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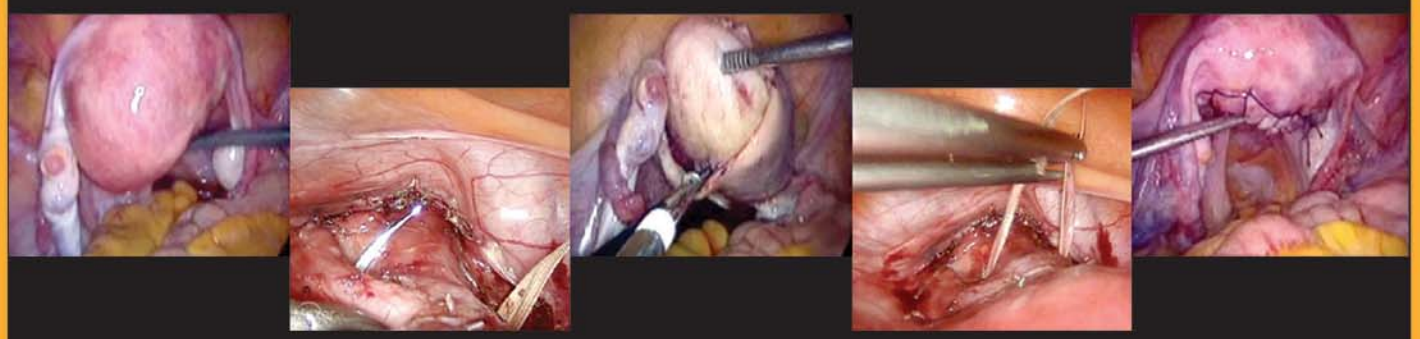
SECOND EDITION

PRACTICAL ENDOSCOPY

Tips by Experts



Sunita R Tandulwadkar
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Forewords
Togas Tulandi
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Chapter

3

Energy Sources in Endoscopic Surgery

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INTRODUCTION

Learning energy sources is of paramount importance in doing endosurgical procedure.

A clear understanding of its physics and its application to surgical procedure is necessary.

It is equally important to maximize safe delivery of these energy sources.

AIM

1. To discuss and understand the fundamental therapeutic modalities of the available energy sources.
2. To discuss the inherent risks and advantages of each.

ELECTROSURGERY

FUNDAMENTALS AND BIOPHYSICS OF ELECTROSURGERY

Electrosurgery is the surgical use of high-frequency electric current that produced by electron movement. Electrons revolve around the nucleus of an atom and flow from one atom's orbit to the other orbit. When this mechanism happened, it will make a flow of current. The force that provides the electron's ability to travel from one atom to the other atom is the voltage. The electron has encounter resistance, which produce heat, is called impedance. Only a closed electrical circuit allows electron to circulate.

In electrosurgery, there are some common terms include current, voltage and resistance. Current can be described as flow of electrons in a certain period of time. Current measured in amperes. Voltage is the force that drives the current or flow of electrons, measured in volts. In electrosurgery, voltage is provided by the generator, and current is delivered to the tissues through the electrode tip of the instrument. Resistance is obstacle to the flow of current that measured in ohms. Resistance is similar with impedance. In the electrosurgery use in clinical patient, the source of electron flow and voltage came from the electrosurgical generator (ESG). Circuit is an uninterrupted pathway of flowing electrons and Ohm's Law describes the actions of a given circuit :

$$\text{Voltage} = \text{Current} \times \text{Resistance}$$

A current can be driven in a circuit by an electromotive force supplied by a generator just as water can be driven by a pump. Each monopolar circuit consists of the generator, an active electrode, the patient and the patient-return electrode. Some pathways can be used to ground for leakage current, like OR table, stirrups, staff members and equipment. The impedance from the patient's tissues producing heat when the electrons overcome the impedance. The higher inherent resistance needs the greater voltage for the current to pass. Also, as more superficial tissues are cauterized, they become less electrically conductive, increasing their resistance and requiring higher amounts of the voltage for current to penetrate to the tissues.

