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Laparoscopic Hand Instruments, Accessories and Ergonomics

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Laparoscopic procedures are inherently complex. Due to the complex modern technology, many things can go wrong. Equipment and instrumentation have a much greater impact and importance in laparoscopic surgery. This is a fact that visualization and tactile exploration of the operative field is always only indirectly achieved through optical systems and instruments. The surgeon must be sufficiently familiar with the equipment to use it, troubleshoot and solve the inherent problems.

I. IMAGING SYSTEM

Imaging system includes the Laparoscope, Light source, Light cable, Camera, and Monitor.

A. Laparoscopes

Laparoscopes are either rigid or fibre optics (fig. 1). Commonly used are rigid ones, like 0°, 30°, 3mm, 5mm, and 10mm. The 30° angled scopes can be rotated and can see.

Figure 01: Laparoscopes

down as well look up the anterior abdominal wall and side ways. The scope is attached with light cable and the distal tip is inspected for fibre bundle transmission. If the fibre damage is 25% or more then the scope must be replaced.

B. Light Source

The new light source (fig. 2) such as 250 watt halogen lamp has been provided with a condenser system, But Xenon lamp (cold light source) gives better visual clarity. The light intensity can be regulated manually or automatically. High intensity Xenon lamp gives better visual and photographic clarity.

Figure 02: Light Source

C. Light Cable

Light carrier is very important. It may either be a fluid or a glass fibre light cable (fig. 3). In the cable, there should not be sharp bends and cracks in the plastic sheath, if it

Figure 03: Light Cable

is there, then the cable should be changed for good light transmission. The cable is available at different diameters and lengths. The diameter of the fibre bundle should always be chosen slightly larger then the lens system and should not be too long.

D. Cameras

Now high resolution, small and light weight cameras are available, which is easy to handle, they provide picture of optimal sharpness, high resolution and excellent colour reproduction. A single chip camera has resolution of point 450-600; But the 3 chip cameras with more then 750 horizontal lines give excellent visual clarity. Usually single chip camera is adequate for routine laparoscopic surgeries but if surgery is recorded for later inclusion in larger film or video production, three chip camera is preferable. Now a recent version of digital 3 chip camaras with integrated image processing modules is available (fig. 4).

Figure 04: Camera

E. Monitors

The video monitor must generate high resolution image after the S-VHS connection. Larger video screen is preferred, 20 inches and above, non flickering medical monitors with high resolutions more then camera is preferred (fig. 5).

Figure 05: Monitor

II. GAS FOR PNEUMOPERITONIUM

Air was the first gas used to produce pneumoperitoneum, but has largely been abandoned. The main disadvantage of air is the risk of air embolism.

Characteristics of the ideal insufflating agent

1. The ideal insufflating agent during laparoscopic procedures should be colorless, physiologically inert, and non explosive in the presence of electrocautery or laser coagulation.
2. Its solubility in blood should be high.
3. The insufflating gas should be readily available, inexpensive, and nontoxic.

1. Carbon dioxide

Carbon dioxide is an odorless, colorless gas. It is a readily available, stable, naturally formed in the tissues and subsequently eliminated by the lungs. Due to these features, Carbon dioxide is the most commonly used gas for insufflation during laparoscopic procedure.

Advantages

1. It has relatively low risk of venous gas embolism
2. It does not support combustion

Disadvantages

1. Hypercarbia and acidosis
2. The direct effects of carbon dioxide and acidosis can

lead to decreased cardiac contractility, pulmonary hypertension and systemic vasodilation.

2. Nitrous Oxide

Nitrogen is biologically inert, colorless, gaseous element that is found free in the air. Nitrous oxide has been suggested for the procedures performed under local anesthesia, or for patients with pulmonary disease undergoing longer procedures.

Advantages

1. Insignificant changes in acid-base balance.
2. Decreased pain

Disadvantages

1. Supports combustion in the presence of hydrogen or methane gas.

3. Helium (He)

Helium is a colorless, odorless, tasteless gas that is obtained from natural gas. This inert gas is neither combustible itself, nor supports combustion. Helium is less soluble in water than carbon dioxide.

