Use of the Argon Beam Coagulator as an Adjuvant for Treating Bone Tumors

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Summary: Argon beam coagulation is becoming a user-friendly, safe adjuvant for treatment of benign aggressive bone tumors, despite little scientific literature available pertaining to the use of the device for bone tumors. It is becoming a part of the orthopaedic oncologist armamentarium used in treating bone tumors with a documented high rate of local recurrence. Our goal is to discuss the literature available on this technique as it applies to other surgical fields and to demonstrate how this modality can be applied to orthopaedic surgery. Further basic science research is necessary to better understand the overall safety and efficacy of this technique when applied for bone procedures. Key Words: Argon beam coagulator—Bone tumors—Adjuvant—Giant cell tumor—Thermal treatment.

The treatment of benign bone tumors is multi-faceted and involves both removal of the tumor and reconstruction of the affected area to minimize the risk of local recurrence and maximize the patient’s function. Adjuvant therapies have a long track record in orthopaedic oncology for use in treating aggressive benign bone lesions. Giant cell tumors of bone are the most studied lesion because of their high rate of local recurrence with simple curettage.1,13,15,19,20 The logic behind using an adjuvant therapy after intralesional curettage and high-speed burring is that it theoretically decreases the incidence of local recurrence by helping to eradicate microscopic disease at the lesion to bone interface and extend the zone of tumor necrosis without removing more structural bone. Minimizing the amount of bone removed when treating a benign bone lesion likely leads to decreased postoperative complications and improved function for the patient. A marginal or wide resection of the bone involved would certainly decrease recurrence rates for benign aggressive tumors but would lead to increased morbidity from this larger resection and likely decreased function associated with skeletal reconstruction.

Many adjuvants have been used in the management of locally aggressive tumors such as giant cell tumors (GCT). The efficacy of adjuvant therapies such as liquid nitrogen,10,11,14 phenol,3,16,18 hydrogen peroxide,12 ethanol,8 or polymethylmethacrylate13,15,19,20 must be weighed against the potential tissue toxicity of these substances and the effect of this toxicity on patient functional outcomes. The choice of any particular adjuvant therapy is usually determined by the treating surgeon’s personal experience. Because of some of the tissue toxicity concerns with the two most frequently used adjuvants, phenol, and liquid nitrogen, the argon beam coagulator has begun to gain in popularity in the treatment of locally aggressive bone tumors. A major advantage over other modalities is that it avoids the possibility of chemical burns seen with phenol,16 and the tissue necrosis seen with cryosurgery and the use of liquid nitrogen.10,11,14 It is a highly directable adjuvant and the application is similar to standard electrocautery and does not require any formal training.

To date there is limited data in the orthopaedic literature discussing the utilization of this device and its efficacy and safety.5,9 A recently published single institution, multi-surgeon study by Lewis et al.,9 examined the recurrence rate and functional outcome of patients...
with giant cell tumors who were treated with the argon beam coagulator, as an adjunct to curettage and cementation. Thirty-seven patients were included over an 8-year period. Average follow up time was 73.7 months. Overall recurrence rate was 10% with most recurring in bone and one in soft tissue. The average musculoskeletal tumor society (MSTS) functional score was 28 and the SF-36 subscale scores were similar to ultrasound (US) norms.

No data are available on the zone or depth of necrosis of bone treated with argon beam coagulation. Future research utilizing an animal model would be able to study depth of tumor necrosis with varying power settings and exposure times. This data would be useful in helping guide the surgeon in the safe application of this newly applied technique.

**HOW THE ARGON BEAM COAGULATOR WORKS**

Argon beam coagulation was developed to help make hemostasis during surgery more effective. Standard electrosurgical devices apply radiofrequency electrical current directly to the tissue to cauterize and control bleeding. The argon beam coagulator produces a spray of argon gas that conducts electrical energy to the tissue in a directed beam of ionized argon gas. As argon has a lower ionization potential than oxygen, the current is directed along the gas to the tissue in question. The stream of gas may also help to clear away blood and other tissue from the site and thereby increase visualization. The use of this technique has a successful track record in both gynecologic and hepatic surgery to eliminate metastasis as well as achieve hemostasis in a more effective and cost efficient manner. Most of the available literature is in these surgical fields. Over the past decade other surgical subspecialties including orthopaedics, otolaryngology, and urology have started to use the argon beam coagulator and more information is becoming available within these fields referring to the efficacy of its use.

