0.11	0.00
2	344	340.33	3.67	13.47	0.04
3	354	340.33	13.67	186.87	0.55
4	328	340.33	-12.33	152.03	0.45
5	336	340.33	-4.33	18.75	0.06
6	340	340.33	-0.33	0.11	0.00
	m=340.33				X^2=1.09
Average timing = 340.33 seconds					
P-value (30.139) > X2					

Timing for surgeon's knot tying in Oesophagectomy for each case with manipulation angle 30^0 is shown in Table 5.1A(b).

Average timing is 340.33 seconds, X^2 value is 1.09 at which level p value is 30.141. So, $p>X^2$.

Table- 5.1B(a): Timing for surgeon's knot tying in Oesophagectomy with manipulation angle 60^0	
Mean	304.50
Std. Deviation	±1.98
Minimum	300.00
Maximum	310.00

Timing (in seconds) for surgeon's knot tying in Oesophagectomy with manipulation angle 60^0 is shown in Table 5.1B(a).

Mean time for knot tying in Oesophagectomy at 60^0 angle of manipulation is 304.50 (±1.98) seconds. Minimum and Maximum time required were 300.0 and 310.0 respectively.

Table- 5.1B(b): Timing for surgeon's knot tying in Oesophagectomy with manipulation angle 60^0

Sl. No	Observed (O)	Expected (E)	(O-E)	(O-E)2	(O-E)2/E
1	300	304.50	-4.50	20.25	0.07
2	305	304.50	0.50	0.25	0.00
3	309	304.50	4.50	20.25	0.07
4	301	304.50	-3.50	12.25	0.04
5	302	304.50	-2.50	6.25	0.02
6	310	304.50	5.50	30.25	0.10
	m=304.50				X^2=0.29
Average timing = 304.50 seconds					
P-value (30.141) > X^2					

Timing for surgeon's knot tying in Oesophagectomy for each case with manipulation angle 60^0 is shown in Table 5.1B(b).

Average timing is 304.50 seconds, X^2 value is 0.29 at which level p value is 30.141. So, $p>X^2$.

Table- 5.1C(a): Timing for surgeon's knot tying in Oesophagectomy with manipulation angle 90^0	
Mean	359.33
Std. Deviation	±4.14
Minimum	351.00
Maximum	369.00

Timing (in seconds) for surgeon's knot tying in Oesophagectomy with manipulation angle 90^0 is shown in Table 5.1C(a).

Mean time for knot tying in Oesophagectomy at 90^0 angle of manipulation is 359.33 (±4.14) seconds. Minimum and Maximum time required were 351.0 and 369.0 respectively.

Table- 5.1C(b): Timing for surgeon's knot tying in Oesophagectomy with manipulation angle 90^0

Sl. No	Observed (O)	Expected (E)	(O-E)	(O-E)2	(O-E)2/E
1	358	359.33	-1.33	1.77	0.00
2	360	359.33	0.67	0.45	0.00
3	361	359.33	1.67	2.79	0.01
4	357	359.33	-2.33	5.43	0.02
5	369	359.33	9.67	93.51	0.26
6	351	359.33	-8.33	69.39	0.19
	359.33				X^2=0.48
Average timing = 359.33 seconds					
P-value (30.141) > X^2					

Timing for surgeon's knot tying in Oesophagectomy for each case with manipulation angle 90^0 is shown in Table 5.1C(b).

Average timing is 359.33 seconds, X^2 value is 0.48 at which level p value is 30.141. So, $p>X^2$.

Table- 5.1D: Average timing for surgeon's knot tying in Oesophagectomy with manipulation

Manipulation angle	30^0	60^0	90^0
Average timing in seconds	340.33	304.50	359.33
X^2	1.09	0.29	0.48

Average timing (mean time) in seconds for surgeon's knot tying in Oesophagectomy at 30^0, 60^0 and 90^0 angle is 340.33, 304.50 and 359.33 respectively. X^2 values at those angles are 1.09, 0.29 and 0.48. The lowest time required is at 60^0 degree angle manipulation.

Tables 5A to 5D showed readings of timing of surgeon's knot tying in Oesophagectomy of dummies at different manipulation angles which were validated by χ^2 tests and average obtained. The average timing in seconds for 30^0, 60^0 and 90º were 340.33, 304.50 and 359.33 respectively. Despite the facts that, the first two readings were reproducible at p-value (30.141) at 5% level of significance it has demonstrated that the 60º angle has shorter operative time than that of 30º and 90º angle. It indicates increased difficulties and time consumption when ports are positioned in such a way that will give working angle of 90º and above.

2. Timing for circular stapler device in Oesophagectomy

Table- 5.2A(a): Timing for circular stapler device in Oesophagectomy with manipulation angle 30^0	
Mean	635.50
Std. Deviation	±3.36
Minimum	627.00
Maximum	645.00

Timing (in seconds) for circular stapler device in Oesophagectomy with manipulation angle 30^0 is shown in Table **5.2A(a)**.

Mean time for circular stapler device in Oesophagectomy at 30^0 angle of manipulation is 635.50 (±3.36) seconds. Minimum and Maximum time required were 627.0 and 645.0 respectively.

