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Microwave Ablation Therapy of Giant Cell Tumors of Bone

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Abstract

Aim: Recurrence of giant cell tumor of bone was a hot topic, and the best treatment remains controversial. We tried using Microwave Ablation (MWA) to further reduce the recurrent rate.

Materials and Methods: From May 1992 to December 2015, 233 cases of GCTs of bone were treated by MWA and 28 cases of sacral GCTs were treated by curettage plus regional chemotherapy. The procedure involved dissection of the tumor-bearing bone from the surrounding normal tissues. Antennas were inserted into the tumor cavity. The aim was to ensure that the temperature at any part of the tumor reached 80°C or higher and maintained for 20-30 minutes. Then, traditional curettage and reconstruction was takened.

Results: Survival rate: 98.5%. For 199 patients with long tube bones GCT (including 18 cases transferred from other hospitals due to recurrence), three patients who are firstly operated received revision operations for recurrence; (3/181=1.65%) two patients who are transferred to our hospital due to recurrence received secondary revision operations for recurrence. (2/18=11.1%) For 34 patients with pelvis GCT, recurrence occurred in three cases: one patient received revision surgery without later recurrence, while two patients received an amputation. (3/34=8.8%) For sacrum, all cases achieved local control, but 4 cases received revision surgery 2 or 3 times. (4/28=14.2%) The final local control rate was 99.2% (259/261). Two patients had plate breakage. Two patients had mild infections.

Conclusions: Microwave ablation is a reliable, effective technique to deal with GCT of bone.

Keywords: Ablation; GCT of Bone; Microwave

Introduction

Giant cell tumors of bone are common in aggressive tumors and account for 4-5% of all primary bone tumors and 20% of benign bone tumors, although they occasionally cause so-called "benign metastasis" or malignant transformation. (2-4%) It affects young adults between the ages of 20 and 40 years. In the literature, the most common locations are the distal femur, the proximal tibia, the distal radius, and the sacrum, arranged in decreasing order. Disease-free survival can be achieved in 96-100 % of patients if they have received adequate treatment. Surgically complete removal of tumor cells is the universal standard of care for treatment of a GCT of bone. There are two approaches: 1. wide resection, which is associated with a decreased risk of local recurrence (recurrence rate of 0-5 %) but with a sacrifice of joint function and a necessity for reconstruction; and 2. intralesional curettage, which preserves the anatomy of the bone and the natural joint, but it has a higher relative recurrence rate [1,2]. The lesions have a non-sclerotic and sharply defined border. There are many bony ridges and small pockets on the wall of the tumor cavity. Even if intralesional excision is performed thoroughly, it is still possible to leave microscopic residual tumor cells. Its obstinacy for recurrence (15-25%) is a pending problem (Figure 1).

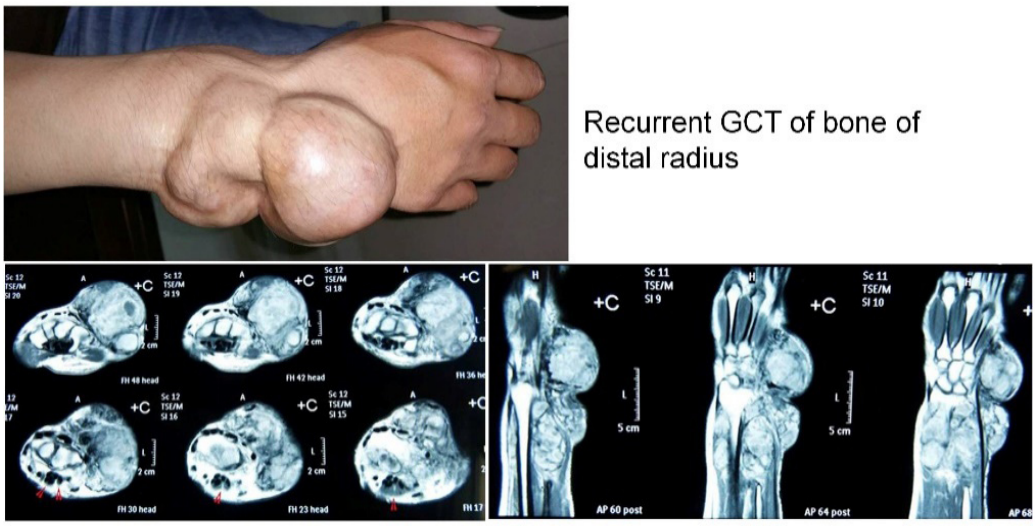


Figure 1: Repeated recurrent case of distal radius GCT. It is very hard to preserve the hand.