Advantage

1. The main physiologic advantage is the minimal effect on acid- base balance.

Disadvantages

1. The development of postoperative subcutaneous emphysema has been observed, as it is relatively poorly soluble in water.
2. Risk of venous gas embolism because it is less soluble in water then carbon dioxide. It is more diffusible because of its low density.

4. Argon

Argon gas is colorless, odorless, noncombustible, and chemically nonreactive.

Advantage

1. The major physiologic advantage is stable acid base status.

Disadvantage

1. The major possible physiologic disadvantage is cardiac depression.

III. LAPROFLATTOR

The Electronic CO_2 Laproflattor is a general purpose insufflation unit for use in laparoscopic operations (fig. 6). Controlled pressure insufflation of the peritoneal cavity is used to achieve the necessary work space for laparoscopic surgery by distending the abdominal wall and depressing the hollow organs. Automatic insufflators allow the surgeon to preset the insufflating pressure and it supplies gas until the required intra-abdominal pressure is reached. The insufflator activates and delivers gas automatically when the intra-abdominal pressure falls because of gas escape or leakage from the ports. Insufflation pressure can be continuously varied from 0 to 30 mm Hg; total gas flow volumes can be set to any value in the range 0-9.9 liters/mm. Patient safety is ensured by optical and acoustic alarms as well as several mutually independent safety circuits. The important indicators of insufflators are preset pressure, actual pressure, flow rate and total gas used.

Figure 06: Insufflator

IV. SUCTION IRRIGATION MACHINE

It is used for flushing the abdominal cavity and cleaning during endoscopic operative intrusions. It has been designed for use with the 26173 AR suction /instillation tube. Its electrically driven pressure/suction pump is protected against entry of bodily secretions. The suction irrigation machine is used frequently at the time of laparoscopy to make the field of vision clear. Most of the surgeons use normal saline or ringer lactate for irrigation purposes. Sometimes, heparinized saline is used to dissolve blood clot to facilitate proper suction in case of excessive intra-abdominal bleeding.

Suction and Irrigation hand apparatus

Irrigation and suction are very important during laparoscopic surgeries specially to maintain clear visual field and maintained hemostasis. It comes in 5mm and 10mm reusable sizes (fig 7). The suction tip is highly

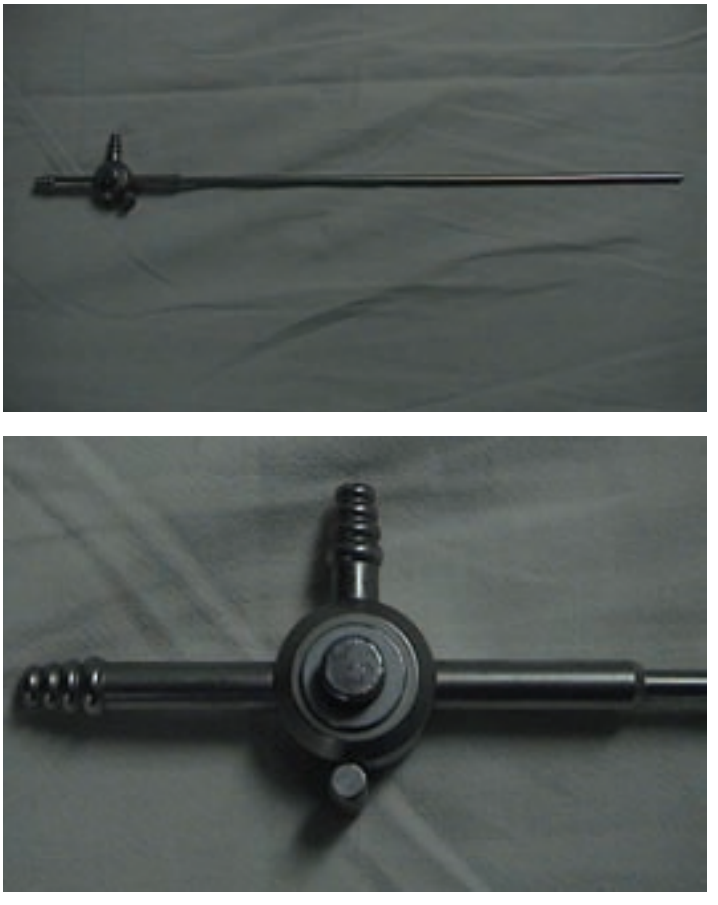

Figure 07: Suction and Irrigation Hand Instrument

useful for intermittent suction and as blunt dissecting instrument in place of finger, as we use in conventional surgeries.