Table- 5.2A(b): Timing for circular stapler device in Oesophagectomy with manipulation angle 30^0

Sl. No	Observed (O)	Expected (E)	(O-E)	(O-E)2	(O-E)2/E
1	636	635.50	0.50	0.25	0.00
2	638	635.50	2.50	6.25	0.01
3	627	635.50	-8.50	72.25	0.11
4	629	635.50	-6.50	42.25	0.07
5	638	635.50	2.50	6.25	0.01
6	645	635.50	9.50	90.25	0.14
	m= 635.50				X^2=0.34
Average timing = 635.50 seconds					
P-value (30.119) > X^2					

Timing for circular stapler device in Oesophagectomy for each case with manipulation angle 30^0 is shown in Table 5.2A(b).

Average timing is 635.50 seconds, X^2 value is 0.34 at which level p value is 30.141. So, $p>X^2$.

Table- 5.2B(a): Timing for circular stapler device in Oesophagectomy with manipulation angle 60^0	
Mean	598.50
Std. Deviation	±4.98
Minimum	592.00
Maximum	604.00

Timing (in seconds) for circular stapler device in Oesophagectomy with manipulation angle 60^0 is shown in Table 5.2B(a).

Mean time for circular stapler device in Oesophagectomy at 60^0 angle of manipulation is 598.50 (±4.98) seconds. Minimum and Maximum time required were 592.0 and 604.0 respectively.

Table- 5.2B(b): Timing for circular stapler device in Oesophagectomy with manipulation angle 60^0

Sl. No	Observed (O)	Expected (E)	(O-E)	$(O-E)^2$	$(O-E)^2/E$
1	592	598.50	-6.50	42.25	0.07
2	602	598.50	3.50	12.25	0.02
3	595	598.50	-3.50	12.25	0.02
4	601	598.50	2.50	6.25	0.01
5	597	598.50	-1.50	2.25	0.00
6	604	598.50	5.50	30.25	0.05
	m=598.50				X^2=0.18
Average timing = 598.50 seconds					
P-value (30.141) > X^2					

Timing for circular stapler device in Oesophagectomy for each case with manipulation angle 60^0 is shown in Table 5.2B(b).

Average timing is 598.50 seconds, X^2 value is 0.18 at which level p value is 30.141. So, $p>X^2$.

Table- 5.2C(a): Timing for circular stapler device in Oesophagectomy with manipulation angle 90^0	
Mean	659.33
Std. Deviation	±3.78
Minimum	650.00
Maximum	668.00

Timing (in seconds) for circular stapler device in Oesophagectomy with manipulation angle 90^0 is shown in Table 5.2C(a).

Mean time for circular stapler device in Oesophagectomy at 90^0 angle of manipulation is 659.33 (±6.06) seconds. Minimum and Maximum time required were 650.0 and 668.0 respectively.

Table- 5.2C(b): Timing for circular stapler device in Oesophagectomy with manipulation angle 90^0

Sl. No	Observed (O)	Expected (E)	(O-E)	(O-E)2	(O-E)2/E
1	658	659.33	-1.33	1.77	0.00
2	659	659.33	-0.33	0.11	0.00
3	650	659.33	-9.33	87.05	0.13
4	662	659.33	2.67	7.13	0.01
5	659	659.33	-0.33	0.11	0.00
6	668	659.33	8.67	75.17	0.11
	m=659.33				X^2=0.26
Average timing = 659.33 seconds					
P-value (30.129) > X^2					

Timing for circular stapler device in Oesophagectomy for each case with manipulation angle 90^0 is shown in Table 5.2C(b).
Average timing is 659.33 seconds, X^2 value is 0.26 at which level p value is 30.141. So, p>X^2.

Table- 5.2D: Average timing for circular stapler device in Oesophagectomy with manipulation

Manipulation angle	30^0	60^0	90^0
Average timing in seconds	635.50	598.50	659.33
X^2	0.34	0.18	0.26

Average timing (mean time) in seconds for circular stapler device in Oesophagectomy at 30^0, 60^0 and 90^0 angle is 635.50, 598.50 and

659.33 respectively. X^2 values at those angles are 0.34, 0.18 and 0.26. The lowest time required is at 60^0 degree angle manipulation.

