International Orthopaedics (SICOT) (2003) 27:249–253
DOI 10.1007/s00264-003-0463-8

ORIGINAL PAPER

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Early results of a modified technique of cryosurgery

Accepted: 13 March 2003 / Published online: 20 May 2003

Abstract The objective of this study was to present a simple, convenient, and reliable technique for the application of liquid nitrogen and to evaluate the effectiveness of curettage and cryosurgery. Between 1992 and 2002, 24 patients who had benign aggressive and low-grade malignant bone tumors were treated by curettage and cryosurgery. While cryosurgery was applied by the "direct pour" technique in the first seven patients, it was applied by the "pressurized spraying" technique in the others. Functional results were graded according to Enneking. The mean follow-up was 47 (range 9–131) months. There were no local recurrences. Three patients who underwent the direct pour technique developed partial skin necrosis. The functional results were excellent in 14 patients, good in six, and fair in four. When compared with previous reports on cryosurgery and its application techniques, we detected no tumor recurrence or complications, including soft-tissue injury, infection, and late fracture with liquid nitrogen applied by the pressurized spraying technique.

Résumé L'objectif de cette étude était présenter une technique simple, pratique et fiable pour l'application d'azote liquide et évaluer l'efficacité du curetage avec cryochirurgie. Entre 1992 et 2002, vingt-quatre malades qui avaient des tumeurs osseuses bénignes agressives ou des tumeurs malignes de bas grade ont été traités par curetage et cryochirurgie. Cette cryochirurgie a été appliquée par versement direct chez les sept premiers malades, et par une technique de vaporisation chez les autres. Les résultats fonctionnels ont été notés d'après Enneking. Le suivi moyen était de 47 mois (9 –131). Il n'y avait pas de récidive locale. Trois malades qui ont subi le versement direct ont développé une nécrose cutanée partielle. Les résultats fonctionnels étaient excellents pour 14 malades, bons pour six, et médiocres pour quatre. En comparant avec les précédentes publications nous n'avons retrouvé ni récidive de la tumeur ni les complications incluant l'atteinte des parties molles, l'infection ou la fracture tardive lorsque l'azote liquide a été appliqué par la technique de vaporisation.

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Introduction

Cryosurgery as an adjuvant technique to curettage for the treatment of aggressive benign and low-grade malignant bone tumors has been described earlier [1, 2, 5, 6, 15]. However, some reports mentioned that cryosurgery was also associated with serious complications such as skin necrosis, infection, late fractures, delayed healing, and nerve injury [2, 6, 10, 11, 12, 13]. It is noted that many of the complications are related to the method of applying liquid nitrogen (LN).

Our objective is to describe a simple, convenient, and reliable technique for the application of LN, to present our experience in surgical treatment, and to evaluate the results of 24 patients treated with curettage and cryosurgery.

Patients and methods

Between October 1992 and January 2002, 24 patients (13 male and 11 female) were treated with curettage and cryosurgery for aggressive benign and metastatic bone tumors. Their average age at the time of surgery was 24.1 (4–60) years. Eleven patients had aneurysmal bone cysts (ABC), six had giant-cell tumours (GCT), four had enchondromas, and three had metastatic bone tumor. Three of these were recurrences primarily treated at another hospital and diagnosed histopathologically. Clinical details, including the bones involved and the treatment methods applied, are shown in Table 1.

All were treated by intralesional excision after cortical fenestration followed by meticulous curettage and bone drilling. In five patients with GCT, the cavity was filled with acrylic cement. In one patient with a recurrence of GCT, acrylic cement and allografting was used. In ten patients with ABC, the cavity was filled with allograft, autograft, or xenograft. In patients with enchondromas, the cavity was filled with allograft. In patients with metastatic bone tumor, acrylic cement eventually in combination with internal fixation was used.