The transformation of electrical energy into heat can be describe by Joules Law and the following formula :

$$\text{Energy} = (\text{Current/Cross-sectional area})^2 \times \text{Resistance} \times \text{Time}$$

Heat given off is a function of current density (current per cross-sectional area), time and resistance. The heat produced is proportional to the surface area of electrode. Larger electrodes will require longer periods of current application to achieve the same large heat production.

When an oscillating current is applied to tissue, the rapid movement of electrons through the cytoplasm of cells cause the intracellular temperature rising. In general, thermal damage to tissue is reversible in below 45°C. As tissue temperature exceed 45°C, the proteins in the tissue become denatured and losing their structural integrity. The liquid in the tissue will evaporate when it reach above 90°C. Once the tissue temperatures reach 200°C, the remaining solid components of the tissue are reduced to carbon.

TYPES OF ENERGY SOURCE

Electrosurgical generators can apply energy in either a monopolar or bipolar fashion. In the monopolar system, the current from the generator pass from the active electrode through the patient and out of the body through a dispersive electrode pad connected to the generator to form a complete circuit. The active electrode is at the surgical site (Fig. 3.1). Bipolar does not require a dispersive return electrode pad because the active electrode and the return electrode are integrated into the energy delivery forceps (Fig. 3.1) with the target tissue to complete the circuit. The damage produced in the tissue is limited and the risk of thermal injury in distant tissues is lower. The advantage of bipolar modality over monopolar modality has been depicted in Table 3.1.

In general, electrosurgical generators provide energy delivery in two types of modes: continuous and interrupted. The continuous mode is referred to the "cut" mode, the interrupted mode is referred to the "coag" or coagulation mode.

There are various forms of electric current :

- Direct current (DC): The electron flow continuously in the same direction. This type of current is used for therapeutic purposes, for example acupuncture and pain electrotherapy.
- Pulsed current: A relatively high amount of energy at short interval. It is used for nerve stimulation.
- Alternating current (AC): The current changes direction periodically between two electrodes (bidirectional). This type of current is used in electrosurgery.

When an electric current flows through biological tissue, we can observe thermal effect, electrolytic effect and faradic effect. The amount of heat in thermal effect depends on the intensity of the electrical current, the resistance of the tissue and the duration of current flows. The electrolytic effect can cause polarization of the electronic compound which can cause potential damage. To avoid this effect, the electrosurgery uses alternating current with constant reversal of polarity. Faradic effect is the reaction in the nerve ending when the electric current passing through the tissue. The reaction includes muscle contraction and pain.

This time, the modern concept of electrosurgery performed safely at frequencies above 100 kHz. This high

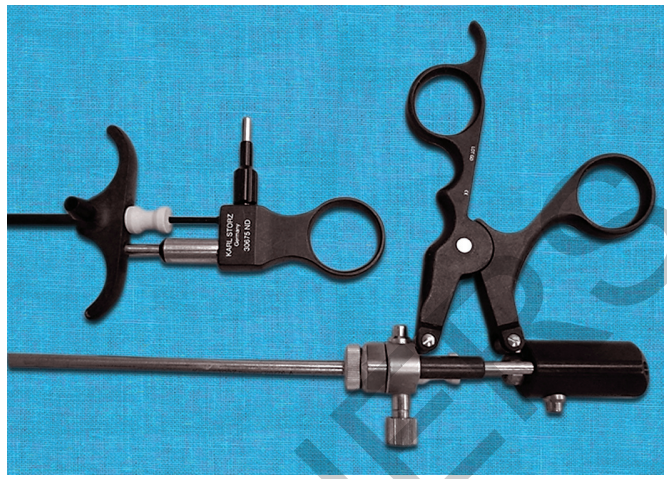

Fig. 3.1: Electrosurgery forceps: Monopolar (left) and bipolar (right)

