White Paper - Plasma Technology and its Clinical Application

An introduction to Plasma Surgery and the PlasmaJet® – a new surgical technology

PlasmaJet®

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Introduction

The PlasmaJet® system from Plasma Surgical employs an entirely new energy source for use in surgery and introduces the new technique of Plasma surgery. Since the clinical use of a true plasma is novel, this paper provides a summary of how this technology works and describes its effects on tissue. The clinical benefits of Plasma surgery are also discussed.

As a new technology in surgery, there is a possibility that this novel approach is confused with one or more existing technologies that are more familiar. Thus for example, the technology employed by the PlasmaJet® is often confused with that used in the argon beam coagulator or in a surgical laser. In practice, both the PlasmaJet® device and its clinical effects are very different from either of these existing surgical tools.

This paper considers the answers to three simple questions:

1) What is a plasma?

2) What are the effects of the PlasmaJet® on tissue?

3) What are the clinical benefits and applications of the neutral plasma technology?

1) What is a plasma?

A plasma is often referred to as the fourth state of matter (after solid, liquid and gas). A more simple definition is that of “a system containing charged particles”. A better illustration (shown figure 1) is provided by considering the phase transitions of matter when heat is added, for example by electrical energy or a flame.

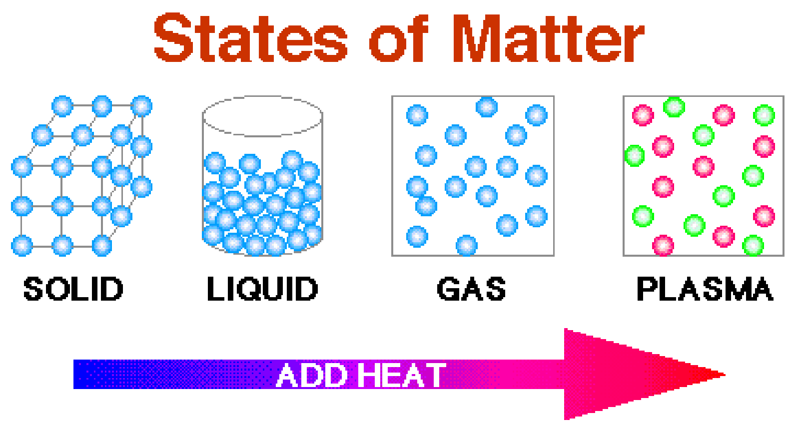

Figure 1: Different states of matter when heat is added

At low temperatures (different for all materials) all matter exists in solid form. When heat is added, solid material melts into liquid and if more heat is added liquid material evaporates into a gas. A good example of this phenomenon is provided by considering the different states of water. If you apply heat to ice, it will turn into fluid water and if you add more heat it will boil into the gaseous state as steam. But what happens to a gas if you add more heat? Is there a fourth state of matter?

The answer to this question is yes, the fourth state of matter is plasma. If enough heat is added into a gas, atoms and molecules are ionized and form plasma. For a gas like argon, a very low flow of which is used in the PlasmaJet® handpiece, when electrical energy is applied the argon gas dissociates completely – meaning that electrons and argon ions separate (see figure 2) to form a pure argon plasma. In this state, the energy contained in the plasma volume, or the energy density is very much higher compared to the other three states.

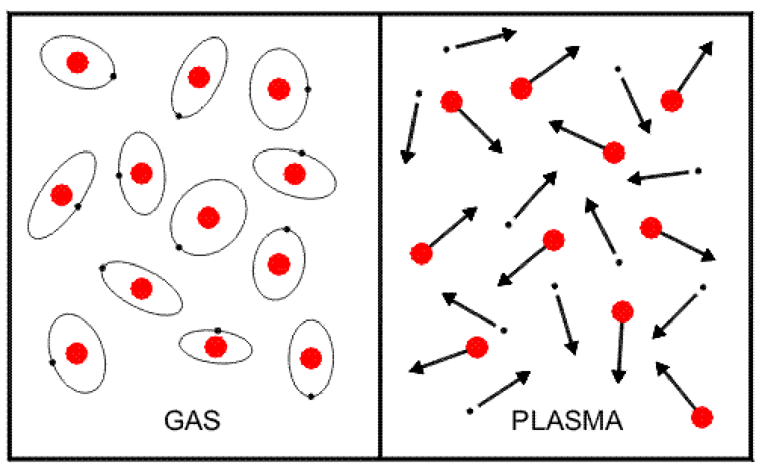

Figure 2: When energy is applied, the gas atoms on the left are transformed into the plasma – a mixture of positive ions (red dots) and negative electrons (black dots) on the right.

In the PlasmaJet® system, a low flow of argon gas is concentrated into a small space within the handpiece and excited by a low DC voltage applied between internal bipolar electrodes. The resulting argon plasma is a mixture of high energy argon ions and electrons that emerge from the tip of the handpiece in a precise jet stream (See Figure 3). An important property of the plasma stream is that since it contains an equal number of positively charges ions and electrons, the resulting plasma jet is electrically neutral. In this respect the PlasmaJet® differs markedly from all electrosurgical techniques, since in plasma surgery there is no external electrical current flow to the tissue.