Table 1 Clinical details of 24 patients. [a]All patients were treated with curettage and cryosurgery. "Direct pour" technique was used in the first seven patients and "pressurized spraying" technique was used in the others. *DF* distal femur, *C* calcaneus, *PF* proximal femur, *DT* distal tibia, *Pf* proximal fibula, *PT* proximal tibia, *Mt* metatarsal bone, *Df* distal fibula, *PH* proximal humerus, *Mc* metacarpal bone, *GCT* giant cell tumor, *RABC* recurrence aneurysmal bone cyst, *ABC* aneurismal bone cyst, *RGCT* recurrence giant cell tumor, *AC* acrylic cementation, *DBM* demineralized bone matrix, *IMN* intramedullary nailing

Case	Age (years)	Site	Tumor	Treatment method[a]	Complication	Follow-up	Function
1	19	DF	GCT	AC	Skin necrosis	24	Excellent
2	4	DT	RABC	Autografting+xenografting	Skin necrosis	84	Excellent
3	36	PT	GCT	AC	–	124	Good
4	13	Df	ABC	Autografting	–	106	Excellent
5	60	DF	GCT	AC	Skin necrosis	84	Good
6	30	DF	GCT	AC	–	79	Excellent
7	12	PH	ABC	Allografting	–	89	Excellent
8	21	C	RABC	Autografting+allografting	–	21	Fair
9	18	DF	GCT	AC	–	60	Excellent
10	17	PF	ABC	Allografting+DBM	–	10	Excellent
11	36	DF	RGCT	AC+allografting	–	45	Good
12	9	Pf	ABC	Xenografting+DBM	–	15	Excellent
13	23	PT	ABC	Allografting	–	42	Excellent
14	9	Mt	Enchondroma	Allografting	–	33	Excellent
15	40	PT	Enchondroma	Allografting+DBM	–	9	Good
16	32	C	ABC	Allografting+DBM	–	11	Excellent
17	16	Pf	ABC	Allografting	–	54	Good
18	22	PF	ABC	Allografting	–	71	Excellent
19	20	Mc	Enchondroma	Allografting	–	83	Good
20	21	PT	Metastasis	AC	Infection	19	Fair
21	17	PF	Metastasis	AC+IMN	–	38	Fair
22	48	DF	Enchondroma	Allografting+DBM	–	12	Excellent
23	40	PT	Metastasis	AC+plating	–	12	Fair
24	15	PH	ABC	Allografting+DBM	–	10	Excellent

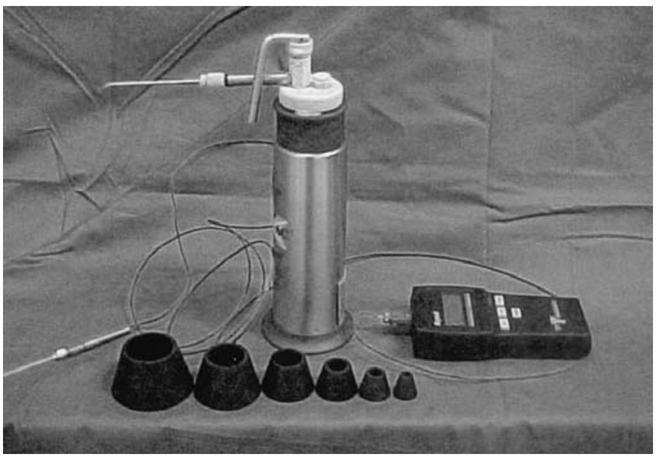

Fig. 1 Brymill CRY-AC Cryogen system and its conical apparatuses and spray tips of different sizes, and a thermocouple device

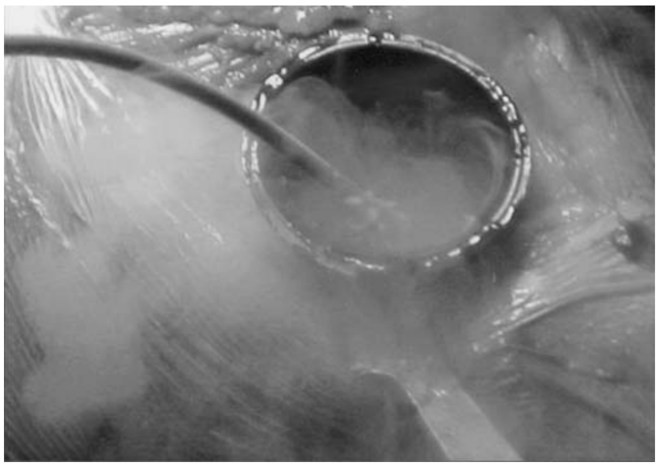

Fig. 2 Intraoperative photograph demonstrates the pressurized spraying technique of cryosurgery. The tip of Brymill CRY-AC Cryogen system was inserted into the cavity, and liquid nitrogen (LN) was sprayed with pressure on the all surfaces of the cavity. Temperature within the cavity is measured with thermocouples

Plain radiographs were taken preoperatively, early postoperatively, and at each follow-up. In the postoperative period, patients were protected by casting or bracing until complete radiographic consolidation. Functional assessments were performed at the last follow-up using the Enneking et al. functional evaluation system [3].