V. OPERATIVE HAND INSTRUMENTS

Reusable and disposable instruments are commercially available. Disposable instruments provide better performance and higher safety on single use. To make it cost effective the surgeon has to reuse the disposable instruments after sterilisation. Reusable instruments are significantly cheaper in the long run, however, they need proper cleaning and maintenance.

A. Insuffalation cannulas

1. Veress Needle

Veress needle was invented by a chest physician for aspiration of pleural effusion keeping in mind that its spring mechanism and blunt tip will prevent the injury of lung tissue. Veress needle consists of an outer cannula with a beveled needle point for cutting through tissues (fig. 8). Inside the cannula there is an inner stylet, which is loaded with a spring. This spring springs forward in response to the sudden decrease in pressure encountered upon crossing the abdominal wall and entering the peritoneal cavity. The lateral hole on this stylet enables CO_2 gas to be delivered intra-abdominaly.

Veress needle is used for creating initial pneumoperitoneum so that the trocar can enter safely and the distance of abdominal wall from the abdominal viscera should increase. Veress needle technique is the most widely practiced way of access. It is very important to check veress needle every time before using it, for its (1) potency and, (2) spring action. Veress needle is available in three lengths 80mm, 100mm, 120mm. In obese patient 120mm and in very thin patient with scaphoid abdomen 80mm veress needle should be used. Veress needle should be held like a dart at the time of insertion.

Figure 08: Veress Needle

2. Hassan Cannula

It is less commonly used than veress. It usually reduces the risk of vascular and hollow visceral injury. It is an extremely safe instrument to enter the abdomen, especially in a patient who has previously undergone intra-abdominal procedures. This cannula consists of three pieces: a cone-shaped sleeve, a metal or plastic sheath with a trumpet or flap valve, and a blunt tipped obturator. On the sheath there are two struts for affixing two fascial sutures. These sutures are then wrapped tightly around the struts. Thereby firmly seating the cone-shaped sleeve into the laparoscopic port. This creates an effective seal to maintain penumoperitoneum.

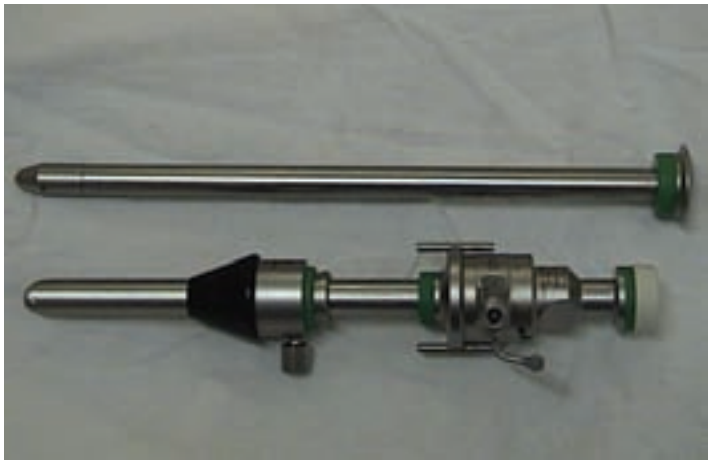

Figure 09: Hassan Cannula

Figure 10: Tips and Trocars

B. Trocars

The word "trocar" is usually used to refer to the entire assembly but actual trocar is a stylet which is introduced through the cannula. The trocars are available with different type of tips (fig. 10). The cutting tips of these trocars are either in the shape of a three edged pyramid or a flat two edged blade. Conical tipped trocars are supposed to be less traumatic to the tissue. The tip can be penetrated through the parietal wall without cutting and a decreased risk of herniation or haemorrhage is reported.

