CHAPTER **31**

USE OF ARGON GAS PLASMA IN FOOT AND ANKLE SURGERY

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INTRODUCTION

Plasma is one of the four fundamental states of matter after solid, liquid , and gas. In fact it is by far the most common phase of ordinary matter in the universe. Our sun, all stars, interstellar medium, and comet tails are examples of naturally occurring plasmas. There are numerous examples of artificial terrestrial plasmas as well, for example neon signs and arc welding. These plasmas are formed by heating a gas, through electric or electromagnetic means, ionizing its atoms into individually charged particles. The plasma itself is however electrically neutral and as either a cold plasma or a thermal plasma is now finding promising applications in medicine (1,2).

Gas plasmas have been used for many years in a variety of applications, from cutting metals, to illuminating signs, to rocket engines used to position satellites in space. This is because plasma gas readily gives up its energy as heat and light. Nikolay Suslov, professor of thermal and molecular physics at the Moscow Institute of Science and Technology, and his colleagues at Plasma Surgical developed a means in the PlasmaJet system (3) to bring this technology to medical and surgical applications. When applied to tissue, a high-energy beam of the plasma can cut and dissect tissue rapidly creating a very thin and flexible coagulation layer, preventing bleeding and lymphatic oozing.

Because the PlasmaJet system employs a very low gas flow, it can achieve its surgical effect with minimal damage to underlying tissue. Although plasma has a high energy, this dissipates rapidly on contact with tissue, allowing for a controlled depth of action with minimal thermal effect to surrounding tissues. Unlike conventional, argon- enhanced, or fluid-enhanced electrosurgical devices that rely on passing electricity through the tissue to cause the desired effect, plasma energy does not have any external electrical current that can cause alternate site burns or interfere with patient monitoring.

Foot and ankle surgery often requires precise and deliberate dissection through vascularized areas and in very tight spaces. While generally controllable through mechanical (tamponade, tourniquet use) or chemical (epinephrine) means, bleeding can often complicate a procedure. The PlasmaJet system is an innovative device that uses a precise jet of argon plasma to provide fast and precise control of bleeding, leaving a wound sealed. The handpiece generates a fine jet of thermal plasma at the tip, and uses an internal sealed water cooling system to maintain the handpiece at a safe low temperature. In addition to the ability to cut, vaporize, and coagulate, the jet provides a kinetic energy that sweeps material from the target tissue and the light emitted from the ionized gas further illuminates the target for increased precision.

INSTEP FASCIOTOMY SURGICAL TECHNIQUE

The patient is placed supine on the operating table with the foot elevated on a towel brick or slightly dangling off of the end. Tourniquet use is optional as generally bleeding is minimal in this region once through the subcutaneous layer. A transverse incision is made approximately 1.5 cm distal to the heel pad directly over the medial and central fascial bands, extending for 4-5 cm (Figure 1). Sharp incision is made through the skin and subcutaneous fascia just until the denser deep fascia is felt, with care taken not to excessively divide or disturb the plantar fat chambers. A Weitlaner retractor is used to maintain the wound open in the distal to proximal direction. Senn retractors are then placed medial and lateral to clear out the remaining subcutaneous fat and the fascia is identified (Figure 2).

The PlasmaJet is brought to an approximately 5 mm distance from the fascia. Using the lowest cut setting, the handpiece is swept slowly back and forth between the medial edge of the fascia to the lateral edge of the central band. Beginning at the lowest setting gives the surgeon a feel for the tissue response to the energy delivered. Increasing the power may be necessary in cases of dense or thick fascial tissue for expediency (Figures 3, 4, 5).

Once the fascia is released, the densely vascular underlying muscle belly will be apparent. Complete fascial release can be completed within a few seconds. Inspection of the wound should reveal no bleeders or oozing as these would be coagulated by the PlasmaJet. I generally would remove a few millimeter section of the fascia so as to

Figure 1. Transverse incision is made distal to the weight-bearing surface, long enough to accommodate retractors and ensure adequate visualization of the fascial bands. The PlasmaJet wand is included in the field of view as a pencil-grip hand piece with triggers for cut and coagulation functions.

Figure 2. The initial incision is made using a #10 blade in a single sweep through the skin and subcutaneous fat layer, allowing for clean retraction of the fat layer. Here the deep/plantar fascia is identified by its dense longitudinal fibers.

Figure 3. PlasmaJet settings are simplified as yellow (cutting) and blue (coagulation) for consistency with existing handheld coagulation modules. Power level and thermal energy are adjustable, and the program directs the user on suggested distance from the target tissue for optimal effect. Depicted is the lowest setting of the range available, which is suggested for initiation of cutting to determine tissue response.

Figure 4. The handpiece is brought just up to the fascia and cutting is initiated with a sweeping motion, beginning at one side of the fascia. Kinetic energy from the wand disperses unwanted fatty tissue from the target, in this case the plantar fascia.