frequency electric current can avoid the negative effect of neuromuscular stimulation that ceases at 10,000 cycles/second (10 kHz). This is important to minimize nerve and muscle stimulation. The possible effects of applying current to the tissue are fulguration, desiccation/coagulation or vaporization/ablation. An electrosurgical generator can produces 60 cycle current and increases the frequency to over 300,000 cycles per second which can pass through the patient with minimal neuromuscular stimulation and no risk of electrocution. Electrosurgical units operating in the frequency range of 300,000 to 600,000 Hz (300 kHz to 600 kHz) typically offer the best balance of safety and performance, instead of low-frequency current, which has a "faradic effect" with possible muscular twitching, pain, even ventricular fibrillation, and cardiac arrest (Fig. 3.2).

USE OF THE THERMAL EFFECT (FIG. 3.3)

There are two basic methods of thermal tissue destruction, which is used in electrosurgery.

Cutting

When a high current density is applied to the tissue, the heating of the intracellular fluid is increased so fast from 37°C to 100°C. There is no time for the water to evaporate. The vapor pressure leads to explosion of the cellular membranes (evaporation). The separation of tissues

Table 3.1: The bipolar modality has some advantages compared to the monopolar

Monopolar Modality	*Bipolar Modality*
The current passes through many tissues outside the surgeon's visual control before it can return to the electrosurgical generator	The current flow through the tissue is restricted to the area between two jaws of the electrode, which is under the direct vision of the surgeon
High risk of thermal injuries in distant tissues	The risk of thermal injuries in distant tissues due to direct contact of instrument, faulty insulation or diffusion of the electrical current is reduced
This modality interferes with other electronic equipment connected to the patient at the same time	The risk of interference with other electronic equipment (ECG, pacemakers and others) connected to the patient at the same time is lower

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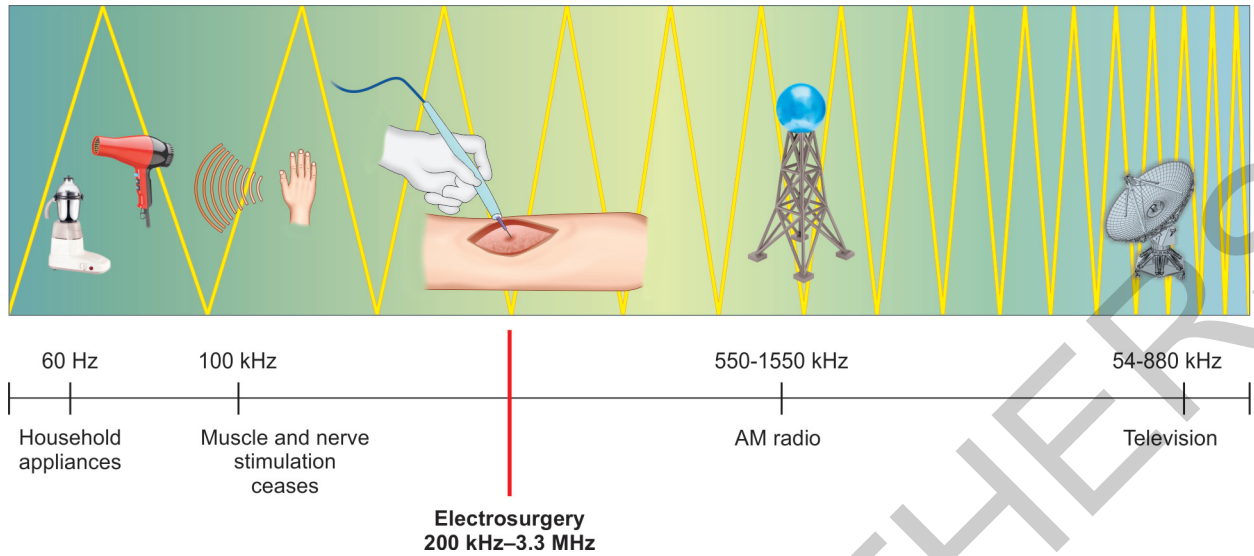

