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TECHNIQUES AND INSTRUMENTATION

First clinical experience of argon neutral plasma energy in gynaecological surgery in the UK

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Abstract We describe the first in vivo use of neutral argon plasma energy in gynaecological surgery in the UK and the largest series worldwide. The use of PlasmaJet® (PJ) in different applications in 118 selected cases in a tertiary referral centre for gynaecological oncology and minimal access surgery was assessed. The effectiveness, ease of use, ergonomics and safety of PJ in gynaecological surgery is evaluated prospectively. Following this experience, we have devised a table of recommended power settings for different applications.

Keywords Neutral argon plasma energy · Electrosurgery · Laparoscopic surgery · Endometriosis · Ovarian cancer · Peritoneal metastases

Introduction

PlasmaJet® (PJ) is a new device designed to produce a fine jet of argon plasma by heating argon gas. The technology utilises neutral plasma energy to desiccate and vaporise soft and hard tissues. The physics employed are entirely different to those used in both the argon laser which produces a high energy light source of fixed wavelength (514 nm) and the argon beam coagulator (ABC) which produces a monopolar current of high energy electrons carried on a stream of argon gas [1, 2].

Energy from argon plasma is rapidly dissipated as light, kinetic energy and thermal energy. The light produced is in the visible and near ultra-violet parts of the spectrum which illuminates the operative field and helps to indicate the position of the jet. The kinetic energy released is sufficient to blow away any fluid or debris from the tissue surface enabling wet or bleeding surfaces to be treated effectively. Indeed, the PJ may be used under water or other fluids. However, the gas flow used is approximately 10% of that used by an ABC. The thermal energy produced by the argon plasma also has unusual properties, in that there is a rapid loss of energy from the particles within the plasma, the resulting tissue effects are superficial and lateral thermal effects are minimised. Effectiveness, ease of use, ergonomics and safety of PJ in gynaecological surgery is evaluated in this prospective study.

Materials and methods

A prospective audit was undertaken between June 2008 and May 2009 in a tertiary gynaecological centre under the auspices of one lead surgeon. Women with a wide spectrum of benign and malignant gynaecological conditions were included. PJ version 2 (V2) system (Table 1) was used in 71 cases and superseded by version 3 (V3) in 47 cases. One hundred eighteen hand-pieces were evaluated. Prior to surgery, all patients were offered information discussing the possibility of using the device during their procedure. Efficacy and safety data was prospectively collected including procedure performed, power settings and resulting tissue effects. Effectiveness of PJ was measured in

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Table 1 Type of operations

Operation type	No. of patients Version 2	No. of patients Version 3	Power settings of PlasmaJet™ (%)	PJ tip to tissue distance
Open surgery				
Ovarian cancer laparotomy debulking	5	8	10–40	5mm
Peritoneal cancer laparotomy debulking	2	1	10–40	0-2mm
Groin node dissection	1	2	10–40	5-8mm
Wide local excision of vulva	0	1	10–20	0-2mm
Laparoscopy				
Endometriosis	32	16	10–20	5mm
Ovarian cyst including polycystic ovaries	11	11	10–45	5mm
Adhesions including omental	15	5	10–65	0-5mm
Myomectomy	1	1	10–80	0-2mm
Tubal surgery: salpingectomy or salpingotomy	4	2	20–40	0-2mm

terms of precision, ease of use, coagulation and cutting effects.

The power settings used were developed in conjunction with the manufacturers during the course of the study. A cautious approach was adopted commencing on the lowest setting (10% power) increasing power when necessary to gain desired tissue effects. The range of settings used was then recorded for different applications using V3 (Table 1). The hand-piece was activated at an angle of approximately 45° to the tissues at both laparoscopic and open surgery so that the jet could be clearly visualised. The distance required to achieve tissue cutting is much less with close proximity to the tissues.

Results

All procedures were performed under general anaesthesia, under the supervision of the lead consultant. Ease of use was assessed by both the surgeon and the theatre staff. PJ proved to be easy to set up and is essentially 'plug and play' with a console, service trolley and disposable hand-pieces. The ergonomics of the device and the hand-piece were convenient to use and available in both 12 cm for open and 28 cm for laparoscopic surgery which is able to pass down a 5-mm port. An integrated fluid circulation keeps the entire hand-piece cool at all times even when the PJ is activated. The tip of the hand-piece is smooth and rounded, enabling it to be used as a blunt dissecting probe.