Cryosurgery technique

Tourniquet was used in definite cases in which there were no tumors located in the proximal part of the limb. A cortical fenestration was created to allow adequate exposure of the tumor cavity. After all gross tumor was removed by hand curettage; a high-speed burr was used meticulously until bleeding healthy bone was visible throughout the cavity. Before the application of LN, bony perforations were detected and sealed with bone wax. After the first seven patients, we started to apply LN by spraying with a special device. We used a Brymill CRY-AC Cryogen system (Brymill Cryogenic Systems, Ellington, CT, USA) (Fig. 1). The system has a conical apparatus and spray tip of different sizes and a thermocouple device for measuring the temperature within the cavity. A spraying tip suitable for the size and depth of the cavity was used. After covering the edges of the incision with wet sponges soaked in bone wax, the tip of the Cryogen was inserted into the cavity. The entire surface of the cavity was sprayed with pressure for 3 min (Fig. 2). Thermocouples were used to monitor the freezing

Fig. 3 (Case 9): A giant cell tumor involving the supracondylar area of the right femur treated by cryosurgery and acrylic cementation. **a** Preoperative anteroposterior, and **b** preoperative lateral radiograph shows the extent of the tumor. **c** Preoperative axial computed t omography shows location of the lateral condyle. Sixty years later, **d** postoperative anteroposterior radiograph, and **e** postoperative lateral radiograph shows no change in the appearance of the lateral articular surface and no recurrence

effect within the cavity and its surface. At the spraying time, the temperature within the cavity was measured at approximately −190°C. Just after, it was recorded at approximately −30°C. We then waited for the LN to evaporate and the bone to thaw slowly. Once the temperature of the cavity was above 0°C, the cycle was complete. The soft tissue was then irrigated with warm saline solution, and irrigation was repeated twice for benign aggressive lesions and three times for low-grade malignant lesions. After cryosurgery, the redundant cavity was reconstructed in an adequate manner, and soft tissues were closed.

Results

Average follow-up was 3 years 11 months (range 9 months to10 years 11 months). No recurrence was detected during the follow-up period. No patients required any additional surgical procedure. The patients whose redundant cavity had been reconstructed with bone grafts had complete radiographic incorporation. The results of functional evaluations were excellent or good in 20 patients (Fig. 3) and fair in four patients.

All operations were performed under general or spinal anesthesia. A tourniquet was used in 18 patients. There were four complications: partial skin necrosis caused by the freezing effect of LN in three patients, and superficial soft tissue infection developed in one patient. All healed without observed further complications.

Discussion

For many years, the conventional treatment of benign aggressive and low-grade malignant bone tumors has been curettage with or without bone grafts or acrylic cementation. However, the results were discouraging because of high recurrence rates. It was reported that intralesional curettage alone was associated with recurrence rates of 28–85% [6, 17]. Mechanical curettage by high-speed burr and acrylic cementation decreased recurrence rates to merely 10–20% [6]. The failure of treatment directed orthopedic surgeons toward new adjuvant treatment modalities such as irradiation, acrylic cementation, phenol application, and cryosurgery [6, 18]. Although irradiation was found to be effective, its use has declined due to postirradiation sarcoma [16].

The rationale of acrylic cementation as an adjuvant treatment modality is based on its heating effect. Wilkins et al. [19] demonstrated that a tumoricidal effect does not occur until temperatures exceed 60°C. In their results, acrylic cement temperatures did not exceed 46°C [19]. On the other hand, the tumoricidal capability of acrylic cementation is not well defined.