Fig. 3.2: Applications of different current frequencies

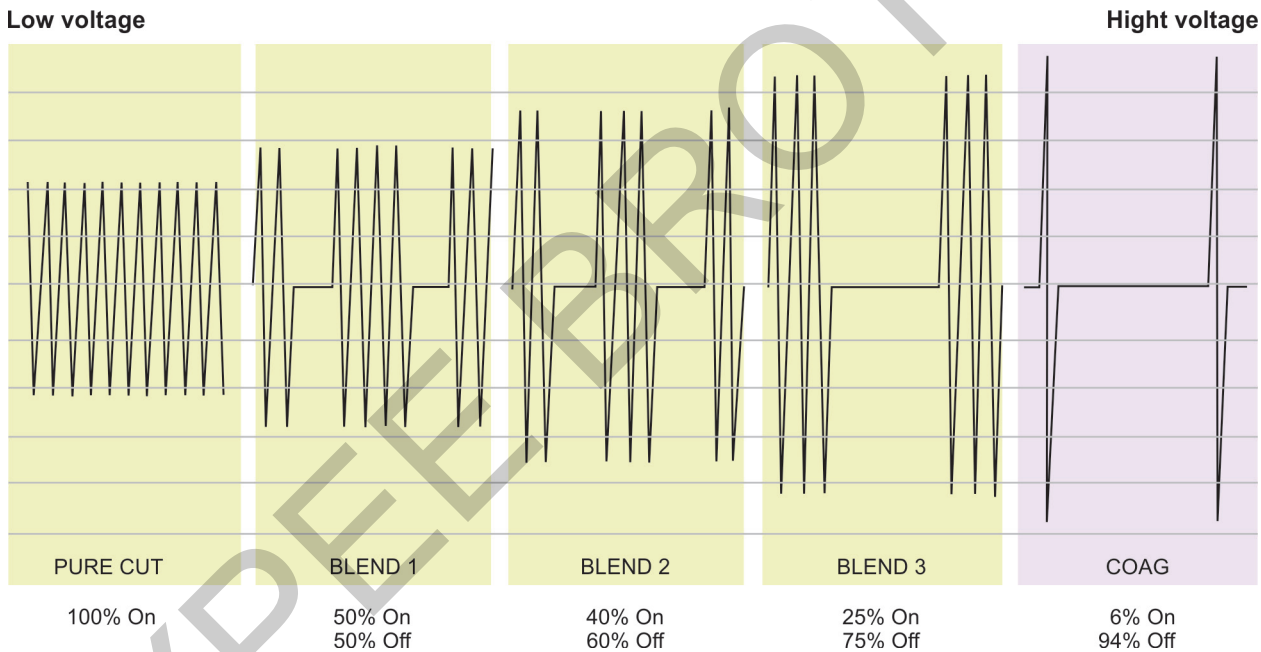

Fig. 3.3: Relationship between voltage and thermal effect

can be used to cut. This modality is more powerful and generally less penetrating. It also allows precise cutting with minimal coagulation and also reduce operating time.

With thicker or wider electrodes, the contact area and also the potential for thermal injury are increased. The electrosurgical cutting effect is used on vascular tissue, such as adhesiolysis and also for peritoneal endometriosis resection.

Coagulation

For coagulation, a low current density is applied so that the tissue temperature increases slowly, giving the water enough time to evaporate. In order to overcom the high impedance of air, the coagulation waveform has significantly higher voltage than the cutting current. Use of a high voltage coagulation current has implications during minimally invasive surgery.

Some surgeons cut with the coagulation current. It may be necessary to adjust power settings and electrode size to achieve the desired surgical effect. The advantage of coagulation with the cutting current is that a much lower voltage is used.