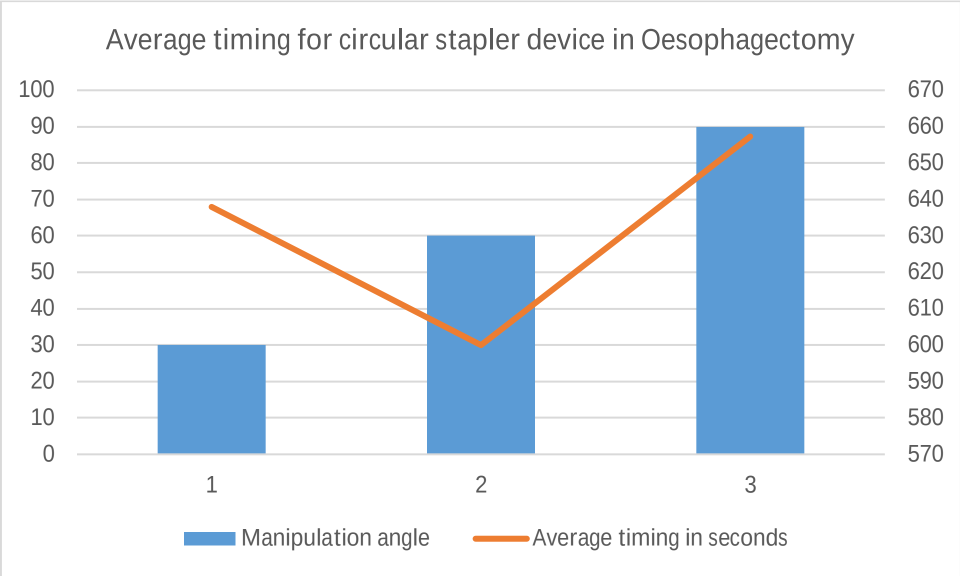


Fig- 5.2D: Average timing for circular stapler device in Oesophagectomy with manipulation angles

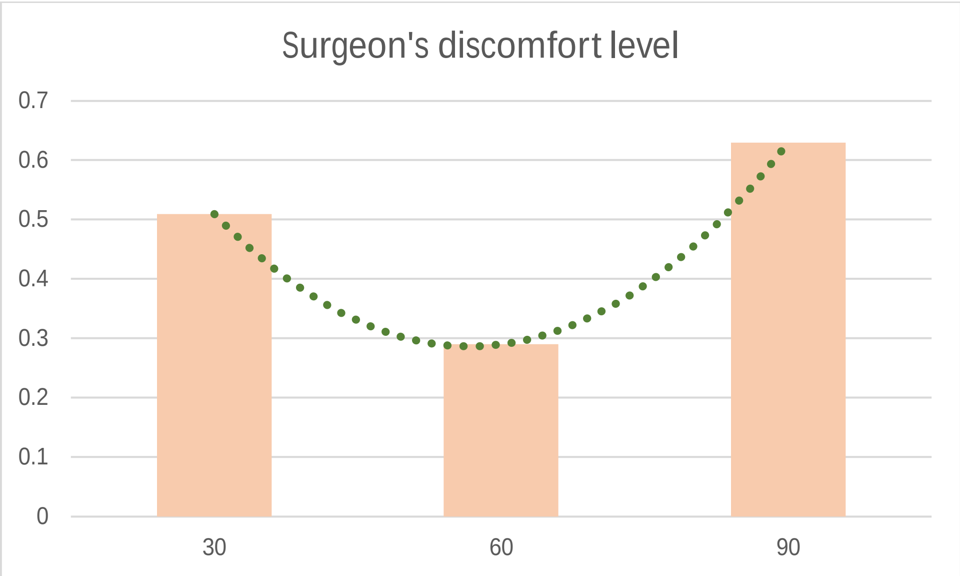


Fig- 5.2D: Surgeon's discomfort level for circular stapler device in Oesophagectomy with manipulation angles

From above discussions, the average timing of all tasks were shorter with 60º manipulation and all were reproducible. Irrespective of the difficulty of the tasks then it was followed by 30º and 90º angle. The closer the manipulation angle is to the 90º and above, the more the likely to take longer operative time. It may be due to fatigue from increased elevation angle and shoulder over stretching.

From above figures and discussion, it is obvious that surgeon's discomfort level is least at 60 degree port position.

Chapter-05

DISCUSSION

A total of 30 procedures were done in this prospective experimental study. Triangle Port Placement (TTP) principle was used.

The details of the procedures are 6 (20%) Lung Resection, 6 (20%) Atrial Septal Defect closure, 6 (20%) Thymectomy, 6 (20%) Internal Thoracic Artery Harvesting for TECABG and 6 (20%) Oesophagectomy on 30 animals through minimal access procedure.

Execution time (sum of the ports Access Time and the Actual Procedure Time), Error rates and the Surgeon's discomfort for each of the three angles of manipulation were evaluated.

A. LUNG RESECTION

Timing for surgeon's suturing and knot tying in lung resection

In this study it was found that average timing (mean time) in seconds for surgeon's suturing and knot tying in Lung resection at 30^0, 60^0 and 90^0 angle is 311.83, 304.33 and 344.50 respectively. X^2 values at those angles are 6.55, 2.73 and 10.84. The lowest time required is at 60^0 degree angle manipulation.
Readings of timing obtained while making a surgeon's suturing and knot tying in Lung resection in the dummy at different manipulation angles (30^0, 60^0, 90^0) are shown in above tables which were validated and average obtained by χ^2 tests. All the readings were reproducible at p-value (30.144), 5% level of significance. It has demonstrated that the 60º angle has shorter ope time followed by 30^0 and then 90º.
These findings were supported by some other studies. Yunusa et al. (2014) and Ismail AJ and Mishra RK (2014) also mentioned that the 60º angle has shorter operative time followed by 30^0 and then 90º.