Cannulas are in general made from plastic or metal. Plastic devices whether they are transparent or opaque, need to be designed in such a way as to minimize the reflection of light from the telescope. Reusable and disposable trocars are constructed by a combination of metal and plastic. The tip of disposable trocar has a two edged blade. These are very effective at penetrating the abdominal wall by cutting the tissue as they pass through. Most of the disposable plastic trocar have a spring loaded mechanism that withdraws the sharp tip immediately after it passes through the abdominal wall to reduce the incidence of injury of viscera. Trocar and cannula are of different sizes and diameter depending upon the instrument for which it is used. The diameter of cannula ranges from 3 mm to 30 mm; the most common size is 5mm and 10 mm (fig. 11).

Some new disposable trocar designs incorporate unique design features such as direct serial incision of the tissue under visual control [Excel trocar-(fig.12)].

Figure 11: Different Sizes of Trocars

Figure 12: Xcel Trocar

All the cannulas have a valve mechanism at the top. Always inspect the trocar to ensure that all the valves move smoothly and, that the insufflation valve is closed (to avoid losing pneumoperitoneum). The valves of cannula provide internal air seals, which allow instruments to move in and out within cannula without the loss of pneumoperitoneum. These valves can be oblique, transverse, or in piston configuration. These valves can be manually or automatically retractable during instrument passage.

Surgeon should remember that sharp trocars although looking dangerous are actually better than blunt ones, because they need less force to introduce inside the abdominal cavity and the chances of inadvertent forceful entry of full length of trocar is lesser. The end of the cannula is either straight or oblique. An oblique tip is felt to facilitate the easy passage of the trocar through the abdominal wall.

Figure 13: Reducing Sleeve

C. Reducing Sleeve

It is used to reduce the size of the port from 10mm to 5mm or 5mm to 3 mm, so that pneumoperitoneum is maintained when ever surgeon changes the instrument from larger diameter to smaller diameter (fig. 13).

D. Needle holder

Laparoscopic needle holder is available with a straight or curved tip. Two needle holders are necessary to perform swift endo-suturing, although endo-suturing can be done satisfactorily with a single needle holder and a grasper. In-line grip needle holders are ergonomically better than pistol grip needle holder (fig. 14).

