Today we are going to talk about principles of electrosurgery. Electrosurgery came into wide use because of the need to control bleeding during operative procedures.
Surgeons have used electrical energy for most of the last century. It is one of the most useful and adaptable surgical tools. However, the dangers of electrosurgery are well recognised in conventional open surgery but appear more marked when the energy is used laparascopically.

It is essential that gynaecologists are formally trained in the use of electrical energy and that they understand the principles behind its safe use. Whenever current passes through tissues, a heating effect occurs. The amount of heat produced depends upon the resistance of the tissue and the density of the current flow.

The more current, the higher the tissue heating effect and tissues that respond in a predictable manner to heat.

A generator is used to produce electrical current that is delivered to the patient’s tissues through electrosurgery equipment. At the site of application it produces heat to achieve this desired effect. This desired effect could be coagulation to achieve haemostasis or it can be a cutting effect. It is important that the operator optimises the heating effect. It can be potentially dangerous for the patient as well as for the operator. So, the operator must minimise risk.
Let’s revise some basic concepts of physics as it will help us to understand the concept better. Electrons, as you will all remember, are negatively charged particles. And the circuit is the path on which these electrons flow. Now one of the most important definitions which you should remember in electrosurgery would be current and voltage.

Current is the rate of flow of electrons and it is measured in amps. And the voltage is the force of flow of electrons and it is measured in volts. Have you ever wondered why electrosurgery generators do not shock patients? Because of the higher frequencies that heat generators operate. Radio frequency current alternates so rapidly that cells do not react to this current. Electrosurgery generators operate in the 200 kHz to 3.3 MHz range. Both of these are well above the range where neuromuscular stimulation or electrocution could occur.
In electrosurgery, current and voltage is provided by a generator. This current flows through the electrocautery device which in turns comes in contact with the patient and the current flows through the patient tissues and it returns back to the generator. Now here, the tissue provides resistance and the heat is produced at the site of application. And thus it produces a circuit through the patient.
The amount of heat and effect on tissue depends on current, voltage, duration of application, modulation of flow and tissue contact. And we are going to talk about that in detail.
Whenever current passes through tissues, a heating effect occurs. The amount of heat produced depends upon the resistance of the tissues and the density of the current flow. That is, the more current, the higher the tissue-heating effect. Tissues respond in a predictable manner to heat. Tissue death tends to occur at about 45°C as the proteins are denatured. The coagulation of the protein tends to occur at about 70°C. And this is visualised as a blanching of tissues. And this is adequate for coagulation.

A further increase in temperature is likely to be detrimental. And as the temperature approaches 100°C, the intracellular water starts boiling and you might have noticed sometimes you see small bubbles at the site of application of electrosurgery equipment and steam escapes as the individual cells vaporise. When the tissue temperature rises further, residual tissue becomes carbonised and develops the characteristic charred colour.
Electrosurgical generators can produce current in different modes, each with distinct tissue effects. In the Cut mode, the continuous wave form of current is produced. And since the delivery of current is continuous, much lower voltages are required to achieve the desired effect of tissue vaporisation. In order to achieve a cutting effect, the tip of the active electrode should be held just over the target tissue. You do not have to use the active electrode as a knife to cut the tissues. The current vaporises cells in such a way that a clean tissue cut is achieved.

On the other hand, in the Coagulation mode, the current is produced as spikes of voltage and the tissue is heated when the wave form spikes and it cools down in between spikes, thus producing coagulation of the cell.

As you can see from these diagrams, the current at the top is a continuous low voltage cut flow and at the bottom, it is a high voltage coagulation modulated wave form in which there are spikes and then in between there are periods when the current is not flowing.

And the generators can use the Cut and Coagulation mode to create a Blend mode. Blended currents produce voltages higher than that of the pure cut mode. The generator output is modified in such a way that it produces some haemostasis during cutting. There are different variations of Blend mode. As you can see, Blend 1 – current is on for 50% of the time and off for 50% of the time. And you can have different settings. However a higher Blend number generally means more coagulation.
This diagram shows the effect of electricity depending on surgical instrument electrode size. With the smaller electrode tip, there’s a high current concentration and with the broader electrode tip, there is low current concentration. If a high density current, which is also high current concentration in other terms, is applied a very short distance above tissues, it will jump the intervening space in the form of a spark and clinically results in a cutting effect. If exactly the same current is applied directly to the tissues with the electrode very firmly in contact with the underlying tissue, a spark will not occur and instead the heat will be rapidly dissipated over a wider area, producing a lower but more diffuse and gentler heating effect.
This diagram shows that the size of the elective electrode influences the tissue effect of the generator. A large electrode, as you can see on the left-hand side of the diagram, needs a higher powered setting than a smaller one because the current is dispersed over a wider surface area. And on the right-hand side, you can see that a small electrode size needs lower power setting requirements as the current concentration and the heat at the tip of the small electrode is high.
This diagram shows how an electrical circuit is produced. The generator produces the current which flows through the diathermy equipment to the patient and then it returns back to the generator, thus completing the electrical circuit.
In Monopolar circuits, a small active electrode produces heat at the operative site and then the electricity passes through the patient and is returned back to the generator. In early days of electrosurgery, earth reference circuits were used. This diagram shows a classic system. As you can see, the current is produced by the electrical generator, goes through the Diathermy equipment to the active electrode to the patient and then it returns back to the generator through the earth ground. And it is this earth ground that completes the electrosurgical circuit.