Consequently, a method called aggressive curettage was invented. The use of chemical or physical adjuvants after curettage, such as liquid nitrogen, acrylic cement, phenol, hydrogen peroxide, and zinc chlorite, is to facilitate better local control. A high-power burr was used to break the bony ridges. A pulsatile jet-lavage system was used at the end of the curettage, which helps to bare raw, cancellous bone and to physically wash out tumor cells. Local adjuvant therapy has been shown to be useful in controlling recurrence rates. For curettage only, the recurrence rate is 25-50%. For curettage plus adjuvants, the recurrence rate is 6-25% [1-5]. In contrast, Algawahmed, et al. [6] suggested that surgical adjuvants are not required, since data from 387 patients did not show a significant difference in the recurrence rate compared to the control with the use of the toxic adjuvants in addition to high-speed burring. As a result, recurrence remains a hot topic and the best treatments for these tumors remain controversial. The microwave uses the energy of electromagnetic waves to cause agitation among polar molecules, such as water. The oscillation produces frictional heating, causing tissue-heating effects and ultimately generating tissue necrosis within solid tumors [7-10]. A GCT of bone appears brownish and as a softened solid, and some tumors may have a hemorrhagic, cystic component. There is no visible mineralization within the tumor matrix. Fluid-fluid levels are consistent with secondary formation of aneurysmal bone cysts, are seen in 14% of cases. Consequently, a GCT of bone is rich in water. It means that GCT is easy to receive the microwave energy (Figure 2).

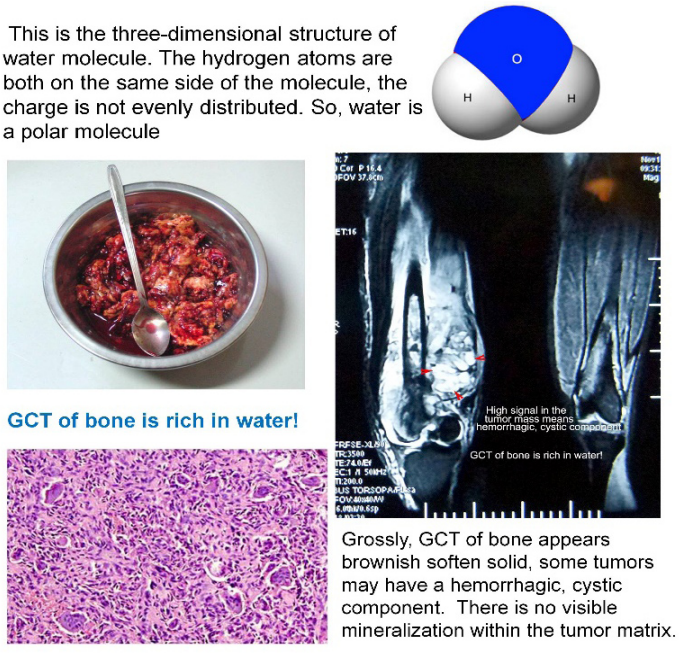


Figure 2: GCT of bone is a kind of tumor rich in water so it is a good recipient of microwave energy. We tried using microwave ablation as an alternative aggressive curettage to further reduce the recurrent rate.

Materials and Methods

From May 1992 to December 2015, 261 cases of GCTs of bone were treated in our department. Of those, 230 cases were treated by Microwave Ablation (MWA) and 28 cases of sacral GCT were treated by curettage plus regional cisplatin chemotherapy (Table 1).

