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Landmark historic events, Endovision system: Maintenance and trouble shooting

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As we enter in the 21st century, we are witnessing dawn of a new era in which closed body operating procedures are more often being performed through minimal access. This development is the result of vision and work of many dedicated individuals. They include early pioneers of endoscopy who planted the seed and finally the modern pioneers who pushed and expanded these frontiers to give rise the birth of modern laparoscopy. Therapeutic laparoscopic surgery was introduced into the surgical practice recently and within a short span of time, it has become established as gold standard for the treatment of chronic cholelithiasis and many advanced laparoscopic procedures can be performed safely. Laparoscopic surgery, what we witness today, is the culmination of over a century of painstaking efforts of the number of pioneers in the fields of optics, instrumentation and video laparoscopic camera.

Few advances in medicine occur in isolation. The innate human curiosity to peer inside the body cavities can be traced back to ancient times. However, due to primitive technology and crude instruments, many of these ambitions were not realized. It is probably safe to say that first laparoscopy would not have been performed had it not been for the efforts of many physicians in 19th century to develop endoscope. The device in Fig.1 developed by Theodore Stein in mid 1880 contains all the elements of the current endoscopic documentation system. There was a crude endoscope and a high intensity light source. Illumination was created by continuously feeding a magnesium wire into an ignition chamber using a clockwise mechanism. Light from this combustion was reflected into the tube using a mirror. Finally the image was focused on to a photographic plate through coupling optics.

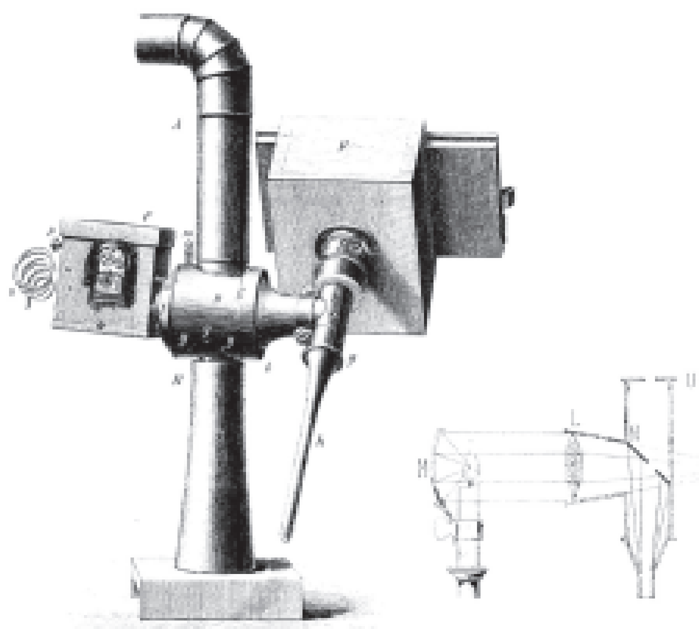

Fig. 1: Early endoscopic device by Theodore Stein

The word laparoscopy is derived from a Greek word lapara, meaning "the soft part of the body between ribs and hip, flank, loin" and skopein, which means "to look at or survey". First documented laparoscopy was undertaken in 1901 by Damitri Oksarovich Ott (1858-1929) of St. Petersburg, Russia, using gynecologic head mirror, an external light source and a speculum to perform the procedure. He termed the procedure "Ventroscopy" (1). In 1902, George Kelling (Fig.2) of Dresden, Germany outlined the technique of visualizing the peritoneal cavity and it's contents in a dog by inserting

Fig. 2: George Kelling of Dresden, Germany

a cystoscope inserted through a trocar and creating pneumoperitoneum with filtered air. At the same time, a Swedish surgeon, Jacobaeus (Fig. 3) in 1910, coined the term " laparoscopy" (2) which has subsequently become the accepted terminology used to describe almost all varieties of this form of intervention. He published his experience on the technique of laparoscopy in humans for the first time. The next technological advance in laparoscopic technology was provided in 1920 by Benzamin Orndoff (3) who developed a sharp pyramidal point on laparoscopic trocar to facilitate puncture.