The length of the flame produced is approximately 2-5 mm in length depending on the settings minimizing risk of overshoot to distant organs in contrast to lasers. The light energy produced by PJ illuminates the operative field and helps to indicate the position of the jet. As a result, the device does not require a separate guide beam. The plume generated by the device is similar to other devices in common use such as the harmonic scalpel, and a smoke filter was required for laparoscopic cases (Cory Bros CB3604). Although V3 offers a wider range of settings and is more powerful than V2, it appears to generate less smoke in both cutting and coagulation modes.

Depth of penetration appears very superficial with minimal lateral heat spread enabling dissection very close to neighbouring organs, e.g. ureteric and bowel dissection. PJ was used to treat peritoneal deposits of ovarian cancer metastases on the serosal surface of the small and large bowel as well as tumour deposits on the serosal surface of the liver, diaphragm and peritoneal undersurface of the pericardium with no adverse affects achieving the desired effect in all cases.

Mean blood loss was 850 ml in open and 64 ml in laparoscopic procedures, reflecting the wide variety of cases operated on. Its ability to coagulate vessels enabled fast accurate tissue dissection with good haemostasis. Larger vessels (>3 mm) were dealt with bipolar electrosurgery or the harmonic scalpel. V3 offered optional hand activation. A percentage power output for each is visible for each with corresponding yellow and blue hand-activated buttons on the hand-piece. The yellow power settings utilises a higher argon gas flow which creates greater cutting and vaporisation, while the lower flow on the blue settings provides greater tissue desiccation and hence coagulation.

Findings

Conventional electrosurgery uses high frequency current to coagulate tissues and achieve haemostasis. This is achieved through a combined effect of local heating and arcing generated between the active electrode and the grounded tissue. The results have been documented previously and are recognised to cause deep tissue effects with significant lateral heat spread. The same principle is employed in the

ABC, which also produces monopolar current carried on argon gas.

Neutral plasma energy removes the risk of arcing, alternate site burns and lateral heat effects, which are potential risks of electrosurgery systems. A thin flexible layer is formed in the surface tissues with a small amount of visible surface carbonization. The underlying tissue necrosis is composed of two layers: a spongy layer and a deeper compact layer. These effects are very superficial and limit depth of penetration at the point of contact to within 0.5–2.0 mm under normal operating conditions [3]. The depth of penetration varies depending on the proximity of the PJ to the tissue surface, the time of exposure and the power setting used but does not exceed 2.0 mm when used for surface ablation. It is possible to vaporise more deeply into tissues to achieve complete removal of all deep infiltrating endometriosis using the latest version 3 PJ on its cutting setting.

CO2 laser has proven to be a very sensitive instrument which may be used to ablate lesions on delicate tissues with proven beneficial effects on endometriosis. However, the articulated arm of the CO2 laser is cumbersome to use, is quite fragile and prone to beam misalignment unless regularly serviced or repaired. A qualified laser operator is required to be present for all laser cases [5]. The PJ appears to have similar tissue effects to the CO2 laser but is easier to use, less cumbersome and avoids the risk of overshoot damage to the other tissues. This allows a wider range of operations at laparoscopy. The principle for the device is based on neutral plasma coagulation with no electric current flow to the tissue. Nehzat et al. reported their experience of using the PJ but with much higher settings compared to our study with similar results [4, 6]. Our experience in this study also shows the wider range of applications as compared to other groups.

Conclusion

Globally, to date, this is the largest study of the use of the PJ as a multifunctional device for ablation, cutting and coagulation reducing instrument exchanges during surgery, hence reducing operating time and risk of inadvertent visceral injury. Hand activation has been developed in V3 if preferred as an alternative to the footswitch. The overall performance of the PJ was very favourable as compared to the current devices being used in our centre (Harmonic Scalpel™ and CO_2 laser).

This initial experience with PJ has shown that it appears to be an efficient device for tissue dissection and ablation while controlling intra-operative haemostasis with minimal tissue damage in both laparoscopic and open surgery. Large multicentre randomised studies are required to completely assess the full potential of this innovative technology in both benign and malignant gynaecological surgery.

Conflicts of interest PlasmaJet® device and hand-pieces were provided free of cost for the first 50 cases of the study period.

Harmonic Scalpel™ is a trademark of Ethicon Endo-Surgery Inc. PlasmaJet® is a trademark of Plasma Surgical, Ltd.

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