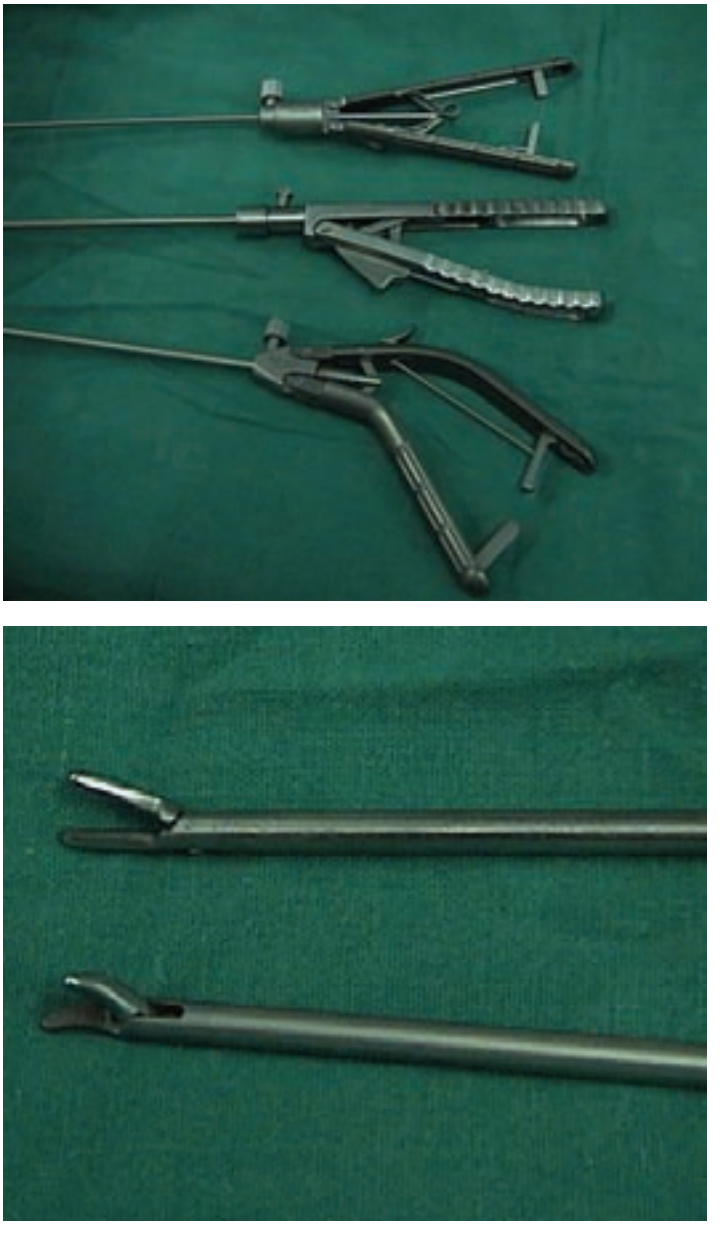

Figure 14: Needle Holder

E. Port closure instrument

These are self innovative hand instruments to close the laparoscopic ports, especially 10mm or larger ports, if needed (fig. 15).

Figure 15: Different Types of Port Closure

Figure 16: Disposable (left) and Reusable (right) Hand Instruments

VI. OTHER HAND INSTRUMENTS

Disposable or Reusable Instruments (fig. 16)

Several factors should be considered at the time of choosing laparoscopic instrument, including cost, availability and reliability. Reusable instruments are expensive initially but in long run they are cost effective. In developing countries, disposable instruments are very rarely used because labour cost is low compare to the cost of disposable instrument. In Europe and USA, surgeons often choose to use disposable instrument in order to save high labour cost. The disposable instruments are not sterilized properly by dipping in gluteraldehyde because they are not dismountable. Insulation of disposable instrument also can be torn easily which can lead to electrosurgical injuries.

Laparoscopic hand instruments vary in diameter from 1.8 to 12mm but majority of instruments are designed to pass through 5 to 10mm of cannula. The instruments are also of different lengths (vary from company to company, usually varies from 18 to 45cm) but they are ergonomically convenient to work with if they have same length of approximately 36 cm in adult and 28 cm in pediatric practice. Shorter instruments 18 to 25cm are adapted for cervical and pediatric surgery. Certain procedures for adult can also be performed with shorter instrument where the space is constricted. Forty-five centimetre instruments are used in obese or very tall patients. For better ergonomics half of the instruments should be inside the abdomen and half outside. If half of the instrument is in and half out, it behaves like a class-1 lever; and it stabilizes the port nicely and thus surgery becomes convenient.

Most of the laparoscopic procedures require a mixture of sharp and blunt dissection techniques, often using the same instrument in a number of different ways. Many laparoscopic instruments are available in both re-usable and disposable version. Most re-usable instruments are partially dismountable so that it can be cleaned and washed properly. Some manufacturer have produced modular system where part of the instrument can be changed to suit the surgeon favorite attachment like handle or working tip.

Most laparoscopic instruments like graspers and scissors have basic opening and closing function. Many instruments manufactured during past few years are able to rotate at 360 degree angle which increases the degree of freedom of these instruments.

Most of the hand instruments have three detachable parts.

a. Handle
b. Insulated outer tube
c. Insert which makes the tip of the instrument.

a. Different Handles of Hand instrument (fig. 17)

Certain instrument handles are designed to allow locking of the jaw. This can be very useful when the tissue needs to be grasped firmly for long period of time preventing the surgeons hand from getting fatigued. The locking mechanism is usually incorporated into the handle so that surgeon can easily lock or release the jaws. These systems usually have a ratchet so that the jaws can be closed in different positions and to different pressures. Most of the laparoscopic instrument handles have attachments for unipolar electrosurgical lead and many have rotator mechanism to rotate the tip of the instrument. Some multifunctional laparoscopic handles have attachment for suction and irrigation.

The **Cuschieri Ball Handle** was invented by Prof. Sir Alfred Cuschieri. This handle lies comfortably in surgeon's palm. This design reduces the fatigue of surgeon and eases rotation of the instrument by allowing rotation within the palm rather than using wrist rotation. Squeezing the front of the handle between the thumb and the first fingers increases the jaw closing force; squeezing the rear of the handle between the thenar eminence of the thumb and last fingers opens the jaws.