Fig. 3: Hans Christian Jacobaeus of Stockholm, Sweden

Professor Kalk (Fig. 4) from Germany pioneered the use of laparoscopy for disorders of liver and biliary tract. He introduced the oblique viewing optics from longitudinal axis permitting better inspection of organs, as the image could be changed by altering the viewing direction of the optics such that the lens moved around the object. In 1929 he was the first to describe dual puncture technique. The use of second puncture opened the way for the development of operative laparoscopy. The next significant development in laparoscopic technology occurred in 1938 when Hungarian surgeon, Janos Varess (Fig. 5) described a spring loaded needle with an inner stylet that automatically converted the sharp cutting edge to a rounded end by incorporating a side hole (4) . for creation of pneumoperitoneum. He was the chief physician at the Komitat hospital in Hungary. The needle had initially been used to create a pneumothorax to treat tuberculosis. The first description of operation performed under laparoscopic vision came from Fervers in 1933. He performed laparoscopic adhesiolysis with biopsy instruments. He used oxygen as distending medium and experienced "great concern" at the audible explosion and flashes of light produced by electrocautery within the abdominal cavity. He recommended changing to carbon di oxide as insufflating gas for creating pneumoperitoneum.

Kurt Semm, a gynecologist (Fig.6), played the vital role in the development of operative laparoscopy. It was Semm who developed the automatic insufflating device that monitored intra abdominal pressure and gas flow in 1963 (5). Prior to this, air was introduced by most workers into peritoneal cavity with the help of a syringe. Semm

Fig 4: Professor Kalk, promoter of the oblique (45 degrees) lens system

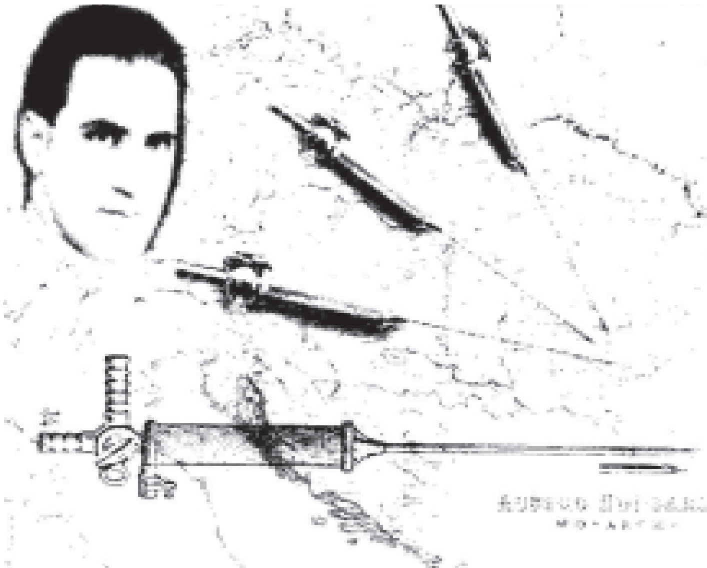

Fig. 5: Janos Varess, Hungarian Surgeon

designed the pre tied suture loop (Roeder knot) to allow adequate haemostasis. He also developed a high volume suction/irrigation apparatus with design modifications to prevent tube clogging. Many more instruments i.e. needle holder, micro scissors, clip applier, morcellator were conceptualized, created and first utilized at Kiel University by him. He also created pelvi trainer, designed to teach surgeons the video eye hand coordination and suture tying techniques He was the first person to perform laparoscopic appendectomy in 1982 and soon thereafter, using his instruments, Erich Muhe, a surgeon from Boblingen performed first laparoscopic cholecystectomy in 1985. Unfortunately his technical presentation to Congress of German Surgical Society met with considerable resistance. The surgery was later performed with the help- of video camera in France by Phillipe Mouret (Fig. 7) in 1987.

Fig 6: Gynecologist Kurt Semm of Kiel, Germany

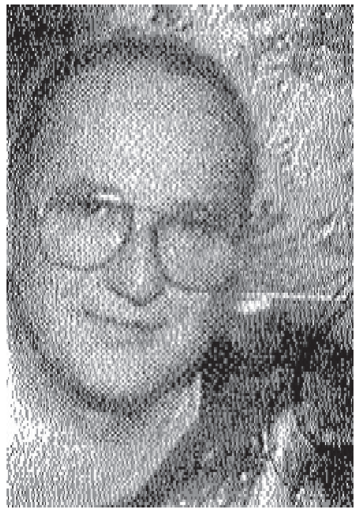

Fig. 7: Phillipe Mouret, France

No one has contributed more widely to the development and use of laparoscopy in general surgery than George Berci (6) in Los Angeles, both in the design of instrumentation and identifying clinical situations in surgical practice where laparoscopy would materially benefit management of the patient. He pioneered the use of laparoscopy for the management of diagnostic dilemmas, especially in emergency situations, and was instrumental in the development of laparoscopy for trauma.