Gale et al. in 1998, reported on the histologic effects of laparoscopic argon beam coagulation and the extent of tissue necrosis at various power settings and exposure times. Various power settings (40, 60, 80 W) at increasing exposure times (1, 3, 5 seconds) were used during laparoscopic application of argon beam coagulation to different tissues (uterus, bladder, ureter, kidney, bowel, liver). Histologic evaluation of animal tissue killed 1 hour after coagulation was assessed for depth of tissue necrosis. The authors found that laparoscopic argon beam coagulation results in tissue effects that are dependent on both power setting and duration of application, as well as on electrical and physical characteristics of target tissue. Depth of necrosis or thermal tissue injury can be expected to be less than 2 mm in bowel, bladder, and ureter, and less than 5 mm in kidney and liver, with exposure times of 5 seconds and at a power setting as high as 80 Watts.

Johanns et al.7 did a similar analysis looking at the depth and diameters of tissue coagulation in fresh operative specimens from the stomach, small intestine, and colon. Five different power and gas flow settings between 40 and 155 Watts and 2 and 7 L per min (LPM) were used. The maximum depth of necrosis was 2.4 mm, the maximum diameter 1.1 cm, with no perforations observed. Subsequent to their in vitro model, they then applied argon beam coagulation in 66 patients treated for lesions accessible with gastrointestinal endoscopy with good results.

Hernandez et al.6 studied the use of argon beam coagulation in 25 canine partial nephrectomies to determine its hemostatic capabilities, safety, and degree of thermal injury to renal parenchyma. A regular eschar with a mean depth of tissue necrosis of 2.4 mm was observed with the argon coagulator. They had a control group in their study and found that the surgical time and blood loss were significantly less in the argon beam coagulation group versus their standard control group (P < 0.0001).

Bristow et al.2 evaluated the histopathologic effects of electrosurgical tumor destruction of metastatic ovarian carcinoma using the argon beam coagulator (ABC) and evaluated the depth of tissue damage produced by a range of power settings and tissue interaction times. Microscopic evaluation revealed that the total depth of destruction (TDD) produced by the ABC was composed of three distinct zones of tissue injury: vaporization, carbonized eschar (ESC), and coagulative necrosis (NEC). For each power setting, the mean TDD increased in a linear fashion as the interaction time interval increased from 1 to 5 seconds (60 W, 1.71–2.43 mm; 80 W, 2.24–3.69 mm; 100 W, 3.21–5.58 mm). By regression analysis, both power setting and tissue interaction time were independently associated with increasing TDD, with power having the strongest effect.

The destruction of ovarian carcinoma tumor tissue produced by the ABC is dependent on both power setting and tissue interaction time.

**ABC DEVICES AND SETTING FOR BONE LESIONS**

Suppliers of argon coagulators are Birtcher Medical Systems, Irvine, CA; Beacon Laboratories, Broomfield,
CO; and Valleylab, Boulder, CO. The authors are most familiar with Valleylab equipment but efficacy should be similar among the available distributors (Fig. 1). The disposable probe or “pencil” used for open procedures is similar in design to standard electrocautery bovie type device. It can be used as a standard electrocautery device by controlling the argon switch on the handset of the probe. When the surgeon switches between Argon and standard electrocautery the power settings need to be adjusted. For example, with Argon application, a power setting of 80 Watts would be used, and with standard application, the power should be decreased to 40 Watts.