Cuschieri pencil handle also has great ergonomic value specially when used with needle holder. This handle allows the angle between the handle and the instrument to be altered to suit the surgeon's wrist angle. The conveniently placed lever of this pencil handle when pressed can change the angle. Just like ball handle, pressure at the front increases the jaw closing force while pressure at the rear opens the jaw.

Figure 17: Different types of Handles

b. Insulated outer tube (fig. 18)

The insulation covering of outer sheath of hand instrument should be of good quality in hand instrument to prevent accidental electric burn to bowel or other viscera. Insulation covering may be of silicon or plastic. At the time of cleaning the hand instrument, utmost care should be taken so that insulation should not be scratched with any sharp contact. A pin hole breach in insulation is not easily seen by naked eye but may be dangerous at the time of electro surgery.

Figure 18: Outer Sheeth

c. Insert of Hand Instrument (fig. 19)

Insert of hand instrument varies only at the tip. It may be grasper, scissors, or forceps. This grasper may have single action jaw or double action jaw. Single action jaw open

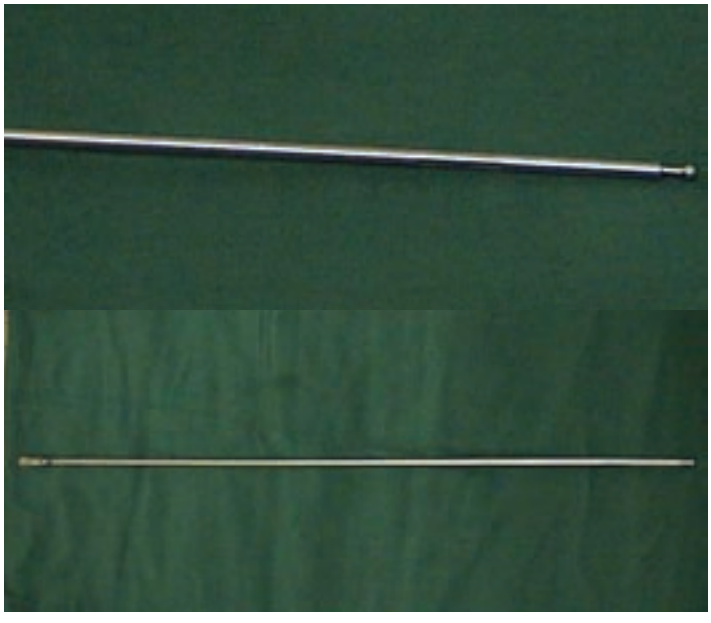

Figure 19: Inserts

less than double action jaw but close with greater force thus, most of the needle holders are single action jaw. The necessary wider opening in double action jaw is present in grasper and dissecting forceps. Single action graspers and dissectors are used where more force is required.

d. Different type of Graspers (fig. 20 & 21)

These graspers are good when you don't have control over depth and surgeon wants to work in single plane in controlled manner particularly during adhesiolysis.

Figure 20: Single Action Jaw Grasper

Figure 21: Double Action Jaw Graspers

e. Instruments for Sharp Dissection

1. Scissors
2. Electro surgery hook
3. HF Electro surgery spatula (Berci)
4. HF Electro surgery knife
5. Knife

Scissors (fig. 22)

Scissors are one of the oldest surgical instruments used by surgeons. Scissors are used to perform many tasks in open surgical procedure but its use in minimal access surgery is restricted. In minimal access surgery scissors require greater skill because in inexperienced hand it may cause unnecessary bleeding and damage to important structures.

Figure 22: Scissors

Types of Laparoscopic Scissors

1. Straight Scissors
2. Curved Scissors
3. Serrated Scissors
4. Hook Scissors
5. Micro-tip Scissors

Spatula, Hook and Harmonic Scalpel (fig.23)

Spatula has a flat tip for dissecting the gall bladder from the liver bed. It is much safer than the hook. Hook has a L shaped tip. Usually it is used to dissect the gall bladder from the bed of the liver. Some surgeons also use this instrument for opening of the intestine. Now a days in modern laparoscopic surgery ultrasonic scalpel (Harmonic scalpel) is available for advanced procedures.