Timing for surgeon's applying Endo GIA Stapler device (Linear) in Lung resection

Average timing (mean time) in seconds for surgeon's applying Endo GIA Stapler device (Linear) in Lung resection at 30^0, 60^0 and 90^0 angle is 907.17, 835.00 and 988.50 respectively. X^2 values at those angles are 0.69, 0.58 and 0.74. The lowest time required is at 60^0 degree angle manipulation.

Readings of timing obtained while making a surgeon's applying Endo GIA Stapler device (Linear) in Lung resection in the dummy animals at different manipulation angles (30^0, 60^0, 90^0) were shown which were validated and average obtained by χ^2 tests. The average timing in seconds for 30º, 60º and 90º were 907.17, 835.00 and 988.50 respectively. All the readings were reproducible at p-value (30.141), 5% level of significance. It has demonstrated that the 60º angle has shorter operative time followed by 30^0 and then 90º.

Similar findings were demonstrated by some other researchers.[14,19]

B. Atrial Septal Defect closure:

Timing for surgeon's suturing and knot tying in ASD closure

Average timing (mean time) in seconds timing for surgeon's suturing and knot tying in ASD closure at 30^0, 60^0 and 90^0 angle is 225.67, 128.67 and 293.33 respectively. X^2 values at those angles are 12.33, 10.21 and 11.15. The lowest time required is at 60^0 degree angle manipulation.

Readings of timing taken to surgeon's suturing and knot tying in ASD closure in the swine at different manipulation angles are shown which were validated by χ^2 test and means obtained. The average timing in seconds for 30, 60 and 90 degrees were 225.67, 128.67 and 293.33 respectively. It has clearly demonstrated that the 60º angle has shorter operative time followed by 30º and then 90º, although, all the readings were reproducible at p-value (30.141), 5% level of significance.

Different studies showed similarity with the present study.[14,19]

Timing for surgeon's clipping in ASD closure

Average timing (mean time) in seconds for surgeon's clipping in ASD closure at 30^0, 60^0 and 90^0 angle is 32.50, 31.00 and 40.50 respectively. X^2 values at those angles are 2.88, 1.48 and 1.52. The lowest time required is at 60^0 degree angle manipulation.

Readings of timing obtained while making a surgeon's clipping in ASD closure in the swine at different manipulation angles (30^0, 60^0, 90^0) are shown in Tables 2.2A to 2.2D which were validated and average obtained by χ^2 tests. The average timing in seconds for 30º, 60º and 90º were 32.50, 31.00 and 40.50 respectively. All the readings were reproducible at p-value (30.141), 5% level of significance. It has demonstrated that the 60º angle has shorter operative time followed by 30^0 and then 90º.

Similar findings were observed by some other researchers.[14,19]

C. Thymectomy

Timing for surgeon's suturing and knot tying in Thymectomy

Average timing (mean time) in seconds for surgeon's suturing and knot tying in Thymectomy at 30^0, 60^0 and 90^0 angle is 222.17, 133.17 and 282.83 respectively. X^2 values at those angles are 8.39, 7.88 and 8.52. The lowest time required is at 60^0 degree angle manipulation.

Readings of timing taken for suturing and knot tying in Thymectomy in the swine at different manipulation angles which were validated by χ^2 test and average obtained. The average timing in seconds for 30º, 60º and 90º were 222.17, 133.17 and 282.83 respectively. Only readings at 30^0 and 60º were reproducible at p-value (30.141), 5% level of significance but the χ^2 of readings at 90^0 was less than p-value, indicating nonreproducibility. These suggest that the 60º angle has shorter operative time than the 30º and 90º and above.

These findings were consistent with some other researchers.[14,19]

Timing for clipping in Thymectomy

Average timing (mean time) in seconds for clipping in Thymectomy at 30^0, 60^0 and 90^0 angle is 33.00, 32.33 and 39.50 respectively. X^2 value at those angles are 3.03, 0.91 and 1.46. The lowest time required is at 60^0 degree angle manipulation.

Similar findings were found by some other researchers.[14,19]

D. Internal Thoracic Artery (ITA) Harvesting for Coronary Artery Bypass Graft (CABG)

Timing for Electrosurgical device (Diathermy/Harmonic)

Average timing (mean time) in seconds for Electrosurgical device (Diathermy/Harmonic) at 30^0, 60^0 and 90^0 angle is 34.17, 31.83 and 40.33 respectively. X^2 values at those angles are 2.42, 1.28 and 1.52. The lowest time required is at 60^0 degree angle manipulation.

Readings of timing taken Electrosurgical device (Diathermy/Harmonic) of the dummies at different manipulation angles is shown, which were validated by χ^2 test and average obtained. The average timing in seconds for 30º, 60º and 90º were 34.17, 31.83 and 40.33 respectively. Here it is observed that only the readings at 60º manipulation angle were reproducible at p-value (30.141), 5% level of significance which further support any port position that will provide working angle of 60º as the ideal.