GENERAL SAFETY ASPECTS

Grounded Electrosurgery Systems

The electrical current is a continuous flow of electrons. It has an entry and exit site. So the current must return to

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some place and through the current division phenomenon. The current can split and follow the pathways to ground. The circuit to ground is completed whether it travels the intended electrosurgical circuit to the patient return electrode or to an alternative ground. Patient will have a risk of burns at the alternative grounding site if the resistance of the alternative path is low and the current flowing to ground is concentrated.

Isolated Electrosurgical Systems

If the circuit to the patient return electrode is interrupted, an isolated generator will deactivate the system because the current cannot return to its source. This type of generator will reduce the risk of burns at the alternative sites but do not protect the burns caused by the return electrode. The quality of the conductivity and contact area at the plate or patient interface must be maintained to prevent burn injury at the return electrode site.

Patient Return Electrodes

The function of the patient return electrode is to collect and remove current from the patient safely. To eliminate the risk of current density, the plate should present a large contact area to the patient with low impedance, on conductive tissue as close as possible to the operative site. The plate site should be a well vascularized muscle mass.

Direct Coupling

Direct coupling occurs when the user accidentally activates the generator while the active electrode is near another metal instrument. It can cause a potential risk of significant patient injury. The generator should not be activated while the active electrode is touching or in close proximity to another metal object.

Insulation Injury

Many surgeons routinely use the coagulation current, which has a relatively high voltage. The concentrate current can caused significant injury. Simply by using the cutting current, the surgeon can obtain the coagulation effect and reduce the insulation failure without high voltage. By lowering current density the rate at which heat is produced is reduced.

Capacitive Coupling during Laparoscopy

There are three systems of capacitive coupling, including metal trocar system, plastic trocar system, hybrid trocar system. In metal trocar system, the conductive active electrode is surrounded by a conductive metal trocar. A capacitor creates an electrostatic field between the two conductor, a conductor can induce a current in the second conductor. In plastic trocar system, capacitance cannot be entirely eliminated with an all-plastic cannula. Capacitance



Fig. 3.4: Electrosurgery machine

is reduced, but is not eliminated. In hybrid trocar system, a metal cannula is held in place by a plastic anchor. The capacitive coupled current may exit from adjacent tissue to the patient return electrode that can cause significant injury.

PREVENTION OF ELECTROSURGICAL INJURIES

The following steps for preventing electrosurgical injuries:

1. A thorough understanding of the biophysical principles of radiofrequency electrical energy is essential. For example, when the generator output cannot accomplish tissue effect as expected, we should check the ground plate or its connection.
2. Do bowel preparation if it is anticipated that the large bowel is at risk. The use of an orogastric tube is recommended.
3. Choose the proper current waveform mode. In monopolar surgery, either the cutting or coagulation waveform can be used to achieve a cutting effect or fulguration effect. Use the lowest possible generator setting that will achieve the surgical effect and never exceed the power settings recommended by the manufacturers. And also, use a low voltage waveform. Larger diameter scissors will require a higher power setting and will have a bigger footprint on the tissue.
4. Improve dexterity and hand-eye coordination through sequential phases of training, include didactic phase, laboratory experience, observation and/or assistance, and preceptorship. To minimize the chances of direct trauma, activate the electrode only when whole tissue is in the field of vision.
5. Avoid hybrid trocar sleeves. The use of completely metal trocar cannulas can reduce the risk of capacitive coupling. Select an all-metal trocar system as the safest option. It can be avoided by using multiple, short activation times that allows normal tissue to remain cool.
6. Use electrosurgical accessory safety equipment when possible. Do not activate in an open circuit and in close

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proximity to or direct contact with another instrument. Use bipolar eletrosurgery where possible.
7. Frequent cleaning of the electrode tip is recommended.
8. Organize a laparoscopic team that includes a biomedical engineer, perioperative nurses, and other operation room personnel.

OTHER ENERGY SOURCES

Laser

Many media are used to produce laser light in gynecology including CO_2, argon gases, Nd:YAG and KTP crystals for purpose of hemostasis and cutting.