Figure 5. Plasma energy is directed in a very fine column at the target tissue. Shown is the intensity of effect in a small area on the focal tissue (fascia) without collateral tissue damage. The light generated by the device is advantageous for seeing very clearly the target tissue as it being cut.

Figure 6. Fascial release is accomplished rapidly, with a small section ablated to prevent reconnection of the fascial bands under tension. The muscle layer is shown to have sustained no thermal injury.

prevent the two fascial ends from reconnecting under tension in the postoperative period. The plasma sweeping technique allows ablation of this section instead of excision, hastening the procedure (Figure 6).

SOFT TISSUE MASS EXCISION SURGICAL TECHNIQUE

A large subcutaneous mass was appreciated on the lateral aspect of the ankle of this patient adjacent to the peroneal tendons (Figures 7,8). After local anesthetic infiltration consisting of 1% lidocaine with epinephrine and 0.25% Marcaine plain, sterile prep and drape was carried out. No pneumatic tourniquet was used. An incision was made along the course of the peroneal musculature in line with the sural nerve to avoid transection. The diffuse mass became apparent in the deeper subcutaneous layer as an amalgam of vascular channels and fatty infiltrate (Figure 9).

Once an outline of the mass was identified the PlasmaJet was brought in to begin dissection and coagulation. Suction was attached to the tip of the device for smoke evacuation (Figure 10). On the lowest setting the PlasmaJet is swept back and forth at the margins of the mass coagulating as it proceeds to cut the mass from the underlying fascia (Figure 11). Once the mass is removed, an appreciation for the clean underlying layer can be made without excessive bleeding or tissue damage (Figure 12). Because coagulation occurs during the dissection there is no need to go back and ligate bleeders at the end. A simple flush and close is performed with absorbable 4-0 and 5-0 suture.

Figure 7. Clinical appearance of the ankle demonstrating distention over the anterolateral aspect. Palpation reveals a spongy-feeling mass affixed to the deep fascial tissues.

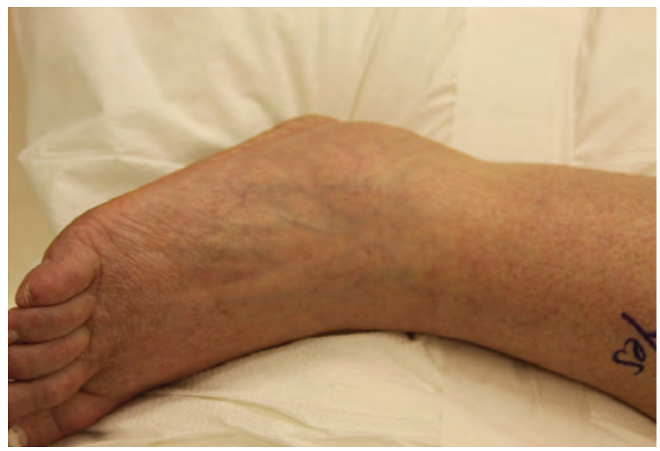

Figure 8. The mass is appreciated in another plane as distention over the anterolateral ankle.

Figure 9. Fat globules separated by loose septae and interspersed vascular channels is noted extending from the margins of the wound. Traditionally these vascular channels would be individually identified and ligated prior to dissection of the lesion.

VERRUCA PLANTARIS SURGICAL TECHNIQUE

Verruca are approached for excision and ablation first using sharp technique, then with discrete and directed cauterization. The case presented demonstrates the common mosaic appearance, with clustering in the crease of the hallux and spreading along the plantar surface (Figure 13). After sedation and local anesthetic is administered, the area is approached with a bone curette. The size and weight of the instrument coupled with the dimensions of the bowl lend readily to excision without penetration of the basement membrane (Figure 14). All verrucous tissue is excised in this manner, leaving behind layers of dermis of varying thickness (Figure 15).

The PlasmaJet is brought in at the lowest coagulation setting and initiated approximately 3 cm from the target dermis. The device is advanced as the tissue is inspected for coagulation of any bleeders and a frost that is characteristic of protein denaturation. Once this is evident the small jet

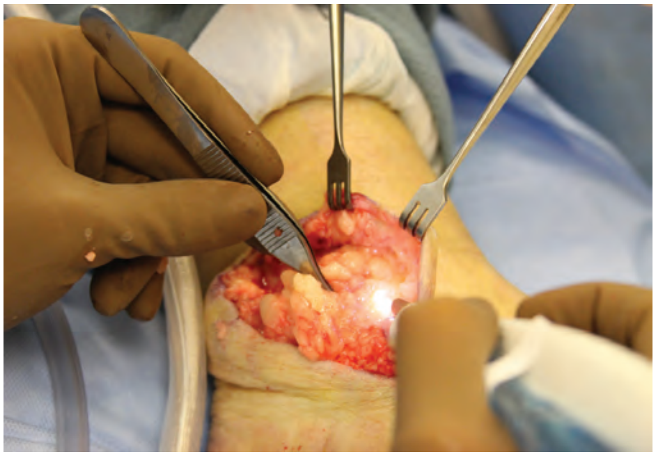

Figure 10. The PlasmaJet is brought into approximation with the tissues and the cutting function is used at the lowest setting intitally. A sweeping motion is used to begin cutting tissue and to prevent excessive thermal effect in one area. Note is made that smoke production is greatest with fatty tissues and decreases as tissue water content increases.