ENDOVISION SYSTEM FOR LAPAROSCOPY

Video camera

It is safe to say that the development of laparoscopic surgery would not have been possible without the video laparoscopic camera in 1986.This instrument allowed all members of the operating team to view operative field simultaneously, permitting the type of coordinating movements required for complex operative procedures. Prior to that operative laparoscopy was restricted to the individual directing the operative procedure and participation by other members of the surgical team was limited.

The foundation of the laparoscopic camera is the solid state chip sensor. The most commonly used sensor is charged coupled device (CCD). The CCD is composed of small pieces of silicone called pixels, which are arranged in rows and columns and are sensitive to light. When light strikes a pixel, the silicon emits electricity, which is transmitted to the monitor. The electronic signals are then reconstructed on the monitor to give the video image. The resolution of the CCD is determined by number of the pixels on the sensor. The resolution is defined as the number of vertical lines that can be discriminated as separate in three quarters of the width of the monitor screen. The laparoscopic camera requires at least 300 lines of resolution to provide an adequate image. Now a day's triple chip camera are available, with each chip devoted to only one color of the spectrum. Since the major spectrum is derived from three colors i.e. red, green and blue, modern three chip camera is able to reconstruct the image consisted of these three primary colors and provide excellent resolution and color but they are significantly more expensive.

Light source & transmission

One of the primary problems in the development of video laparoscopy was the insufficient light. A typical light source consisted of a lamp " bulb", heat filter, a condensing lens and manual or automatic intensity controlled circuit. Lamp or bulb is the most important part of the light source. The Quality of light depends on the lamp used. Several Modern types of light sources are currently available on the market. These light sources mainly differ on the type of bulb used. Four types of lamp are used more recently. 1. Quartz halogen. 2. Incandescent bulbs 3. Metal halide vapor arc lamp 4. Xenon.

A normal light source (a light bulb) uses approximately 2 % in light and 98 % in heat. This heat is mainly due to the infrared spectrum of light and due to obstruction in the pathway of light. If Infrared will travel through the light cable than the cable will be intolerably hot. A heat filter is introduced to filter this infrared to travel in fiber optic cable. A cool light source lowers this ratio by creating more light, but does not reduce the heat produced to zero. The purpose of condensing lens is to converge the light emitted by lamp to the area of light cable input. In most of the light source it is used for increasing the light intensity per square cm of area.

Most common type of light source was halogen bulb. It is highly efficient crisp light source with excellent color rendering. The electrodes are made up of Tungsten. They utilize halogen gas that allows the bulb to burn more intensely without sacrificing its life. They have average life of 2000 hours. These lamps are cheap and can be used for laparoscopic surgery if low budget set up is required. However, they lack in providing the natural white light color. Metal halide vapor arc lamp is a mix of compounds, (mostly salts of rare earths and halides as well as mercury which provided the conduction path) is carefully chosen to produce an output which approximates to "white light" as perceived by the human eye. There are two types of metal halide lamp, iron halide and gallium iodide lamp. Although the light generated was white but not exactly the replica of natural light. This problem has largely been eliminated with the introduction of high intensity Xenon light source. Xenon lamps consist of a spherical or ellipsoidal envelope made of quartz glass, which can withstand high thermal loads and high internal pressure. For ultimate image quality, only the highest-grade clear fused silica quartz is used. It is typically doped, although not visible to the human eye, to absorb harmful UV radiation generated during operation. The color temperature of Xenon lamp is 6000-6400 K. The operating pressures are tens of atmospheres at times, with surface temperatures exceeding 600 degrees C. The light emitted by xenon lamp is slightly bluish and more natural compared to halogen lamp. However, most of the cameras at present analyze and compensate these variations by means of automatic equalization of whites (2100 K to 10000 K), which allows the same image to be obtained with both light sources. A proper white balancing before start of the operation is a very good practice for obtaining a natural color. The white light is composed of the equal proportion of Red, Blue and Green Color and at the time of white balancing the camera sets its digital coding for these primary colors to equal proportion assuming that the target is white. And if at the time of white balancing the telescope is not seeing a perfectly white object then the setup of the camera will be very bad and the color perception will be very poor.