Precautions

- Operation rooms should be labeled.
- All the staff in the OT should wear protective goggles.
- Laser plume can cause respiratory damage.
- Increased equipment costs.

Advantages

- Tissue near an incision is protected, since there is little contact with surrounding skin or other tissue.
- The heat produced by lasers sterilizes the surgical site, thus reducing the risk of infection.
- Less operating time may be needed because the precision of the laser allows for a smaller incision.
- Healing time is often shortened, there is less bleeding, swelling, or scarring.

Disadvantage

- Strict safety precautions must be observed in the operating room.

Ultrasound Dissector/Ultrasonic Scalpel/ Harmonic Scalpel (Fig. 3.5)

Principle

- The instrument operates by means of a blade that vibrate longitudinally at a frequency of 55.5 kHz. The end of the device oscillates at about 50,000 cycles/sec, which results in precise cutting.
- The scalpel coagulates and cuts by using lower temperatures than electrosurgery or lasers.
- Ultrasonic scalpel technology controls bleeding by coaptive coagulation at low temperatures (50 to 100°C). Vessels are tamponaded and sealed by a protein coagulum.
- Coagulation occurs by means of a protein denaturation when the blade couples with protein, denaturing it to form a coagulum that seals small coapted vessels, when the effect is prolonged, secondary heat is produced that seals larger vessels.



Fig. 3.5: Harmonic scalpel machine and forcep

Advantages

- Minimal lateral thermal tissue damage.
- Minimal charring and desiccation.
- Fewer instrument exchanges simplify procedure steps as it coagulates and cut.
- No electricity to or through the patient.
- Greater precision near vital structures.
- Minimal smoke for improved visibility in the surgical field.
- Lesser wear and tear.

Disadvantages

- Slower than other energy sources.
- Ultrasonic tip has a limited life span.
- Disposable attachments increase the cost per patient.
- Can not be used as vessel sealing device for vessels with diameter more than 3 mm.

Argon Beam Coagulator

- Argon beam coagulator used in both open procedures and minimally invasive surgery.
- More effective and cost efficient than conventional electrosurgery.
- Delivers current to the tissue in a directed beam of ionized argon gas.
- Flow of gas blows away blood and debris from the surgical field and produces a coagulated surface that is more uniform and shallower than that produced in standard electrosurgical coagulation.
- Coagulates bleeding tissue faster with reduced blood loss and tissue damage.
- Produce less smoke than conventional electrosurgery.

Gyrus PK Tissue Management System

The Gyrus PK Tissue Management System instruments provide a unique technology called Vapor pulse coagulation (VPC) and plasma kinetic cutting forceps.

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Vapor Pulse Coagulation (VPC)

- Produce faster, more uniform results with pulsed energy instantly delivered in a controlled manner.
- VPC's pulse-off periods allow tissue to cool and moisture to return to the targeted area, greatly reducing hot spots and coagulum formation.
- Results in evenly coagulated target tissue; minimal thermal spread, less sticking, and enhanced hemostasis.
- It does require its own generator, which works in tandem with the instruments manufactured by Gyrus PK.
- This bipolar device is capable of reliably sealing/dividing arteries as large as 6 mm, but it is recommended restricting its use to vessels no larger than 5 mm in diameter to allow a safety margin.
- Thermal spread affects only the area surrounding the divided vessel.

Plasma Kinetic Cutting Forceps

- The second device, the Plasma Kinetic Cutting Forceps, utilizes advanced, solid-state generator software to deliver pulsed energy with continuous feedback control.
- The cycle stops once the device senses that tissue response is complete.
- The cool-down phase ensures that collagen and elastin matrix reforms without tissue fragmentation.

MESSAGE BOX

- Electrosurgery is the surgical use of high-frequency electric current that produced by electron movement.
- In electrosurgery, there are some common terms include current, voltage and resistance.
- Electrosurgical generators can apply energy in either a monopolar or bipolar fashion.
- When an electric current flows through biological tissue, we can observe thermal effect, electrolytic effect and faradic effect.
- There are two basic methods of thermal tissue dectruction, which is used in electrosurgery, cutting and coagulation.
- There are many others energy source which is used in surgery, include laser, ultrasound dissector, argon beam coagulator, Gyrus PK tissue management system, and the ligasure system.