When treating bone lesions an open technique is used. With other surgical subspecialties requiring endoscopic or laparoscopic equipment, there is significant variability between companies in relation to the probe designs and configurations. The settings that are variable include power or wattage and gas flow rate. There are no strict guidelines for settings when utilizing the device for bone tumor procedures. It is safest to start with the Argon gas flow rate at 5 to 10 L per minute (LPM) and the power for cut and coagulation at 50 to 100 Watts and adjust for the desired effect. When the power or gas flow is too high, arching can occur increasing the risk of injury to surrounding structures. Time of exposure to the surface of bone treated is variable and relates to a visual feedback of charring of the lining of the cavity. There is no time length that is ideal and to get the desired visual feedback usually only takes a few seconds of tissue exposure to the argon beam coagulator.

**INDICATIONS FOR USING THE ARGON BEAM COAGULATOR FOR TREATING BONE LESIONS**

Lesions with a documented increased risk for local tumor recurrence with simple curettage are good candidates for treatment with an adjuvant. The most common benign bone lesions suited for treatment with the argon beam coagulator are; giant cell tumors, aneurysmal bone cysts, and chordroblastomas. For select lesions from metastatic bone disease that are treated with curettage or debulking the argon beam coagulator may be useful for both hemostasis and local tumor control. Many benign lesions with low recurrence rates do not require the extra time and expense involved with treatment with the argon beam coagulator. Such lesions would include enchondromas, osteochondromas, fibrous dysplasia, unicameral bone cysts, osteoid osteoma, and nonossifying fibromas.

**PREOPERATIVE EVALUATION AND TREATMENT PLANNING**

When a GCT or similar aggressive benign bone tumor is suspected by the clinical and radiologic evaluation, one should be prepared to treat the lesion with an adjuvant at the time of surgery. When scheduling such a procedure all the equipment necessary should be reserved and support staff familiar with its use should be available. A radiolucent table is frequently used to allow fluoroscopic guidance when needed. A high-speed burr, appropriate size burr tips, curettes, a pulsatile lavage unit, and the argon beam coagulation machine with probes should be requested. Preoperative antibiotic coverage with a first generation cephalosporin or clindamycin in the penicillin allergic patient is standard practice.

**OPERATING ROOM SET-UP**

Placement of all the necessary equipment for procedures involving extended curettage and the use of adjuvant requires some thought and planning to allow easy access to all devices needed. After being placed on a fluoroscopic “friendly” table, the fluoroscopic unit is brought in on the opposite side of the table from the surgeon. The argon beam coagulator is also nice to have across from the surgeon for easy viewing to be assured
the settings are correct during use. Burring and lavage equipment can be passed off on the side of the surgeon or off the foot of the bed (Fig. 2).

**PATIENT POSITIONING AND LESION TARGETING**

The patient should be positioned on a radiolucent table to allow full access with a fluoroscopic unit when needed. A direct approach to the lesion with a longitudinal incision that can be extended in both directions should be designed before the procedure. The location of this incision will direct the positioning of the patient. When possible a supine position should be used as it facilitates access to the patient and their airway for the anesthesiologist. The initial portion of the procedure involves targeting the lesion through a small incision to allow for an open biopsy to obtain tissue for a frozen section and a working diagnosis. This is usually done with fluoroscopic assistance. Careful attention is paid to the adjacent structures as all attempts are made to reduce any contamination of these structures throughout the procedure.

After the bone is exposed, a high-speed burr is used to open the tumor cavity. Frequently, when the lesion has a substantially thinned cortex a small curette can be used to enter the tumor cavity. Once an adequate sample is obtained, histologic evaluation with an experienced musculoskeletal pathologist should lead to a working diagnosis making it safe to proceed with definitive treatment of the lesion. Should the frozen diagnosis not agree with the preoperative differential, definitive therapy should likely be postponed until permanent sections are available.

**INITIAL CURETTAGE**

Once a working diagnosis is available from the frozen section analysis the incision used for the biopsy can be extended longitudinally. The tumor material is removed with the use of curettes and the cortex of the bone overlying the tumor is further removed with the burr to allow for visualization of the entire tumor cavity. It is often helpful for fluoroscopy to assist this process and ensure that no pockets of tumor are left intact. Another area of concern involves bony septa seen in and alongside the tumor cavity as these structures may obscure the view of the surgeon. They are carefully removed with the burr and curettage of the cavity is continued until all gross visible tumor is removed.