Prior to the introduction of fiber optic cables, the light source was incorporated in the laparoscope itself making it heavier, and cumbersome. In 1954 a major breakthrough in technology occurred in the development of fiber optic cables. The principle of fiber optic cable was based on the total internal reflection of light. Light could be transmitted through a curved glass rod due to multiple total internal reflections at the walls of the rod. Light would enter at one end of the fiber and emerge at the other end after numerous internal reflections with virtually all of its strength. Now a days two types of light cable are available in market. 1. Fiber Optic cable 2. Liquid crystal Gel cable. The optical cables are made up of a bundle of optical fiber glass thread swaged at both ends. They have a very high quality of optical transmission, but are fragile. In fact, some of the fibers may break due to repeated use. The broken fibers are seen as black spots when cable is viewed against day light. The gel cables are made up of a sheath that is filled with a clear optical gel. (Liquid crystal) and swaged at both ends by quartz. Theoretically they are capable of transmitting 30% more light than optic fibers. Due to more light and better color temperature transmission this cable is recommended in those circumstances where documentation (movie, photography or TV) is performed. They pose three problems 1. The quartz swaging at the ends is extremely fragile, especially when the cable is hot. The slightest shock, on a bench for example, can cause the quartz end to crack and thus cause a loss in the transmission of the light 2. These cables transmit more heat than optical fiber cables 3. They are more rigid due to metal sheath, which makes them more difficult to maintain.

Of the most crucial invention in operative laparoscopy was by British Physicist, Harold Hopkins in 1952, who developed the idea of the rod lens system. Prior to this development, endoscopes were constructed on an optical system that comprised relay and field lenses made from glass with long intervening air spaces. In Hopkins system, the roles of glass and air are interchanged such that the optical system consists of air lenses and long glass air spaces. As the refractive index is now predominantly that of glass, the light transmission capacity of the endoscopes is doubled. A second advantage of Hopkins rod lens system relates to the "larger radius of clear aperture" available at the viewing optic that was not possible with conventional endoscopes.

MAINTENANCE

Light Cable: Handle it carefully and do not twist it. After the completion of operation, cable should preferably be disconnected from the endoscope and then from light source. Avoid direct fall of light on eyes. The retina can get damaged. The cable should be periodically cleaned with cotton swab moistened with alcohol. The outer covering of the cable should be cleaned with mild detergent or disinfectant. The fiber optic cable should not be placed near the patient when it is connected to illuminated light source. The heat generated may cause burn

Instruments

Meticulous care should be taken in mechanically cleaning all the parts of all laparoscopic instruments. The handles are un-screwed, inserters taken out and the hollow sheath is cleaned with running water or syringe. Instruments are wiped dry gently and lubricated with silicone oil. These are the vital steps before sterilization or disinfection of laparoscopic instruments. All metal instruments or part that can undergo sterilization using a steam autoclave should be handled in this manner. Suction/ Irrigation tubes are thoroughly cleaned with running tap water before autoclaving them.

Telescope and Camera

The telescope eye piece, light cable slot and its patient end must be cleaned with warm water and the patient end, additionally with camera cleaner liquid. The ends of the telescope are sensitive to heat; hence it should be sterilized with chemical sterilizer. Laparoscopic camera will be damaged by heat as well as repeated exposure to chemical germicides. More over the irregular configuration of the surface of camera makes the disinfection difficult and unpredictable. Therefore camera are best treated with the use of barrier such as sterile plastic/ cotton sleeve to avoid contamination of operating field. They are most expensive parts of equipment, hence must be handled with utmost care. Avoid crumpling of its lead and never use alcohol/ spirit to clean the camera head. Instead use camera head cleaner supplied by company or it can be simply cleaned with moist warm cotton.

Sterilization

It is defined as complete elimination/ destruction of all forms of microbial life. It can be achieved with steam, gas or chemical sterilants. Disinfection which is a relative term means elimination of many or all pathogenic organisms except bacterial spores. It is divided into three levels, high, intermediate and low. High level disinfection eliminates all organisms with exception of large number of bacterial spores. Intermediate level disinfection destroys all organisms except spores, most bacteria and some fungi. Low level of disinfection can destroy most bacteria, some viruses and some fungi.

High level disinfection is accomplished by 2% Glutaraldehyde solution, a most popular chemical sterilant used for high level disinfection of laparoscopic equipments. The minimum recommended exposure time is 10 minutes, although some workers prefer and recommend for 20 minutes. It can sterilize the instruments only after ten hours of exposure. The life of the solution is generally 20-25 days. The potency and use life of the solution is determined more by use pattern and not strictly by time. The heavy use and inadvertent dilution or contamination will require early change of sterilant.