Some other researchers found similar findings.[14,19]

Timing for grafting in Internal Thoracic Artery (ITA) Harvesting for Coronary Artery Bypass Graft (CABG)

Average timing (mean time) in seconds grafting in Internal Thoracic Artery (ITA) Harvesting for Coronary Artery Bypass Graft (CABG) at 30^0, 60^0 and 90^0 angle is 2110.83, 2097.33 and 2146.17 respectively. X^2

values at those angles are 0.21, 0.11 and 0.14. The lowest time required is at 60^0 degree angle manipulation.
Similar findings were explored by some other researchers.[14,19]

E. Oesophagectomy

Timing for surgeon's knot tying in Oesophagectomy

Average timing (mean time) in seconds for surgeon's knot tying in Oesophagectomy at 30^0, 60^0 and 90^0 angle is 340.33, 304.50 and 359.33 respectively. X^2 values at those angles are 1.09, 0.29 and 0.48. The lowest time required is at 60^0 degree angle manipulation.

Readings of timing of surgeon's knot tying in Oesophagectomy of dummies at different manipulation angles which were validated by χ^2 tests and average obtained. The average timing in seconds for 30^0, 60^0 and 90º were 340.33, 304.50 and 359.33 respectively. Despite the facts that, the first two readings were reproducible at p-value (30.141) at 5% level of significance it has demonstrated that the 60º angle has shorter operative time than that of 30º and 90º angle. It indicates increased difficulties and time consumption when ports are positioned in such a way that will give working angle of 90º and above.
Similarity of these findings were found by some other researchers.[14,19]

Timing for circular stapler device in Oesophagectomy

Average timing (mean time) in seconds for circular stapler device in Oesophagectomy at 30^0, 60^0 and 90^0 angle is 635.50, 598.50 and 659.33 respectively. X^2 values at those angles are 0.34, 0.18 and 0.26. The lowest time required is at 60^0 degree angle manipulation.
Similar findings were found by some other researchers.[14,19]

From above discussions, the average timing of all tasks were shorter with 60º manipulation and all were reproducible. Irrespective of the difficulty of the tasks then it was followed by 30º and 90º angle. The closer the manipulation angle is to the 90º and above, the more the likely to take longer operative time. It may be due to fatigue from increased elevation angle and shoulder overstretching.

From above figures and discussion, it is obvious that surgeon's discomfort level is least at 60 degree port position.

Fortunately, no errors during surgical procedures occurred. But in some other studies different errors occurred during surgical task performance.[14,19]

Regarding surgeon's discomfort, 30 degree and 90 degree angles were revealed as discomfortable port position whereas 60 degree angle of manipulation showed more comfortable position. Though 60^0 angle showed some discomfort in a few cases, but it was not significant.

In their article Yunusa et al (2014) mentioned that the BDP is the conventional principle for deciding sites of port placement during video-assisted thoracic surgery (VATS).[14-19] It is the background principle to which other principles are compared. The triangle target principle (TTP) was introduced as an alternative principle where BDP is associated with difficulties especially in lung resections.

In a study of VATS Pericardial Window, Yunusa et al (2014) found similar results. The result showed that using the TTP for ports placement led to longer execution time with a mean difference of 93 seconds. The error rates and the surgeons discomfort were however similar.

They explained that the prolonged execution time may be attributable to the mirror image produced when TTP is used. The scissors and the grasping forceps were often alternated between the working port and the target port during the procedure to conform to the different orientations for resecting the pericardial segment. The mirror image distorts the visuals and the orientation which prolongs the execution time.

They also mentioned that with more experience this problem may be addressed by maintaining the grasping forceps in the target port and cutting the pericardial segment with a scissors or monopolar spatula through the working port.

They discussed that the TTP may have a role when dealing with pericardial lesions requiring digital palpation and stapling such as pericardial cysts. The manipulation angle between the grasping forceps and the stapler (through the target and working ports respectively) is then 90° which is the perfect angle for stapling. When BDP is used in this scenario, a different access may be required for the stapler to achieve this angle.

In that study they explained that BDP is preferred for ports placement during VATS pericardial window but TTP may have clear advantages when dealing with pericardial lesions requiring digital palpation and stapling.

In this present study it was also found that the 60 degree angle of manipulation is advantageous for ASD closure and some other procedures.

In VATS Esophagocardiomyotomy Ismail AJ and Mishra RK, and Yunusa et al found almost similar results. From the results the execution time for VATS esophago-cardiomyotomy using BDP for ports placement was more than when TTP was used with a mean difference of 326.67 seconds. This is in contrast to the results of the errors rates and surgeons discomfort which were more when TTP was used.

In the study of Yunusa et al. one episode of esophageal perforation was recorded when using the BDP while 2 major errors (esophageal perforation and descending aortic injury) were recorded when TTP was used. This is significant as it translates to 33.3% error rate. But fortunately, no such error occurred in the present study.

They found that the surgeon's discomfort using TTP was worse with an average of 7 compared to 5.83 recorded for BDP which was contrary with the present study.

They mentioned that the increased error rates and surgeon's discomfort can be explained by the mirror image produced when using TTP and the flimsy nature of the pig's tissue giving rise to injury to the esophagus and the surrounding structures even with minimal force.