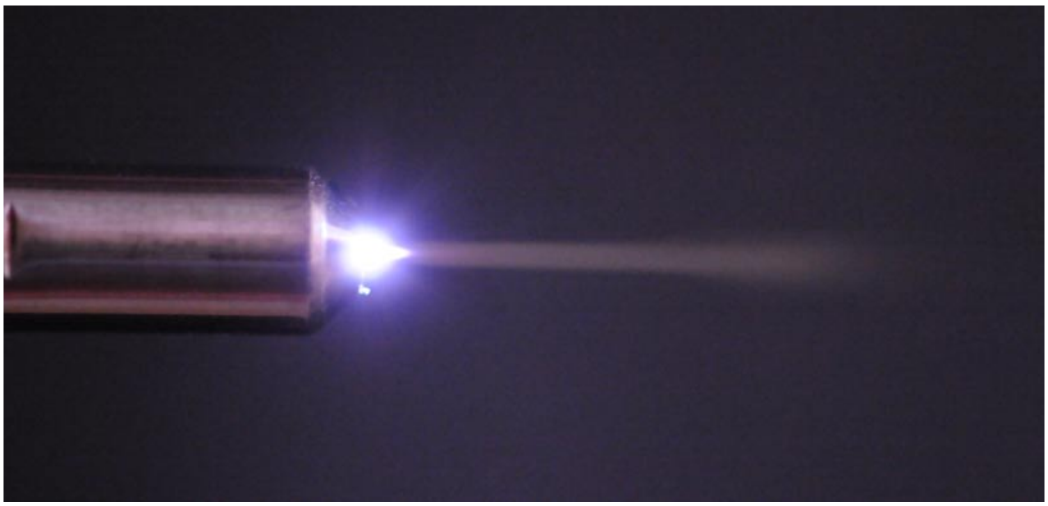

Fig 3 Plasma stream emerging from the tip of the PlasmaJet® handpiece

The argon plasma emitted from the PlasmaJet® handpiece is short-lived, and gives up its energy readily in three forms:

- As light – in the visible and near ultraviolet parts of the spectrum, which usefully illuminates the surgical field, but is not sufficiently intense to cause damage or require any eye-protection,
- As thermal energy – sufficient to heat the tissue to a very limited depth and cause coagulation of the surface; and
- In the form of kinetic energy – that clears any liquid from the surface of the tissue and which we can also harness to cut tissue.

In the most powerful PlasmaJet® cutting handpieces the plasma stream is accelerated to supersonic speed, which allows the plasma to cut through hard tissue such as bone.

2) What are the effects of the PlasmaJet® on tissue?

When held at a distance of about 1cm or more away from tissue, the effect observed is tissue shrinkage and coagulation. The first observable effect when the PlasmaJet® handpiece is activated and moved towards a bleeding tissue surface is that any fluid on the surface of the tissue – be it blood or lymph – is quickly blown away from the point of application to reveal the dry tissue surface. In this way the PlasmaJet® is able to work on an oozing surface and in a laparoscopic setting regardless of the amount of bleeding. Indeed the PlasmaJet® is effective even if the tip of the handpiece is completely immersed in fluid.

When moved much closer to tissue at higher power settings, the plasma vaporises the surface of the tissue, and when placed in contact with the tissue surface will divide the tissue. The PlasmaJet® system is able to cut all tissues, including bone, with simultaneous coagulation of the cut surfaces.

Coagulation is achieved by the rapid formation of a thin and flexible layer that seals the tissue surface. Depending on the duration of application to tissue the thickness of this layer is typically about 0.5mm and never more than 2.0mm for all tissues. The maximum depth of the tissue effect is reached within about 5 seconds of application, and this depth does not materially increase if plasma is applied to tissue for a longer period.

The PlasmaJet® system is not designed for the sealing of large vessels. For most effective coagulation, tip of the handpiece is held about 1cm or more away from tissue and at a Power setting of 40 - 50High. Moving closer to the bleeding tissue or using high power settings will vaporise the sealing layer; so the ideal technique is to back away and use medium power to achieve an optimal coagulation effect.

A closer examination of the histology of tissue after exposure to the PlasmaJet® reveals three zones that comprise the thin flexible layer. On the tissue surface there is usually a very thin (5 -15 µm) carbonized layer, beneath which is an intermediate spongy necrotic layer of up to 0.3 mm in depth, and a deeper more compact necrotic layer of up to approximately 1.6mm in depth.