It should be mentioned that no addition to described protocol is required to deal with HIV or hepatitis-B

Table 1

	Problem	Cause	Solution
1.	Poor insufflation/loss of pneumoperitoneum.	CO_2 tank empty	Change tank
		Open accessory port stopcock(s)	Inspect all accessory ports close stopcock(s)
		Leak in sealing cap or stopcock. Excessive suctioning	Change cap or cannula Allow abdomen to re-insufflate
		Instrument cleaning channel screw cap missing	Replace screw cap
		Loose connection of insufflator tubing at source or at port	Tighten connection
		Hasson stay sutures loose.	Replace or secure sutures
2.	Excessive pressure required for insufflation (initial or subsequent)	Veress needle or cannula tip not in free peritoneal cavity	Reinsert needle or cannula
		Occlusion of tubing (kinking, table wheel, inadequate size tubing, etc.)	Inspect full length of tubing, replace with proper size as necessary
		Port stopcock turned off	Assure stopcock is opened
		Patient is "light"	More muscle relaxant
3.	Inadequate lighting (partial/ complete loss)	Loose connection at source or at scope	Adjust connector
		Light is on "manual minimum"	Go to "automatic"
		Bulb is burned out	Replace bulb
		Fiber optics are damaged	Replace light cable
		Automatic iris adjusting to bright reflection from instrument	Reposition instruments, or switch to "manual"
		Monitor brightness turned down	Readjust setting
4.	Lighting too bright	Light is on "manual-maximum"	Go to "automatic"
		"Boost" on light source activated.	Deactivate "boost"
		Monitor brightness turned up	Readjust setting
5.	No picture on monitor(s)	Camera control unit or other components (VCR, printer, light source, monitor) not on	Make sure all power sources are plugged in and turned on
		Cable connector between camera control unit and/or monitors not attached properly	Cable should run from "video out" on camera control unit to "video in" on primary monitor; use compatible cables for camera unit and light source Cable should run from "video out" on primary monitor to "video in" on secondary monitor

	Problem	Cause	Solution
6.	Poor quality picture. a. Fogging, haze	Condensation on lens of cold scope entering warm abdomen.	Gently wipe lens on viscera; use anti-fog solution, or warm water, gently wiping on liver or uterine surface is preferable
		Condensation on scope eyepiece, camera lens, coupler lens	Detach camera from scope (or camera from coupler), inspect and clean lens as needed
	b. Flickering electrical interference	Moisture in camera cable connecting plug	Use compressed air to dry out moisture (don't use cotton-tip applicators on multi prong plug)
		Poor cable shielding	Replace video cable between monitors
		Insecure connection of video cable between monitors	Reattach video cable at each monitor
	c. Blurring, distortion	Incorrect focus	Adjust camera focus ring
		Cracked lens, internal moisture	Inspect scope and camera, replace as needed
7.	Inadequate suction/ irrigation	Occlusion of tubing (kinking, blood clot, etc.)	Inspect full length of tubing; if necessary detach from instrument and flush tubing with sterile saline
		Occlusion of valves in suction/ irrigator device	Detach tubing, flush device with sterile saline
		Not attached to wall suction	Inspect and secure suction canister connectors, wall source connector
		Irrigation fluid container not pressurized	Inspect compressed gas source, connector, pressure dial setting
8.	Absent/inadequate cauterization	Patient not grounded properly	Assure adequate patient grounding pad contact, and pad cable electro-surgical unit connection
		Connection between electro-surgical unit and pencil not secure	Inspect both connecting points
		Foot pedal or hand switch not connected to electrosurgical unit	Make connection

contaminated equipments. Both hepatitis and HIV virus are inactivated many physical and chemical processes much less potent than high level disinfection.

A new sterilization process, marketed as STERIS is also available. Its active agent is per acetic acid, generally considered to be a stronger germicide that has very little harmful effects on optical instruments. It has the advantage of being a closed system and is not subject to various factors responsible for bringing down the efficacy of chemical germicide.

TROUBLE SHOOTING

Laparoscopic procedures are inherently complex. Many things can go wrong. The surgeon must be sufficiently familiar with the equipment to troubleshoot and solve problems. Table 1 gives an outline of the common problems, their cause, and suggested solutions.

In conclusion, I would say that the pace of development of diagnostic laparoscopy which was hitherto slow but steady over the last century has entered into an exciting era of laparoscopic surgery with invention of miniaturized video endoscopes, quality light source and successful performance of laparoscopic cholecystectomy. Credit goes to many scientists who steadfastly continued their efforts to bring this science to the current state of art. The laparoscopic instruments are long, fine and insulated; hence, they are more vulnerable to wear and tear. Gentle handling and thorough mechanical cleaning & lubrication prior to sterilization/ disinfection will increase their life and efficiency. A laparoscopic surgeon should have knowledge of instrument functioning, basic knowledge of supportive equipments and able to manage the trouble shooting.

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