Distal Femur	73
Proximal Tibia	60
Pelvis	34
Sacrum	28
Distal Radius	19
Proximal Femur	12
Fibular head	7
proximal humerus	7
Distal humerus	5
Distal tibia	5
Distal ulna	3
Scapular	3
Spine	2
Calcaneus	2
Clavicle	1
Total	261

Table 1: Distribution of cases of this series.

The main aim of the preoperative planning was to determine the involved range of the tumor, also called the target volume. According to Goldberg S Hahum, thermal ablation is performed to elevate the temperature of the target volume to 50-100˚C[12], including the vital structures such as nerves and vessels. After dissection of the soft tissues with a proper margin, several pieces of surgical gauze were placed between the normal tissues and the tumor bulk. Antennas 1-3 were evenly inserted into the tumor cavity according to the tumor size. Thermocouples were placed into the cavity to monitor the temperature. The duration of microwave irradiation was also dependent on the tumor size. The aim was to ensure that the temperature at any part of the tumor-bearing bone (the so-called target volume) reached 80˚C or higher and was maintained for at least 20-30 minutes. The water molecules are liable to absorb electromagnetic energy. The tumor tissues soon began "boiling" and releasing steam. All of the tumor cells "hidden" in the small pockets on the walls of tumor cavity could be destroyed. After MWA was accomplished, the loose, devitalized tumor tissues were removed by cutting or curettage, leaving behind the defective bone as a scaffold for reconstruction. A re-strengthening procedure was needed in the majority of patients with autografts or allografts. (Figures 3-13) show the procedure at different anatomy locations.)

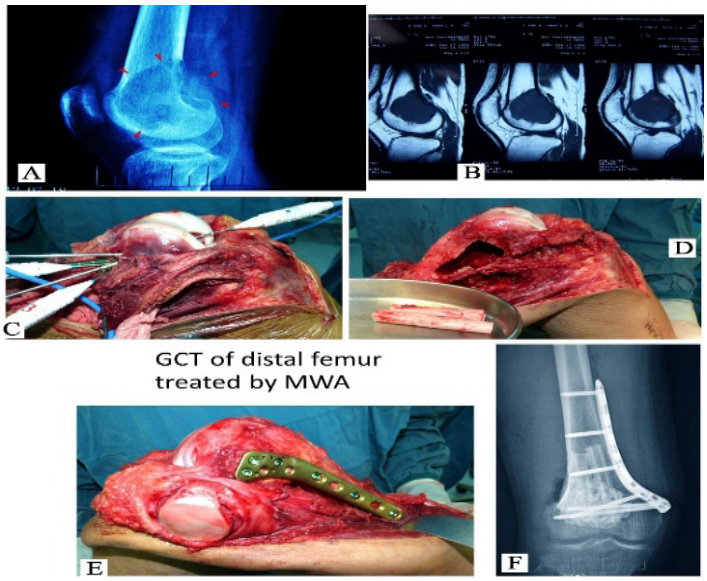


Figure 3: The typical Procedure of Microwave Ablation (MWA) for GCTs of the distal femur. **A,B:** Image data (taken at 5/9/2008) show a lytic/lucent lesions that had an epiphyseal location and grew to the articular surface. **C:** After complete dissection of the tumor-bearing bone from the surrounding normal tissues, thermocouples and antenna were inserted for MWA. **D:** Curettage (almost no bleeding during curettage after MWA.). **E:** Restrengthening the scaffold by fibular autograft. **F:** X-ray film after surgery taken. The function reached sport level after surgery 10 years.

Figure 4: A recurrent case with GCT of proximal tibia. **A,B:** X-ray films before revision surgery. **C,D:** After revision surgery (by MWA).