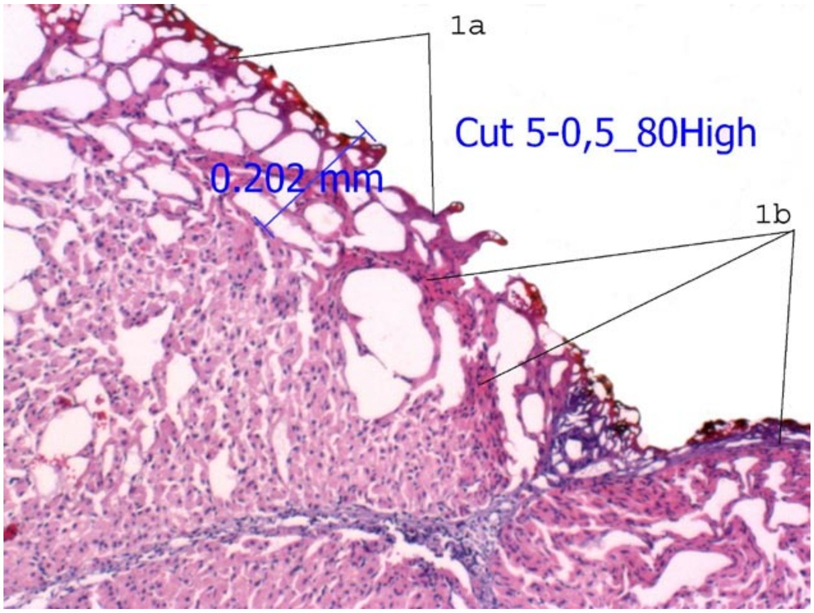

Figure 4: PlasmaJet Coag-Cut handpiece – setting Cut- 80High.
High resolution section after cutting liver tissue with PlasmaJet handpiece shows the spongy layer with a very well defined border to the underlying tissue. Because of the limited penetration of heat, evaporation of the liquid component of the tissue is strictly limited to the spongy layer. Erythrocytes, located in the spongy layer, are deformed by high temperature, but deeper in the border between spongy layer and intact tissue, erythrocytes show normal form which suggests a significant drop in temperature between the spongy layer and intact tissue. The region pointed out by 1a and 1b shows a thin but homogeneous, continuous and very dense structure – the sealing layer.

3) What are the clinical benefits and applications of the neutral plasma technology?

There are no undesirable effects of the PlasmaJet® on tissue. This simple and safe method should be contrasted with other surgical techniques for cutting and coagulation.

In electrosurgery and argon beam coagulation, an electric current flows from the active electrode through the patient to the ground pad. This causes two additional effects – the formation of small holes in the surface of the eschar caused by sparks and which allow continued bleeding, and in these techniques and in fluid-coupled electrosurgery the penetration of the zone of destruction travels deeper into the tissue to depths of up to 14mm along paths of lesser resistance such as blood vessels. With the PlasmaJet® system, the plasma is electrically neutral, no current flows through the patient, no ground pad is used, and a complete coagulation of the tissue surface is achieved with a controlled and always thin layer of tissue damage. With the PlasmaJet® system, the effect on tissue can be described as ‘what you see is what you get’.

The PlasmaJet® system cuts tissue a clean and precise cut, similar to that seen using a CO_2 laser, but without any risk of overshoot. In the true plasma surgery offered by the system the plasma can even be used to cut through hard tissue such as bone. The PlasmaJet® system always coagulates, and it is even possible to coagulate the cut surface of bone. In all tissue surfaces, there is a complete but thin coagulation layer with minimal spread beyond the tissue surface.

The real benefit of the PlasmaJet® system is inherent in the plasma technology – simply the ability to dry a tissue surface, precisely cut through tissue where required and effectively create a very thin flexible layer over the surface that prevents further bleeding or fluid effusion. That this is provided using an electrically neutral energy source is a further benefit, since the PlasmaJet® does not result in any current flow through the patient, and there are no risks of deeper tissue damage or alternate site burns – which are an unwelcome risk associated with electrosurgery in all of its forms.

The very low gas flow used in the PlasmaJet® system – typically about 0.2 – 0.4 l/min is about a tenth of that used in the argon beam coagulator. As a result the system is safe to use in laparoscopic surgery; there is no risk of over-inflation of the pneumoperitoneum, nor a risk of a gas embolism. Studies using the PlasmaJet® on several different tissues confirm its clinical value in the effective coagulation of vascular tissues such as liver, kidney and spleen, and sensitive tissues such as the lung; where it is capable of providing aerostasis as well as haemostasis. A comparison using alternate conventional coagulation technologies such as argon enhanced coagulation and fluid coupled electrosurgery demonstrates the depth of tissue destruction is far less in the case of the PlasmaJet®, and the damage present after 10 and 21 days is considerably less than that found with these existing electrosurgical approaches. Full details of this study are presented in a separate white paper available from Plasma Surgical.[1]

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[1] 'White Paper - A Tissue Study comparing the PlasmaJet® with Argon Enhanced Electrosurgery and Fluid Coupled Electrosurgery' – Plasma Surgical Limited 2006.

CAUTION: Federal law (USA) restricts this device to sale by or on the order of a physician. For listing of indications for use, precautions and warnings please refer to the instructions for use provided in the Operator Manual for the PlasmaJet® system.

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