Pedicle freezing with liquid nitrogen for malignant bone tumour in the radius: a new technique of osteotomy of the ulna

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ABSTRACT

We describe a new technique of pedicle freezing of the distal radius with malignant bone tumour and osteotomy of the normal ulna. The distal radius was sufficiently elevated to enable freezing without damaging adjacent tissues by releasing the distal radio-ulnar and radio-carpal joint and cutting the middle third of the ulna. The distal radius (including the tumour) was soaked in liquid nitrogen and the defect filled with iliac grafts. The ulna was repaired with plate and screws and was united at month 2. There was no local recurrence and the postoperative function score was 93%. This technique decreases the risk of non-union of the osteotomy site of the tumorous bone.

Key words: bone neoplasms; forearm; freezing

INTRODUCTION

In Japan, liquid nitrogen–processed autologous bone grafts are often used for reconstruction following wide resection of malignant bone tumours.1 In this cryosurgery, bones frozen (-196°C) by liquid nitrogen become dead, but viable cells can be found in the frozen bone after months.2 Extracorporeal freezing with liquid nitrogen following en bloc resection is a basic method (Fig. 1a), but it necessitates 2-side osteotomies and there is a risk of non-union, because the return of the osteoblasts and other viable cells in frozen bone may be delayed. Pedicle freezing necessitates no or one-side osteotomy only, and liquid nitrogen–treated bone maintains continuity with remaining bone without freezing (Fig. 1b). This reduces the risk of non-union and enables immediate return of viable cells. Nonetheless, this technique is difficult to perform on distal forearm bones (radius and ulna), as they are strongly connected by the interosseous membrane. We report a new surgical
tecnique, in which a normal ulna osteotomy was performed and the tumour was treated with pedicle freezing without radius osteotomy.

CASE REPORT

In March 2009, a 20-year-old woman presented with right wrist pain and tenderness but no swelling or localised pain. She had a one-year history of wrist pain without any antecedent traumatic episode. Radiographs revealed an osteolytic lesion in the epiphysis to metaphysis of the distal radius, and the marginal sclerosis of the bone was unclear (Fig. 2). No extraskeletal lesions were noted. A biopsy confirmed the pathological diagnosis to be benign giant cell tumour (GCT) of the bone (Fig. 3a).

One month later, the patient underwent curettage (with a high-speed burr) and cryotherapy and bone grafting with artificial bone (β-TCP). At postoperative month 6, the patient had local recurrence in the distal radius and underwent curettage again. Histopathology revealed proliferation of atypical tumour cells (Fig. 3b). The new diagnosis was secondary malignant GCT of the bone (T2N0M0, stage IIB, International Union Against Cancer classification) [Fig. 4]. Chemotherapy was administered immediately, with 2 courses of
high-dose ifosfamide and 2 courses of cisplatin and doxorubicin. Radiotherapy was not performed.

The patient underwent liquid nitrogen processing of the affected bone. An almost 15-cm spindle-shaped skin incision was made from the dorsal side of the wrist to the forearm (including the surgical scar from the previous surgery). The third and the fourth extensor compartments and the extensor pollicis longus, extensor digitorum communis, and extensor indicis proprius tendons were sacrificed, because the previous surgery passed through these compartments, which were considered contaminated with malignant tumour cells. All extensor tendons in the first, second, fifth, and sixth extensor compartments were salvaged. The distal radius was slightly elevated to the dorsal side, and the ligaments and joint capsule around the distal radio-ulnar joint and radio-carpal joint were resected. The volar side of the distal radius could be observed from the dorsal side. The flexor tendons were separated from the distal radius and preserved, and the pronator quadratus muscle was sacrificed with the distal radius. The muscles on the radius along the distal third of the forearm and the interosseous membrane were resected, and the periosteum of the radius was retained as a tumour barrier. Although one third of the radius was freed from any soft-tissue structures, the distal radius could not be sufficiently elevated for liquid nitrogen soaking, because the forearm interosseous membrane remained attached to the middle to proximal portion of the bone (Fig. 5).