Phenol is a nonselective cytotoxic agent. When it is applied directly to the area of curetted tumors, it kills residual tumor and normal cells on the surface. Because of its superficial effect without penetrating beyond the lesion margin, recurrence rates are not lower [18].

The first clinical application of LN was in the treatment of Parkinson's disease, and it was called a "closed system" [2]. Marcove and Miller poured LN through a stainless-steel funnel into the tumor cavity, and they termed this a "direct pour (open system)" technique [9]. Some authors applied LN to the tumor cavity by perfusing it through metal probes.

Cryosurgery was first used in orthopedic surgery by Marcove and Miller [11]. They treated a 48-year-old man with metastatic lung carcinoma located in the proximal part of the humerus. The patient experienced complete pain relief after treatment. Marcove reported that cryosurgery as an adjuvant treatment has local recurrence rates of 4–10% [14]. Reports on cryosurgery proved that it was of significant value in decreasing local recurrence rates in benign aggressive and low-grade malignant bone tumors [1, 2, 5, 6, 15]. However, these reports also noted some complications such as late fracture, bone and soft-tissue injuries, delayed healing, and infection [2, 6, 10, 11, 12, 13]. Because of these complications, it has been infrequently used in orthopedic surgery.

No matter which adjuvant treatment method is used, the basic steps of surgery should be applied meticulously. A cortical fenestration should be opened to allow visualization of the entire cavity. After all the gross tumor is removed with hand curettes, a high-speed burr must be used to remove microscopic tumor until bleeding bone is visible in the entire cavity.

We used the direct pour technique in our first seven patients treated with cryosurgery. While applying this technique, we took extreme care to ensure that no soft-tissue injuries occurred. However, we observed soft-tissue injuries in three patients.

Malawer et al. demonstrated that cryosurgery produced marked bone necrosis, extending 7–12 mm around the circumference of the cavity, which developed between 3 and 7 weeks after LN application [7]. They showed that cryosurgery had no effect on the articular cartilage, it caused bone necrosis, and the pattern of reossification was delayed and altered by freezing. This is the reason for late fractures associated with cryosurgery. Marcove et al. reported a late fracture rate of 28% for their first 25 patients with GCT and 18% for the next 25 patients [10, 11, 12, 13]. Gage et al. studied 18 dog femora [4]. They found a 32% pathologic fracture rate when activity was not restricted and the bone operated on was unprotected. We observed no pathologic or late fractures in our patients.

Another problem is soft-tissue injuries, including skin necrosis, nerve palsy, and infection. Malawer et al. used the direct pour technique and reported no cases of infection and only three cases (2.9%) of partial skin necrosis [8]. In another study, Malawer and Dunham reported incidences of flap necrosis in pediatric and adult cases of 4% and 10%, respectively [6].

Pressurized spraying of LN is a "semi-open" system, and is technically simple, feasible, and reliable. Because of the pressure, we think that LN reaches all the way to healthy bone. In addition, there is no significant bone necrosis due to rapid evaporation of the sprayed LN. Schreuder et al. also preferred spraying LN, in every direction necessary, because it increased the contact area of the coolant with the irregular walls of the cavity, and the freezing process was more easily controlled [18].

One major advantage of the pressurized spraying technique over the direct pour technique is that LN does not remain in the cavity because of rapid evaporation. So there is no soft-tissue injury or bone necrosis. Another major advantage is that LN, due to the pressure, penetrates all unhealthy tissue.

The morbidity in this study appears to be lower than that in many other studies. This may be partly explained by the use of reconstructive procedures such as acrylic cementation, intramedullary nailing, and external immobilization by casting or bracing. The main factor appears to be the method of applying LN. The pressurized spraying of LN provides both ease of application and limited local problems in healthy soft tissues and bone.

Cryosurgery is a powerful and efficient adjuvant to curettage in cases with benign aggressive and low-grade malignant bone tumors. Adequate exposure, mechanical curettage by a high-speed burr of the entire cavity, soft tissue protection, and adequate reconstruction using acrylic cementation, bone graft, and internal fixation is crucial. The improved results we obtained may be compared with those of others in which cryosurgery is applied by the direct pour technique. Future experimental studies on the effects of the pressurized spraying technique on bone will guide the future of orthopedic oncology.

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