The prolongation of the execution time when BDP was used which is in contrast to the trends of the error rates and the surgeon's discomfort could have been due to the increased error rates in TTP use. When these major errors are encountered, the procedure does not usually proceed and the execution time when using TTP is recorded as shortened. This calls for more data from larger sample size to revalidate this and offer more explanations.

They observed that the BDP appears to be better than the TTP of ports placement for VATS esophagocardiomyotomy in terms of the error rates and the surgeon's discomfort, although it took longer time to be executed.

They concluded that the TTP may have clear advantages over BDP when treating other esophageal diseases requiring stapling such as esophageal diverticulum or during esophagectomy due to the 90° manipulation angle between the grasping forceps and the stapler. It is clearly supports the present study.

Yunusa et al and Ismail JA performed study on VATS Thoracic Sympathectomy in 2014. They had almost similar results and observations which was consistent with this study where thymectomy was done instead.

They found that the execution time for VATS thoracic sympathectomy when using the TTP was less than when BDP was used (Mean difference of 194 seconds). But the execution time data is not statistically significant and so not reproducible (X^2 = 21.04 at p-value of 11.07). Thus, there may be need for a larger sample to reassess its reproducibility and then objectively compare it with the TTP. The BDP and the TTP are comparable in terms of the error rates and the surgeon’s discomfort. We also recommend it.

They concluded that it can also be seen that TTP is comparable or more favorable to BDP when the instrument through the target port is used for retraction only and not for other manipulations. When used for other purposes, the mirror image produced will lead to reduced task performance and increase surgeon’s discomfort. It is also consistent with our observations.

Chapter- 06

CHAPTER VI

CONCLUSION AND RECOMMENDATIONS

6.1 CONCLUSION

The Baseball diamond Principle (BDP) is the conventional principle used to decide sites of Port placement during Video Assisted thoracic Surgery. The triangle target principle (TTP) was introduced as an alternative principle when difficulty was observed during some procedures using the BDP especially in pulmonary procedures.

The Triangle Target Principle may offer more advantages when the instruments through the target port are used only for retraction. It may also be preferred in VATS Procedures where Stapling may be required. The manipulation angle of 60^0 in TTP is found more favorable than 30^0 and 90^0 angles, but it needs further evaluation with a large data.

6.2 RECOMMENDATIONS

- The TTP should be preferred during nonpulmonary VATS procedures when the instrument through the target port is used only for retraction or stapling will be required
- The BDP should be preferred during nonpulmonary VATS procedures when stapling may not be required
- There is need for a larger sample size to have a more reproducible and validated result
- There should be caution when translating this data to humans as the swine models have some peculiarities such as flimsy tissues and shortened space between the anterior and posterior axillary lines
- Surgical simulation using animal models is a high fidelity method and should be encouraged when ever feasible

- An alternative to the swine models should be considered for VATS procedures. The sheep models have stronger tissues and are an option.

6.3 LIMITATIONS

1. The sample size is small. It may affect the extrapolation of the results. This is because study on Animal models is guided by stringent legislations and requirements which limit the sources.

2. The duration for the programme is also short. A long cohort should be conducted.

3. The swine models are smaller and adult VATS instruments were used. So, some ergonomic difficulties could be accounted by the peculiarities of the Swine models. Their tissues are more flimsy compared to the humans.

4. The appropriate location of the intercostal spaces and ports placement were more challenging. Translation of the data to humans may also be affected by some differences with the swine models as the space between the anterior and posterior axillary lines and the intercostal spaces are narrower than those in human.

5. There could be other confounding variables such as dysfunctional instruments which could have impacted on the measures of outcome.

References

REFERENCES

1. Agasthian T. Revisiting the prone position in Video—Assisted Thoracoscopic Surgery. Asian Cardiov Thorac Ann 2010;18:364—7
2. Bansal P, Gupta A, Mongha R, Narayan S, Kundu AK, Chakraborty SC, et al. Laparoscopic versus open pyeloplasty: comparison of the two surgical approaches—a single centre experience of three years. J Min Access Surg 2008;3:76-79.
3. Bertolaccini L, Rocco G, Viti A, terzi A. Geometrical Characteristics of Uniportal VATS. J Thorac Dis 2013 Apr 07.
4. Cansino JR, Cisneros J, Aloso S, et al. Laparoscopic radical cystectomy: initial series and analysis of result. European Uro- logy Suppl 2006;5:956-961.
5. Ahlawat RK, Gaulam G. Suprapubic transvesical single-port technique for control of lower end of ureter during laparoscopic nephroureterectomy for upper tract transitional cell carcinoma. Ind J Urol 2011;27:190-195.
6. Cestari A, Buffi NM, Scapaticci E, et al. Simplifying patient positioning and port placement during robotic assisted laparos- copic prostatectomy. European Urology 2010;57:530-533.
7. De Silva MC, Swanson SJ. Video-assisted thoracic surgery in ACS surgery: principles and practice. Chapter 10. 4th ed, 2010. Decker Intellectual Properties.
8. Delhi, Gurgaon, 122 002, India. Port position in Laparoscopy.
9. Chung BI, Liao JC. Laparoscopic radical nephrectomy in a pelvic ectopic kidney: keys to success. JSLS 2010;14:126-129.
10. Columbo JR, Santos B, Hafron J, Gianduzzo T, Haber GP, Kaouk JH. Robotic assisted radical prostatectomy: surgical techniques. Int Braz J Urol 2007;33:803-809.
11. Denny TL. Video-assisted thoracic surgery. 2001. Lands biosci-ence, Georgetown, Texas, USA.
12. Elhage 0, Murphy D, Challacombe V, Shortland A, Dasgupta P. Ergonomics in minimally invasive Surgery. International Journal of clinical practice v.61(2), p 186-188