**USING THE ARGON BEAM COAGULATOR**

After the cavity is free of tumor the area is irrigated thoroughly with pulsatile lavage. The argon beam coagulator is then introduced to the tumor cavity. Settings for the argon beam should start at lower levels and increase to the desired effect as outlined above. The spray of gas is directed about the inner wall of the bone in the tumor cavity in a systematic fashion. As the gas contacts the tissue, it is charred black, thereby providing a visual reference to help confirm that the entirety of the cavity has been exposed to the gas, and any microscopic remnants of tumor are obliterated. It is critical that the argon beam only be used inside the cavity itself as the potential for injury to articular cartilage and soft tissue is present. This point must also be kept in mind in using the coagulator on subchondral bone as any fissures or cracks may cause the articular contents to be exposed to the effects of the argon beam coagulator (Fig. 3).

The operating room lights may be dimmed or directed away from the field as the argon spray is readily visible in lower light conditions and this may help facilitate the application of the spray to the cavity. After the cavity has been thoroughly charred, the high-speed burr is then used to remove all of the desiccated (black) tissue and provide further debridement of any remaining tumor cells. The area is then copiously irrigated to further remove any debris. The coagulator may then be reintroduced to the

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cavity and the cycle repeated to ensure the removal of any residual tumor cells.

**FILLING THE VOID AFTER TUMOR REMOVAL**

After the tumor cavity has been irrigated a final time, the reconstruction phase of the procedure is begun (Fig. 4). The tumor cavity is filled with either bone graft, bone graft substitute, or polymethylmethacrylate. It has been our preference to limit the use of polymethylmethacrylate (PMMA) to skeletally mature patients because of concerns over thermal injury to the physis in immature patients and the lack of remodeling seen with PMMA. With that being said, the use of PMMA, may provide added benefit in that the heat released as the cement cures may provide a thermal adjunct and further decrease the residual tumor burden. In addition, the use of PMMA allows easy visualization of local recurrence in the operative field. This is not the case when bone graft is used. Another consideration in the choice of PMMA versus bone graft is the potential for injury to articular structures from the above mentioned thermal activity. This can be ameliorated by the placement of bone graft immediately beneath the subchondral bone, protecting it from the PMMA. The final portion of the reconstruction phase involves the use of hardware such as plate and screw constructs to reinforce the bone. The amount of reinforcement necessary is directly proportional to the amount of bone removed to expose the tumor as well as the size of the tumor itself. Not all patients require hardware. The strength of the construct must also be kept in mind in determining the patients postoperative weight bearing status and activity level. Attention to closure of the soft tissues and use of atraumatic soft tissue handling help decrease the risk for wound complications for these procedures.

**POSTOPERATIVE CARE AND FOLLOW UP**

Patients are first evaluated 10 to 14 days postoperatively for wound healing. Radiographs are necessary at each follow up interval to assess the stability of the reconstruction, consolidation of bone graft (when used), and for any recurrent disease. The amount of weight bearing allowed is dependent on the size of lesion and reconstruction method. Patients treated with PMMA are usually allowed more immediate weight bearing than those treated with bone grafting. After the initial postoperative recovery phase patients are followed at regular intervals, 3 to 6 months, for 1 to 2 years, and then annually for a few years. Most recurrences will occur within the first 2 years from initial treatment.

**FUTURE RESEARCH**

The use of the argon beam coagulator is relatively new. A literature search on the topic provides few arti-
icles or clinical trials regarding the use of argon beam coagulation, especially in the area of orthopaedics. In the realm of orthopaedic oncology, the efficacy of the argon beam coagulator in comparison to other adjuvant treatments in benign bone tumors would appear to be an area with potential for further investigation. Other important questions to be addressed are the zone or depth of necrosis of bone accomplished with different power settings and exposure times.

The argon beam coagulator is a useful and safe adjunct in the treatment of locally aggressive bone tumors and the above procedure may serve as a roadmap in its use to help care for patients with aggressive benign bone lesions.

REFERENCES