Argon Beam Coagulation as Adjuvant Treatment after Curettage of Aneurysmal Bone Cysts

A Preliminary Study

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Abstract The optimal treatment of aneurysmal bone cysts remains an area of debate. Curettage, with or without adjuvant therapy, has been advocated for tumors in most locations. To evaluate argon beam coagulation as adjuvant therapy to curettage, we retrospectively analyzed the complication and recurrence rates in 40 consecutive patients with a diagnosis of aneurysmal bone cyst. For our analysis of recurrence, we excluded six of the 40 patients who were lost to followup or had less than 18 months followup; five patients treated with resection also were excluded. Of the remaining 29 patients, 17 were treated with curettage and argon beam coagulation and 12 were treated with curettage with or without phenol. None of the 17 patients treated with curettage and argon beam coagulation had a recurrence, whereas four patients treated without argon beam coagulation had recurrences. There were no differences between patients treated with or without argon beam coagulation regarding frequencies of intraoperative complications, neurovascular injury, or bone graft incorporation. Argon beam coagulation seems to offer favorable control rates

when compared with curettage with or without phenol. No complications have been experienced thus far with its use.

Level of Evidence: Level IV, therapeutic study. See Guidelines for Authors for a complete description of levels of evidence.

Introduction

Aneurysmal bone cysts (ABCs) account for approximately 1% to 2% of primary bone tumors [19]. They occur most frequently during the first two decades of life and are seen most commonly in the long bones [4, 7, 9, 22]. Radiographically, ABCs are typically expansile, radiolucent lesions eccentrically located in the metaphysis (Fig. 1). Although cortical perforation is infrequent, marked thinning of the cortex can be seen. Fine trabeculae produce the common soap bubble appearance seen radiographically [11].

The treatment of ABCs is generally surgical, usually with extended curettage and bone grafting (Fig. 2). Resection is reserved for lesions in an expendable location, with control rates ranging from 95% to 100% [2, 10, 25, 27]. Embolization is used infrequently except in extensive vertebral or pelvic lesions not suitable for curettage or resection [6, 21]. DeCristofaro et al. [5] reported an 8% recurrence rate in their series of 24 patients treated with embolization. Radiotherapy usually is reserved for recurrent, incompletely resected, or inaccessible lesions [9]. When used alone, reported recurrence rates vary from 8% to 25% [31]. Some authors have used adjuvants, including cryotherapy, phenol, alcohol, and heat cauterization with polymethylmethacrylate polymerization, to treat benign bone tumors such as ABCs [15, 30]. Reported recurrence rates with these techniques vary greatly, ranging from 5% to 40% [4, 7, 16, 18, 22, 23, 29].

Each author certifies that he has no commercial associations (eg, consultancies, stock ownership, equity interest, patient/licensing arrangements, etc) that pose a conflict of interest in connection with the submitted article.

Each author certifies that his institution has approved the human protocol for this investigation and that all investigations were conducted in conformity with ethical principles of research.

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Fig. 1A–B (A) Anteroposterior and (B) lateral radiographs show an ABC in the distal tibia of a 7-year-old patient.

Fig. 2A–B (A) Anteroposterior and (B) lateral radiographs show the tibia of the patient in Figure 1 after curettage, argon beam coagulation, and reconstruction with a calcium phosphate bone graft substitute.

Argon beam coagulation is well-described in the general and gynecologic surgery literature [1, 12, 28], but its use as an adjuvant for local control of benign bone tumors is

Fig. 3 An intraoperative photograph shows use of the argon beam coagulator.

Fig. 4 An intraoperative photograph shows the tumor cavity after treatment with argon beam showing desiccation and eschar formation.

currently evolving. The argon beam coagulator delivers unipolar electrical current (Fig. 3) to tissue through a directed beam of inert argon gas producing desiccation and coagulation [13]. A wand similar in size and weight to a traditional electrocautery device is used to uniformly paint the tumor cavity wall until an eschar forms (Fig. 4).

In this preliminary study we raised two primary questions: (1) Does the use of argon beam coagulation improve the local control rate for patients with the diagnosis of ABC? (2) Is argon beam coagulation safe with regard to perioperative and postoperative complications?