Figure 11. The margins of the mass are easily identified, and as the mass is raised from the underlying adherent tissue the coagulation effect becomes apparent. Cutting is rapid, and settings can be quickly adjusted up or down depending on the local environment and for expediency.

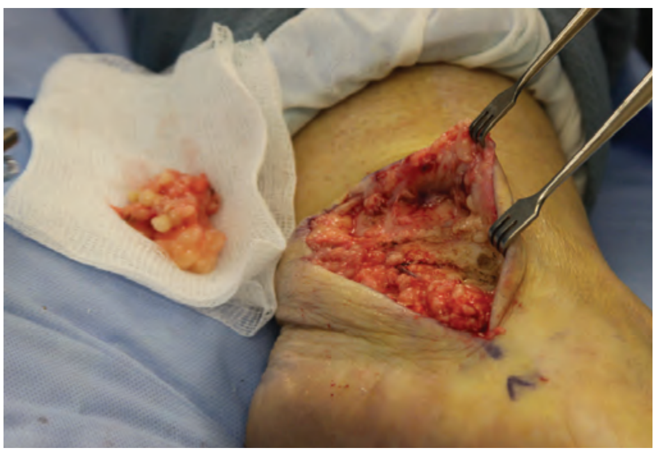

Figure 12. Complete mass excision with preservation of the perineural fat adjacent to the sural nerve. Note the clean appearance of the underlying fascia. A large undamaged vein also is seen running longitudinally at the inferior margin of excision highlighting the precision of thermal effect to only the desired tissue.

Figure 13. Multiple verruca in a mosaic pattern are seen clustering around the plantar surface of the hallux.

Figure 14. A size 0 or 00 bone curette is the ideal instrument for dermal scraping of verrucous tissue. This method avoids penetration of the underlying basement membrane that may result in deep scarring and potential infection.

Figure 15. As the verrucous material is completely excised, one can appreciate the multiple layers of dermis involved. Capillary bleeding is expected with this procedure and is a characteristic of verruca excision.

Figure 16. The PlasmaJet is brought within 3 cm of the dermal target at the lowest setting and the coagulation function is used. Here the beam of plasma energy can be readily appreciated emanating from the tip of the device. Illumination of the target area occurs due to light emitted as a result of argon gas ionization. The frost that develops is immediately visible as the surgeon is not required to wear tinted safety glasses, a requirement while using medical lasers.

of plasma is swept over the affected area with continuous pulsation. Immediate effects are seen in the treated versus non-treated areas. After completion of the treatment bleeding is generally nonexistent, and moist dressings with antimicrobial creams are used (Figure 16).

POSTOPERATIVE MANAGEMENT

Postoperative care is procedure specific and is unchanged from protocols used without PlasmaJet. Full weight bearing is permitted when there is little to no chance of incision or deep repair embarrassment. My experience is that both pain and swelling are lessened with Plasma than without, although this may be patient, procedure, or situationally dependent.

DISCUSSION

The PlasmaJet system provides a welcome new technology for use in surgery that offers distinct advantages over conventional electrosurgery. Monopolar electrosurgical coagulation devices work by Joule heating, whereby the resistance of the tissue converts the electrical energy of the voltage source into thermal energy (heat), causing the tissue temperature to rise. In the monopolar configuration the patient is attached to the return electrode through a flexible metal plate, which is then attached back to the RF generator. The current flows from the monopolar tip, through the patient, and back to the generator. Severe (third degree) burns can occur if contact with the return electrode is insufficient, or when a patient comes into contact with a metal object serving as an unintended leakage path to the ground. As such electrosurgery devices produce currents that pass through the body, they can cause evoked potentials that lead to muscle twitching where muscle relaxants are not used, and the trajectory of the electrosurgical energy can vary significantly as it seeks the path of least resistance.

In contrast, the PlasmaJet system with its electrically neutral thermal plasma does not have these drawbacks. The small jet of plasma energy remains precise and forms an unwavering virtual scalpel. The absence of external electrical current in the PlasmaJet system also provides the advantage over electrosurgery that the coagulation layer formed on treated tissue is complete, thin and flexible. The system is able to cut and to remove unwanted tissue by vaporization, always leaving behind a thin flexible coagulated layer that seals the underlying tissue surface with minimal damage.

Although the PlasmaJet system is currently FDA cleared for cutting, coagulation, and the removal of soft tissue by vaporization, it is also able to cut and coagulate bone. Although the system has been extensively used to date in gynecological surgery, and its advantages as a new energy source for use in surgery are likely to see it finding valuable applications in a wide range of foot and ankle procedures.

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