13. Faddegon S, Tan YK, Olweny EO, Park SK, Sara L. Best BS, Cadeddu JA. Laparoendoscopic single-site (LESS) pyeloplasty for horseshoe ureteropelvic junction obstruction. JSLS 2012;16:151-154.
14. Ismail AJ, Mishra RK. Comparing Task Performance and Comfort during Nonpulmonary Video-assisted Thoracic Surgery Procedures Between the Application of the ‘Baseball Diamond’ and the ‘Triangle Target’ Principles of Port Placement in Swine Models. World J Lap Surg 2014;7(2):1-6.
15. Ganpule AP, Sharma R, Thimmegawda M, Veeramani M, Desai MR. Laparoscopic radical nephrectomy versus open radical nephrec- tomy in T1-T3 renal tumours: an outcome analysis. Ind J Urol 2008;24:39-43.
16. Gupta NP, Gautam G. Laparoscopic nephrectomy for benign non-functioning kidneys. J Min Access Surg 2005;149-154.
17. He J. History and current status of Mini-invasive Thoracic Surgery. J Thorac Dis 2011;31115—121
18. Karthik S, Augustine AJ, Shibumon MM, Pai MV. Analysis of laparoscopic port site complications: a descriptive study. J Min Access surg 2013;9:59-64.
19. Yunusa B, Mishra RK, Chowhan JS. Is There an Ideal Port Position for Laparoscopic Urological Proce-dures? World J Lap Surg 2014;7(2):74-87.
20. Kumar D R. Complications and limitations of Video-Assisted Thoracic Surgery. Current Medical trends/5/2/JUNE/2001
21. Greberg CF, Gettman MT. Instrumentation for natural orifice transluminal endoscopic surgery and laparoendoscopic single site surgery. Ind J Urol 2010;26:385-388.
22. Landreneau RJ, Mack MJ, Hazelrigg SR, Dowling RD, Acuff TE, Magee MJ, Ferson PS. Video-assisted thoracic surgery: basic technical concepts and intercostal approach strategies. Ann Thorac Surg 1992;54:800-807.
23. Kopp RP, Silbestin JL, Derweesh I. Laparoendoscopic single site radical nephrectomy with renal vein thrombectomy: initial report. BMC Urology 2010;8:10.
24. Lewis R J, Caccavale R J, Silver G E, Machenzie J W. One hundred consecutive patients undergoing Video-Assisted Thoracic operations. Ann thorac Surg 1992 Sep,-54(3) : 421-6

25. Link BA, Kruska JD, Wong C, Kropp BP. Two trocar laparos-- copic varicocelectomy: approach and outcomes. JSLS 2006;10:151-154.
26. Marchetti G P, Pinelli V P, Tassi G F. 100 years of Thoracoscopy: Historical notes. Respiration 2011;82:187~192
27. Mishra RK. Textbook of practical laparoscopic surgery. 3rd ed. 2013. Jaypee Brothers Medical Publishers (P) limited, New Delhi, India.
28. Moisiuc F V, Colt H G. Thoracoscopy: Origin revisited. Respiration 2007;74: 344-355
29. Montessi J, de Almeida E P, Vieira J P, Abreu M M, de Souza R L P, Montessi OVD. Video—Assisted Thoracic Sympathectomy in the treatment of primary hyperhidrosis: A retrospective study of 521 cases comparing different levels of ablation. J Brass Pneumol. 2007;33(3): 248-254
30. Mellon MJ, Sethi A, Sundaram CP. Laparoscopic adrenalectomy: surgical techniques. Ind J Urol 2008;24:583-589.
31. Nagraj HK, Kishore TA, Nagalakshmi S. Transperitoneal laparoscopic approach for retrocaval ureter. J Min Access Surg 2006;2:81-82.
32. Nerli RB, Reddy M, Devraju S, Prabha V, Hiremath MB, Jali S. Laparoscopic mitrafanoff appendicovesicostomy: our experience in children. Ind J Urol 2012;28:28-31.
33. Operational guidelines for observance of good practices in CPC-SEA. An Indian committee for the purpose of promotion and supervision of experiments on animals (CPCSEA) Document.
34. Peterson AC, Lance RS, Ahuja SK. Laparoscopic hand assisted radical cystectomy with ileal conduit urinary diversion. J Urol 2002;168:2103-2105.
35. Pow-Sang JM, Velasquez J, Myers MD, Rodriguez AR, Kang LC. Pure laparoscopic and robotic-assisted laparoscopic radical prostatectomy in the management of prostate cancer. Cancer control 2007;14:250-257.
36. Nair B. Concomitant laparoscopic urological procedures: does it contribute to morbidity? J Min Access Surg 2009;5:67-71.
37. Prasad A, Ali M, Kaul S. Endoscopic Thoracic Sympathectomyfor primary Palmar hyperhidrosis. Surg Endosc (2010) 24: 1952-1957
38. Rais-Bahrami S, Waingankar N, Richstone L. Upper tract urologic-laparoendoscopic single site surgery. Ind J Urol 2012;28:60-64.