Materials and Methods

We retrospectively reviewed the records of 40 consecutive patients treated at our institution between January 1994 and

December 2006 (Tables 1, 2). No patients with secondary ABCs were included in our review. Patients were treated by multiple surgeons at one institution with resection, curettage alone, curettage plus phenol, or curettage and argon beam coagulation. Six patients lost to followup or with inadequate followup (< 18 months) were excluded from our analysis, as were five patients treated with resection. Thus, 29 patients who had intralesional treatment (curettage with or without adjuvant therapy) were included in our review. Seventeen of the 29 patients were treated with curettage and argon beam and 12 with curettage without argon beam (seven with phenol as an adjuvant, five with curettage alone). There were 22 males and seven females with an average age of 12.2 years (range, 4–39 years). Twelve of the 29 patients (41%) presented with a pathologic fracture. Ten tumors were located in the humerus, six in the femur, four in the tibia, three in the pelvis, two in the calcaneus, and one each in the fibula, radius, clavicle, and metacarpal bones. The physis was closed in five patients and open in 24 patients. Minimal followup for inclusion in the statistical analysis was 18 months (mean, 38.6 months; range, 19–88 months) because most local recurrences have been reported to occur within 18 months of the index procedure [2, 7, 9, 10, 16, 18, 23]. Six patients with less than 18 months' followup could not be located because of a change in residence and were deemed as lost to followup. Although these six patients and those who underwent resection (five patients) were excluded from recurrence analysis, all 40 patients were analyzed with respect to perioperative complications. From our chart review, variables

that might affect recurrence or complication rates, such as tumor location, patient age and gender, tumor size, radiographic tumor stage, physeal status, type of surgical treatment, use of argon beam coagulation, use of other adjuvants, and use of bone graft or bone graft substitutes, were analyzed with respect to tumor control rate. We had prior IRB approval for the study.

Radiographic staging, using plain radiographs and MR images, was performed by one of the authors (JEC) and was based on the Enneking [8] system for benign bone tumors. In some cases, the original films were not available for review, and the Enneking stages were based on the radiology reports. Latent, or Stage I, lesions are characterized by a margin of mature reactive bone without cortical expansion or destruction. Active, or Stage II, lesions have an irregular margin with some expansion or deformation of the cortex. Aggressive, or Stage III, lesions show incomplete reactive margins and cortical destruction with occasional soft tissue extension. In our series, there were no Stage I lesions, 36 Stage II lesions, and four Stage III lesions.

Although surgical technique varied among surgeons, we have standardized our current technique when using argon beam coagulation. A tourniquet was used whenever possible. The limb was exsanguinated by elevation before inflation of the tourniquet. A cortical window was created to expose the contents of the bone cyst, which were curetted. The cortical window was at least as large as the lesion. After the lesional tissue was removed with large curettes, the tumor cavity was expanded in all directions

Table 1. Patients treated with curettage and argon beam coagulation (no other adjuvant)

Patient	Age (years)	Gender	Physis	Physeal injury	Site	Enneking stage	Previous surgery	Pathologic fracture	Followup (months)	Recurrence
1	6	Male	Open	No	Proximal tibia (left)	II	No	No	35	No
2	4	Female	Open	No	Distal humerus (left)	II	Yes	No	20	No
3	13	Female	Closed	No	Proximal humerus (left)	II	No	Yes	36	No
4	11	Male	Open	No	Acetabulum (left)	III	No	No	76	No
5	7	Female	Open	No	Proximal humerus (left)	II	Yes	No	27	No
6	14	Male	Open	No	Distal femur (left)	III	No	No	38	No
7	9	Male	Open	No	Proximal tibia (left)	II	No	No	27	No
8	12	Male	Open	No	Distal tibia (left)	II	No	No	29	No
9	12	Male	Open	No	Proximal fibula (left)	II	No	No	36	No
10	17	Male	Open	No	Ischium (left)	II	No	No	23	No
11	9	Male	Open	No	Proximal tibia (left)	II	Yes	No	20	No
12	23	Female	Closed	No	Calcaneus (right)	II	No	No	29	No
13	10	Male	Open	No	Proximal humerus (right)	II	No	Yes	28	No
14	9	Male	Open	No	5th metacarpal (left)	II	No	No	24	No
15	12	Male	Open	No	Proximal humerus (right)	II	No	Yes	38	No
16	11	Male	Open	No	Proximal humerus (right)	III	No	Yes	30	No
17	12	Female	Open	No	Distal humerus (right)	II	No	No	24	No