Instead of en bloc resection of the distal radius, we osteotomised the middle third of the ulna, with a 3 cm safety margin to prevent normal soft tissues from freezing. This enabled the forearm to be bent almost 180°, and the remaining protruded radius was treated with liquid nitrogen (Fig. 5). The distal radius, including the tumour and its margin, was isolated from other surgical areas with drapes; curettage was performed to prevent fracture of the radius because tumour was expected to expand when frozen. The distal radius was frozen in liquid nitrogen for 20 minutes followed by defrosting at room temperature for 15 minutes and in distilled water for 10 minutes (Fig. 5). The bone defect was filled with autologous bone grafts from the ilium. The elevated radius was returned to the original position and the lunate-radial, radio-ulnar ligaments, and joint capsule were preserved.

Figure 4  Local recurrence of the osteolytic lesion in the epiphysis of the distal radius showing high intensity in magnetic resonance imaging using fat suppression and gadolinium.

Figure 5  (a) The distal radius cannot be sufficiently elevated to expose the lesion to liquid nitrogen after release of the wrist joint and distal radio-ulnar joint, because the interosseous membrane remains in the middle to proximal region of the forearm. (b) The forearm can be bent almost 180° after osteotomy of the ulna. The distal radius protrudes from the soft tissue of the forearm. (c) The distal radius is soaked with liquid nitrogen.
repaired. The ulna was fixed with a plate and screws. The extensor pollicis longus tendon was repaired with a tendon transfer from the extensor pollicis brevis, whereas the extensor digitorum communis and extensor indicis proprius were repaired with a tendon transfer from the extensor carpi radialis brevis. The skin defect from the spindle-shaped skin incision was reconstructed with a local flap and a free skin graft. Although the distal radio-ulnar joint and radio-carpal joint were stabilised, the arm was immobilised with a short-arm splint for 4 weeks in order to protect the transferred tendons.

The patient then underwent 4 further cycles of chemotherapy. The osteotomy site in the ulna was united at month 2 (Fig. 6). The patient remained continuously disease-free and had a functional score (the Enneking system) of 93% (pain 5, function 5, emotional acceptance 3, hand positioning 5, dexterity 5, lifting ability 5) at year one (Fig. 7). There was no articular cartilage collapse in the distal radius.

DISCUSSION

Liquid nitrogen treatment for malignant bone tumours\textsuperscript{1,3} has been approved as advanced medical
technology by the Ministry of Health, Labor and Welfare of Japan. Reconstruction using liquid nitrogen-processed autologous bone grafts enables osteoinduction, preservation of the cartilage matrix, perfect anatomical fits, easy attachment of tendons and ligaments, low cost, and low risk of infection. The conventional technique for liquid nitrogen treatment involves en bloc resection of the bone and extracorporeal soaking in liquid nitrogen. The treated bone was then returned to its original site for reconstruction. This technique is associated with a relatively high risk of non-union, because it involves a 2-side osteotomy and the bones treated with liquid nitrogen have no viable cells for months. Initially, frozen bone appears to contain no live cells but viable cells become evident again after several months. Four of 36 cases treated with liquid nitrogen resulted in non-union; 3 of which were treated extracorporeally. The pedicle freezing technique requires osteotomy of the proximal side only. The treated bone maintains in continuity with the normal bone. This technique is practical in the thigh and the upper arm (as each contains a single bone). The femur or humerus can be easily elevated for liquid nitrogen soaking after resection of the surrounding soft tissue. Pedicle freezing for bone tumours in the distal shafts of the radius and ulna is difficult, as elevation of either bone in the forearm is not sufficient for liquid nitrogen treatment, owing to the intra-osseous membrane connecting the radius and ulna. Conventional treatment entails total resection of the distal radius and reconstruction with a vascularised fibular graft. Our technique involves osteotomy of normal bone. This eliminates the risk of non-union at the osteotomy site after liquid nitrogen treatment of the tumorous bone. This technique enables restoration of wrist joint function owing to the perfect anatomic fit of the wrist. There is no invasion of the donor site of fibular grafts. It can be easily applied for pasteurisation and intra-operative radiotherapy. The level of osteotomy should be same as the exposure level of the tumorous bone.

REFERENCES