The major hazard with this type of system was that a current division can occur. If the electrical current finds a pathway of lower resistance, it would go through that and the patient could be burned at any point where the current exits the patient’s body. This could happen if the patient’s hand was touching the side of the theatre table or the knee was touching the stirrup or even the surgeon can be injured if the surgeon is in direct contact with the metal table or was touching the patient. These systems were replaced by more modern technology in 1995 and are no longer used.
In the more modern isolated system, current division cannot occur and there is no possibility of alternate site burns. An isolated generator will not work unless the patient return electrode is attached to the patient. As you can see in this diagram, the current produced by the generator flows through the electrosurgical equipment, through the patient and is returning through the diathermy valve back to the generator. And you can compare this diagram with the previous slide, which showed Earth ground completing the circuit to understand the concept better.
In order to improve the safety of the patient return electrode, a split return system was introduced where an interrogation current constantly monitors the quality of the contact between the patient and the patient return electrode. If a condition develops at the patient return electrode site that could result in a patient burn, the system inactivates the generator while giving audible and visual alarm systems. And you would have seen that in your theatre, that if the diathermy valve, that is the patient return electrode, is not applied properly, the generator would not work.
Monopolar circuits are increasingly used during minimally invasive procedures. In hysteroscopic surgery, a non-ionic irrigation fluid, like glycine, is used. However it has a risk of fluid overload because of absorption. In laparoscopic surgery, there is a risk of bowel injury from return of electricity to the generator. In laparoscopic surgery, the risk of injury could be because of insulation failure or because of another instrument touching the active electrode and which could be away from the field of vision.
Bipolar circuits are completed when using two parallel poles located close together. As you can see in the diagram, one pole is positive and the other is negative. The flow of current is restricted between these two poles. Because the poles are in close proximity to each other, low voltages are used to achieve tissue effects. Because the current is confined to the tissue between the poles of the instrument and does not flow through the patient, the patient return electrode is not needed.
Good bipolar diathermy technique requires patience. The electrodes are usually fairly large and so the time required to heat tissue to the desired levels is significant. Attempts to speed up the process by turning up the power are likely to be counterproductive. High energy levels will increase the local heat and char rather than desiccate the cells. Charred cells have a higher impedance, preventing further penetration of the heating effect. A satisfactory tissue desiccation should be associated with blanching and bubbling of tissue with slow release of steam. There should be no tissue charring. A good desiccation should look white and an unsatisfactory one is black. This diagram shows that the resistance to flow increases with tissue desiccation and it is detected by the generator, stopping the current.
In second-generation methods of haemostasis, special instruments have been developed which bring the vessel walls together with a hand piece. The heat is produced by electrical resistance causing denaturation of vessel wall proteins. And the proteins, they become sticky and they create a seal. The generator responds to increasing electrical resistance by modifying the power output to optimise haemostasis through tissue desiccation without charring.
Some examples of second-generation bipolar circuits which are used for haemostasis are Ligasure or Tripolar. You might have come across some nonelectrical methods of achieving haemostasis. One of the examples is a modern instrument commonly called the Harmonic Scalpel. It uses sonic vibration to denature vessel wall protein with little heating effect.
For the safety of the patient as well as staff present in theatre, it is important to use lowest power and lowest voltage settings on the generator to achieve tissue effect. It is preferable to use bipolar not monopolar and to be aware of the electrical circuit.
It is very important to place the active electrode in a sheath when not in use as if it is inadvertently activated it can cause injury to the patient or to the surgeon. You should avoid monopolar equipment in patients with a cardiac pacemaker. Always use a split plate as your patient return electrode. This patient return electrode or diathermic valve should always be applied away from an artificial joint, away from scar or a bony prominence.
When you are using electrosurgical equipment during laparoscopy, you should always keep the tip of the active electrode in your field of view.
In this diagram, you can see that if you are using a metal retractor and it comes in contact with the active electrode, the current will flow from active electrode to the metal retractor. And if that metal retractor is touching bowel away from the laparoscopic view, it can result in a bowel injury.
One of the hazards associated with endoscopic electrosurgery is capacitance coupling. When two conductors are separated by an insulator, a capacitor is created. Thus, an insulated active electrode within a metal cannula forms a capacitor which can produce a capacitively coupled electrical current that is transferred from the active electrode through the intact insulation into the metal cannula. Should the cannula come into contact with tissue, current is discharged which can damage that tissue.

This phenomenon of capacitive coupling is well-known to electricians and engineers but seems a distant concept to most surgeons. Problems arise if the coupled energy cannot escape and is stored in the cannula to take an alternative pathway of least resistance. Severe bowel burns have been produced in this manner. This unfortunate situation will occur when the metal cannula is insulated from the abdominal wall by a plastic thread mechanism. Such mix - plastic and metal cannula – must be strictly avoided if used for electrosurgical work. And only all metal or all plastic cannula should be used.
The other hazards associated with endoscopic electrosurgery use are production of surgical smoke, which creates poor view and because of the toxic gases, it can be a risk to theatre staff. And it should be sucked during the procedure. Another hazard is insulation failure. Insulation failure occurs when the coating that is applied to insulate the active electrode is compromised. It is important to always visually inspect the protective insulation sheath on your equipment and also to try to feel for any cracks in the insulation by running your fingers over your equipment.
We will show you some videos now to illustrate how electrosurgery is used in endoscopic surgery.