Table 2. Patients treated with curettage without argon beam coagulation

Patient	Age (years)	Gender	Physis	Physal injury	Site	Enneking stage	Previous surgery	Pathologic fracture	Followup (months)	Other adjuvant	Recurrence
1	39	Male	Closed	No	Distal femur (left)	II	No	No	60	None	No
2	15	Male	Open	No	Calcaneus (right)	II	No	No	24	None	No
3	13	Male	Open	No	Superior ramus (left)	III	No	No	26	None	Yes
4	16	Male	Open	No	Proximal femur (right)	II	No	Yes	107	Phenol	Yes
5	10	Female	Open	No	Proximal femur (right)	II	No	Yes	78	Phenol	No
6	11	Male	Open	No	Proximal humerus (right)	II	Yes	Yes	48	Phenol	Yes
7	11	Male	Open	No	Proximal humerus (right)	II	No	Yes	88	Phenol	Yes
8	5	Male	Open	No	Distal radius (right)	II	No	Yes	26	Phenol	No
9	14	Male	Open	Yes	Proximal humerus (left)	II	Yes	Yes	80	Phenol	No
10	4	Male	Open	No	Proximal femur (right)	II	No	Yes	39	Phenol	No
11	11	Female	Open	No	Medial clavicle (left)	II	No	No	19	None	No
12	14	Male	Closed	No	Femur (right)	II	No	Yes	26	None	No

using a power burr with the exception that care was taken to minimize damage to an open physis. The tumor cavity then was treated with the argon beam. The argon beam coagulator was set at 50 W for small bones of the hand or foot and 100 to 150 W for larger bones, depending on the amount of cortical bone remaining after curettage and the relationship of nearby anatomic structures. The coagulated tissue appeared black, usually after 20 to 30 seconds application. Argon beam coagulation was not applied directly to the exposed physis. After irrigation with saline, argon beam coagulation was repeated to ensure thorough and even treatment of the tumor cavity.

Of the 29 patients treated with curettage (alone or with an adjuvant), only one did not receive bone grafting or a bone graft substitute. This was a surface lesion of the distal femur that did not require grafting. The defect present after curettage of the remaining 28 tumors was filled with allograft in 15 patients, bone graft substitute in seven, autograft in four, and a combination of allograft and autograft in two.

Our postoperative treatment protocol included weekly clinic visits until wound healing occurred. Radiographs were obtained 6 weeks and 3 months postoperatively and then at 3-month intervals for 2 years (or until restoration of normal bony anatomy). Protected use of the extremity was maintained until bone graft incorporation, usually 6 weeks postoperatively.

Outcome variables used to assess the safety of operative and adjuvant treatments were obtained from the medical records. These included intraoperative complications, postoperative complications, physal disturbance, and need for reoperation.

Differences in tumor recurrence rates between patients treated with and without argon beam coagulation were analyzed using Yates corrected chi square for low sample sizes. Nonparametric analyses were performed to

determine significance of association; the strength of association was determined using the phi coefficient (0–1, with 0 being no association and 1 being perfect association). We used SYSTAT[®] 5 Version 5.2 for Macintosh[®] software (Systat Software Inc, San Jose, CA) for all analyses.

Results

Four of 12 patients treated without argon beam coagulation had local recurrences. There were no recurrences among patients treated with argon beam coagulation. There was an association between tumor recurrence and curettage without argon beam coagulation ($p = 0.044$) compared with no recurrences with argon beam coagulation. Strength of association was fair (-0.476) as measured by phi coefficient. These data indicate an interaction, but the association is not strong because of the small sample size.

One physal growth arrest occurred in a 14-year-old boy with a proximal humeral lesion who was treated with curettage alone. No angular deformity or loss of functional motion was noted. Radiographs of the contralateral arm were not available to assess the amount of limb shortening. One patient treated with argon beam coagulation underwent a second operation to bone graft a residual defect from the original curettage; otherwise, there were no perioperative or postoperative complications associated with its use.

Discussion

The need for adjuvants when treating ABCs is an issue for debate. Adjuvant therapy can extend the zone of tissue

Table 3. Reported recurrence rates without adjuvant treatment and with various adjuvant agents

Study	Number of patients	Treatment	Adjuvant treatment	Number of recurrences	Average time to recurrence (months)	Risk factors for recurrence	Complications
Marcove et al. [18] (1995)	51	Curettage	Liquid nitrogen	9 (18%)	20		1 skin necrosis 1 nerve palsy 5 fractures 1 joint stiffness
	44	Curettage	None	26 (59%)			
Ozaki et al. [22] (1996)	65	Curettage	PMMA in 30	17 (26%)	17	Use of bone graft instead of PMMA	1 fracture 3 joint stiffness
Gibbs et al. [10] (1999)	40	Curettage Resection	None	4 (12%)	10.5	Young age Open physis	
Ramirez and Stanton [25] (2002)	29	Curettage Resection	None	8 (28%)	18.7		3 physeal arrests 2 fractures 1 infection
Dormans et al. [7] (2004)	45	Curettage	Cauterization Phenol Hydrogen peroxide	8 (18%)	< 6		
Mankin et al. [17] (2005)	150	Curettage Resection	PMMA in 20	30 (20%)	14	Young age Femoral or clavicular location	3 fractures 1 allograft fracture
Basarir et al. [2] (2007)	56	Curettage Resection	Cauterization Embolization	9 (16%)	15	Age < 5 years Previous surgery	4 deformities 2 limb inequalities 1 infection 1 nerve palsy
Lin et al. [14] (2008)	53	Curettage		10 (19%)	17	Age < 12 years Juxtaphyseal location	
Current study	40	Curettage Resection	Argon beam coagulation in 17	4 (10%)	24	Curettage without argon beam coagulation	1 physeal arrest