39. Rocco G. Operative VATS: The need for different Intra-Thoracic approach-Letter to the Editor. European Journal of cardiothoracic Surgery 28 (2005) 358-367
40. Sasaki M, Harai S, Kawabe M, Uesaka T, Morioka K, Ihaya A, Tanaka K. Triangle target principle for trocar placement during video-assisted thoracic surgery. European J Cardiothoracic Surg 2005;27:307-312.
41. Singh O, Gupta SS, Hastir A, Arvind NK. Laparoscopic trans- peritoneal pyelo-pyelostomy and ureteroureterostomy of retro- caval ureter: report of two cases and review of the literature. J Min Access Surg 2010;6:53-55.
42. Supe AN, Kulkarni GV, Supe PA. Ergonomics in laparoscopic surgery. J Min Access Surg 2010;6:31-36.
43. Takao M, Tarukawa T, Shimamoto A, Shimpo H. Principle of Video-Assisted Thoracic Surgery-Letter to the Editor. European Journal of cardiothoracic Surgery 28 (2005) 657-664
44. Thiel DD. Navigating the difficult robotic assisted pyeloplasty. ISRN Urol 2012;2:34.
45. Scott-Conner C E H. The SAGES Manual: Fundamentals of Laparoscopy, Thoracoscopy and GI Endoscopy. Second edition, 2006. Springer Science+ Business Media, Inc. New York, USA.
46. Veenstra GM, Fossion LMCL, de Laet K, Luijten AAPM. Syn- chronous laparoscopic radical nephrectomy left and contralateral right hemicolectomy during the same endoscopic procedure. J Laparoendosc Adv Surg Tech 2004.
47. World Laparoscopy Hospital. Cyberciti, DLF Phase II, NCR.
48. Vordos D, Hoznek A, Gettman M, Abbon CC. Laparoscopic cystectomy: evolution of a new technique. EAU series 2005;3:147-155.
49. De U. Ergonomics and Laparoscopy. Indian J Surg 2005;67:164-6.
50. Menozzi M, von Buol A, Krueger H, Miege C. Direction of gaze and comfort: Discovering the relation for the ergonomic optimization of visual tasks. Ophthalmic Physiol Opt 1994;14:393-9.
51. Hanna GB, Shimi SM, Cuschieri A. Task performance in endoscopic surgery is influenced by location of the image display. Ann Surg 1998;227:481-4. [PUBMED] [FULLTEXT]
52. Trejo A, Jung MC, Oleynikov D, Hallbeck MS. Effect of handle design and target location on the insertion and aim with a laparoscopic surgical tool. Appl Ergon 2007;38:745-53. [PUBMED] [FULLTEXT]

53. Manasnayakorn S, Cuschieri A, Hanna GB. Ergonomic assessment of optimum operating table height for hand-assisted laparoscopic surgery. Surg Endosc 2009;23:783-9. [PUBMED] [FULLTEXT]
54. Manasnayakorn S, Cuschieri A, Hanna GB. Ideal manipulation angle and instrument length in hand-assistedlaparoscopic surgery. Surg Endosc 2008;22:924-9. [PUBMED] [FULLTEXT]
55. Available from: http://www.laparoscopyhospital.com/table_of_contents_files/pdf/optimal%20manipulation%20angle%20for%20best%20laparoscopic%20task%20performance.pdf . [Last accessed on 2010 May 9].
56. Kant IJ, de Jong LC, van Rijssen-Moll M, Borm PJ. A survey of static and dynamic work postures of operating room staff. Int Arch Occup Environ Health 1992;63:423-8. [PUBMED]

APPENDIX 1:

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Pacheri Bari, Jhunjhunu - 333515, Rajasthan, India

CENTRE: WORLD LAPAROSCOPY HOSPITAL
Cyber City, DLF Phase-II, Gurgaon, NCR Delhi, India
Pin Code-122002

PROFORMA FOR MS (MAS) RESEARCH ON CARDIO-THORACIC SURGERY

TITLE : Evaluation of Various Port Positions in Minimal Access Cardiothoracic Procedures.
OBJECTIVE : To evaluate and compare task performance at different port positions during Minimally Access Cardiothoracic Surgery on Swine.

DATE:

PORT PLACEMENT PRINCIPLE:

SIDE FOR THE PROCEDURE:

PROCEDURE:

PORT ACCESS TIME:

ACTUAL PROCEDURE TIME:

EXECUTION TIME:

ERRORS:

DISCOMFORT AFTER THE PROCEDURE (VISUAL ANALOGUE SCALE):

1—--2—-—3——-—4—--5—--6——-7—--8—--9—--10

Dr. Md. Anwarul Islam.