Figure 23: Spatula, Hook and Harmonic Scalpel

Figure 24: Clip Applicator

Clip Applicator (fig. 24)

They are available as either disposable or reusable. Reusables are of of three sizes, large, medium large and medium. They are used to clip cystic artery and cystic duct according to their size. Disposable clip applier comes with preloaded 20 clips per unit as the Protack (commonly used in mesh repair in hernia) comes in 30 per unit.

ERGONOMICS

- **Word derivation:** ergon (labor) and nomia (arrangement)
- **Concept:** of designing the working environment to fit the worker, instead of forcing the worker to fit the working environment
- **Application:** to make the OT more user-friendly, to reduce stress, to increase efficiency and safety
- **Includes:** instrument, machines and OT design
- **Involves:** understanding the interactions between humans with other elements in the system to optimize human well-being and overall performance of the system

Operative laparoscopy has changed the concept of surgery from prolonged painful recuperative periods with long scars of open surgery to short stay, painless, and cosmetically satisfying surgery. This has been achieved at the expense of surgeons' discomfort and fatigue, thus putting both the surgeon and patient at risk. Inadequate knowledge about ergonomics together with ergonomically deficient design of laparoscopic instruments has been cited as possible causes.

Increased technological complexity and sometimes poorly adapted equipment have led to increased complaints of surgeons' fatigue and discomfort during laparoscopic surgery.

Ergonomic Variable

The important variables which have been studied include hand size, handle to tip force transmission, optimum height of the surgeon's hand and height of the operating table, view site in relation to monitor position and the technique of gripping the instruments.

Hand size

Hand size is an important variable to consider when designing laparoscopic hand tools. This is because laparoscopic surgeons, especially women using glove sizes 6.5 or smaller, experience musculoskeletal problems while using common laparoscopic instruments.

Moreover, subjects who reported musculoskeletal problems performed a significantly greater percentage of laparoscopic cases and found the stapler and graspers difficult to use for a greater percentage of time than those not reporting problems.

Handle to tip force transmission

Data from the Society of American Gastrointestinal and Endoscopic Surgeons (SAGES) reveal that laparoscopic instruments suffer from ergonomically inadequate handle designs and inefficient handle to tip force transmission, which lead to surgeons' fatigue, discomfort, and hand paresthesias. Studies quantifying forearm and thumb muscle workload by processed electro-myogram (EMG) demonstrated that the peak and total muscle effort of forearm and thumb muscles were significantly greater when the grasping task was performed using the laparoscopic instrument. This was found to be more prevalent among junior laparoscopic surgeons having less than two years of experience.

Optimum height

Discomfort and difficulty ratings were lowest when instrument handles were positioned at elbow height. The position of laparoscopic instrument handles needed to be close to surgeons' elbow level to minimize discomfort and upper arm and shoulder muscle work. This was found to correspond to an approximate table height of 64 to 77 cm above floor level.

Technique of gripping

Palm grip hand position with the pistol handle (thumb outside the ring with the palm resting on the thumb ring) is more efficient than the finger-in-ring grasp because it significantly reduces the muscle forces required for grasping with a laparoscopic instrument. Many surgeons do, in fact, use the palm grasping hand position for sustained grasping tasks during laparoscopic surgery. Moreover, use of finger tips rather than finger base during finger-in-ring grasp during tissue dissection reduces discomfort.

Majority of the surgeons performing regular laparoscopy are unaware of the complications of nerve injury and neuropraxia following improper gripping technique. Experience in laparoscopic surgery does play a major impact on knowledge about ergonomical problems. Operating for prolonged hours with eyes focused on video monitors results in eye strains among laparoscopic surgeons. Placement and adjustment of monitors have little benefit in improving the situation though experience resulted in some improvement.

Use of laparoscopy is associated with significant ergonomic problems, hence proper training and awareness among laparoscopic surgeons is essential in India. This is only possible if an authorized accreditation council sets up guidelines and oversees the training programs, thus making laparoscopy safer for both surgeons and patients.

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