PMMA = polymethylmethacrylate.

necrosis by eliminating microscopic residual disease. Although some authors have reported decreased recurrence rates [10, 23] when adjuvant therapy was used, many have observed no appreciable benefit [16, 24, 26]. Nonetheless, the theoretic advantage of broadening the zone of tissue necrosis to reach residual microscopic tumor cells after curettage is intriguing, especially with aggressive or recurrent lesions. Unfortunately, many of the popular adjuvants currently used, such as liquid nitrogen and phenol, have well-described complications associated with their use, including local and systemic toxicity, tissue necrosis, fracture, and osteonecrosis [16, 18, 20, 28–30]. This highlights the need for a safe and easily applied adjuvant if one is to be used at all. Lewis et al. [13] reported the use of an argon beam for treatment of giant cell tumor; however, to our knowledge, there are no published series regarding its use in treating ABCs. We therefore raised two questions: (1) Has the use of argon beam coagulation improved the local control rate for patients with the diagnosis of ABC? (2) Is argon beam

coagulation safe with regard to perioperative and postoperative complications?

Several weaknesses exist in this retrospective analysis. Variables including surgeon technique, young patient age, juxtaphyseal tumors, and tumor location have been associated with increased recurrence rates [2, 7, 9, 10, 14, 16–18, 22, 23]. We did not control for these variables owing to the small patient cohort size. Specifically, our series of 40 patients were treated by several different surgeons, making uniformity of surgical treatment and exact comparisons impossible. The specific technique used in each case was based on surgeon preference. Furthermore, the thoroughness of the initial curettage, which is arguably the most critical aspect of treatment, likely varied among surgeons. Additionally, tumors occurring in varying locations were included in the statistical analysis. Locations such as the spine and pelvis pose anatomic challenges regarding surgical exposure and treatment, making comparison to extremity lesions difficult.

In our early experience, tumor control rates with argon beam coagulation compare favorably with those of curettage with or without phenol or other adjuvants (Table 3). There were no recurrences among our 17 patients treated with argon beam coagulation, whereas four of our 12 patients treated without argon beam coagulation had recurrences develop, a frequency similar to reported rates that range from 5% to 40% [3, 4, 7, 18, 22, 23, 29].

We have experienced no operative complications with the argon beam coagulator. One patient treated with curettage and phenol had a physal growth arrest. Whether this was attributable to the adjuvant used or related to the technique of curettage is unknown. Complications after the use of established adjuvants, such as liquid nitrogen or phenol, are well documented, with published rates ranging from 6% to 25% [15, 16, 26, 30].

The questions posed by this study have been at least partially answered. It appears curettage with argon beam coagulation provided improved local control of ABCs compared with curettage without argon beam coagulation (with or without phenol as an adjuvant). Furthermore, the use of argon beam coagulation was not associated with an increase in perioperative or postoperative complications.

Limited data exist regarding the effects of argon beam coagulation on cancellous bone. In a porcine study performed at our institution (unpublished data), we evaluated the depth of necrosis of argon beam coagulation when set at multiple power levels. Depth of necrosis was 1 mm in cancellous bone when the argon beam coagulator was set at 50 W, 3 mm when set at 100 W, and 4 mm when set at 150 W.

Although argon beam coagulation has gained popularity and acceptance in general and gynecologic surgery applications, its use in orthopaedic applications is still relatively limited. In our early experience, we found argon beam coagulation very user-friendly and safe. The application of argon gas in a directed beam ensures precise application without concerns of spillage or local tissue contamination. Also, there is no concern for systemic toxicity. To date, there have been no fractures after treatment of residual cavity defects with argon beam coagulation, and there have been no tumor recurrences among patients treated with argon beam coagulation. More followup is needed to document long-term outcomes.

Our preliminary data do not confirm argon beam coagulation is superior to other forms of adjuvant therapy, nor do they confirm any adjuvant is required for effective treatment of ABCs. However, in our patients, argon beam coagulation seems to have provided some benefit, and our early experience suggests argon beam coagulation is at least as effective as other adjuvants reported in the literature. Also, many of the complications associated with traditional adjuvants thus far have been avoided.

A prospective randomized study is required to prove these associations.

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