The Ligasure System (Valleylab, Boulder, Colorado)

- Uses a unique combination of pressure and energy to create vessel fusion.
- Melting the collagen and elastin in the vessel walls, and reforming it into a permanent, plastic-like seal accomplish is this fusion.
- A feedback-controlled response system automatically discontinues energy delivery when the seal cycle is complete, eliminating guesswork and minimizing thermal spread to approximately 2 mm for most ligasure instruments.

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Practical Endoscopy
Tips by Experts

This book is a clear and concise reference for beginners as well as the busy surgeons in need of precise practical tips during endoscopic surgery. Its purpose is to provide a fast and efficient way to identify important practical information. To limit its size, less emphasis has been placed on pathophysiology and epidemiology with more emphasis on practical clinical information. Colorful and self-explanatory illustrations have been used extensively throughout the manual to simplify difficult topics and to enhance recollection of principal points. We are hopeful that the book's concise style will help the reader, particularly during an active clinical service, when time to read is extremely limited. Progress in the field of endoscopy has been extensive and rapid in the recent years, and this fascinating text reviews the pros and cons of its use in a range of medical conditions that affect reproductive health. International and national contributors of this book have expertise in their respective fields with a plethora of experience and have shared their knowledge through this book.



Sunita R Tandulwadkar MD FICS FICOG is the Head, Department of Obstetrics and Gynecology at Ruby Hall Clinic, Pune, India. She is the Chief of the IVF and Endoscopy Center at Ruby Hall Clinic, Pune, India. She represents Asia as the Board Member of the International Society of Gynecologic Endoscopy, Indian Association of Gynecological Endoscopy, and Indian Society of Assisted Reproduction (ISAR).

She is the one who started the trend of laparoscopic hysterectomy and all advanced laparoscopic surgeries in the city of Pune way back in 1995. She has conducted endoscopic workshops at many places in India and has trained many gynecologists and surgeons from India and abroad for endoscopic surgeries at her center.

She has received awards for her innovative work in hysteroscopic surgeries, e.g. metroplasty for unicornuate uterus to improve the reproductive outcomes. Her skill in endoscopic surgery is the biggest asset to the center as well as her patients. She has many videos in the library of the American Association of Gynecological Laparoscopy and American Society of Reproductive Medicine.

She has been awarded the Sarvashree award and Gold Medal for her pioneering work in the field of endoscopy and ART in 2004. She has also been awarded the 'Masters award' for her dedication towards teaching endoscopy by IMAGES. She is also the recipient of the Punyashlok Ahilyabai Holkar award by the Ministry of Women and Child Development, Government of India, for her dedication and passion towards improving women's health in India.



Nirzari Mangeshikar MBBS DNB (OBGY) is a third year postgraduate student in obstetrics and gynecology (National Board of Examinations), under Dr Tandulwadkar at Ruby Hall Clinic, Pune, India. She has tremendous interest in Endoscopy and ART and has helped Dr Tandulwadkar in writing chapters and compiling the second edition of this book.



Ruby Hall IVF and Endoscopy Center is recognized for postdoctoral fellowship in reproductive medicine by the National Board of Examinations. It is the only center in India recognized for the 'International Fellowship of Institute of Reproductive Medicine and Endoscopic Surgery' (IRMES). It has achieved its name and reputation in a very short span of time because of Dr Tandulwadkar's hard work, dedication and honesty.

The greatest asset of Ruby Hall Clinic's IVF and Endoscopy Center is the team members. It is the hard work, sincere efforts and the high spirit of each team member that has helped us achieve great success in a limited time

Every team member works with tremendous passion, devotion, love and team spirit.

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ISBN 978-93-5152-587-5