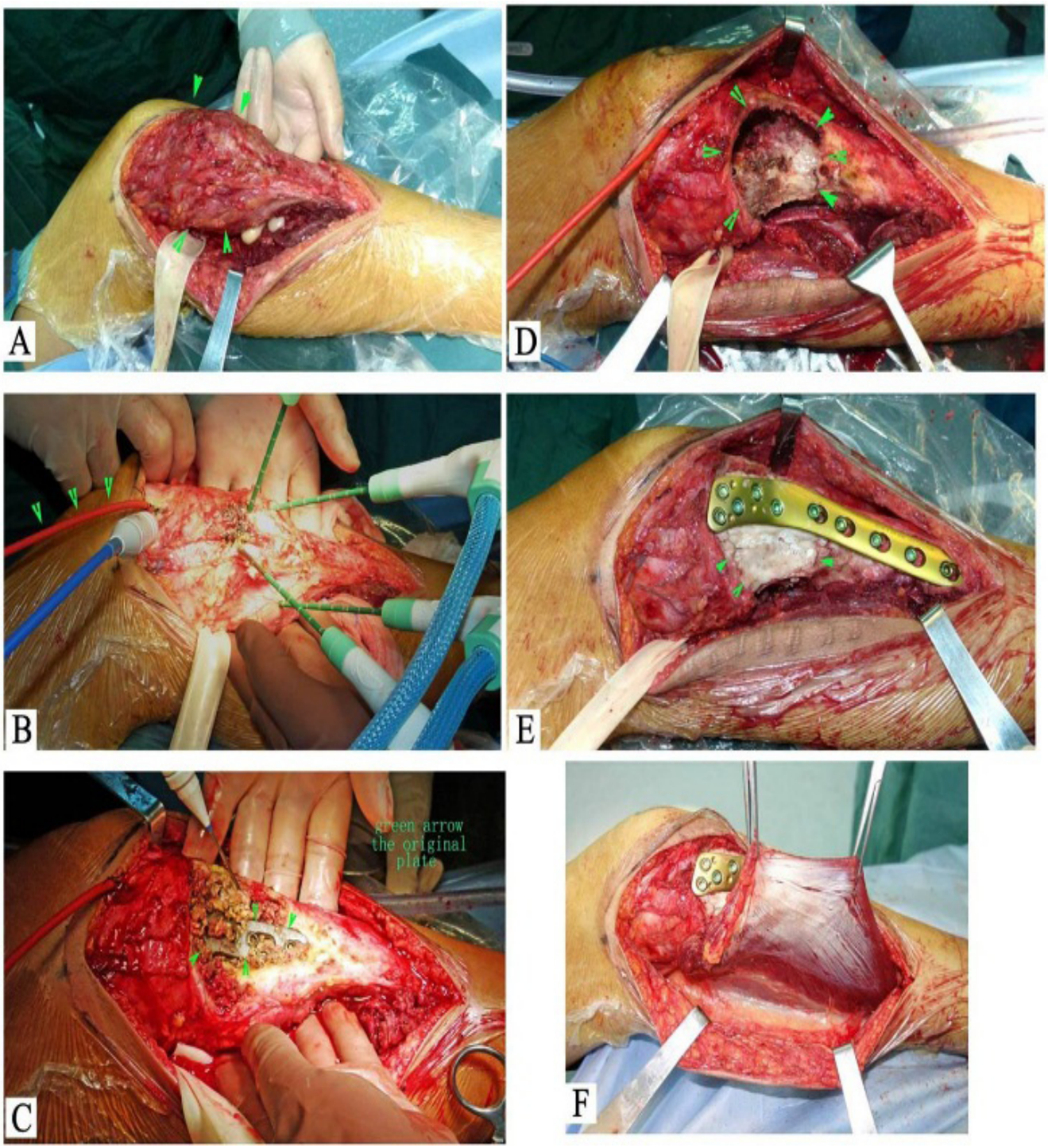


Figure 5: Surgical procedure of MWA for the case showed in (Figure 4). **A:** disect the tumor-bearing bone from the surrounding normal tissues. **B:** insert the antenna array into the tumor and a tube into the knee joint for cooling the cartilage by perfusion of saline. **C:** after MWA, the green arrows showing the original plate. **D:** after curettage. **E:** filling the cavity by the fibular bone and cement, then fixed by plate and screws. **F:** transfer the medial head of gastrocnemius to cover the plate.

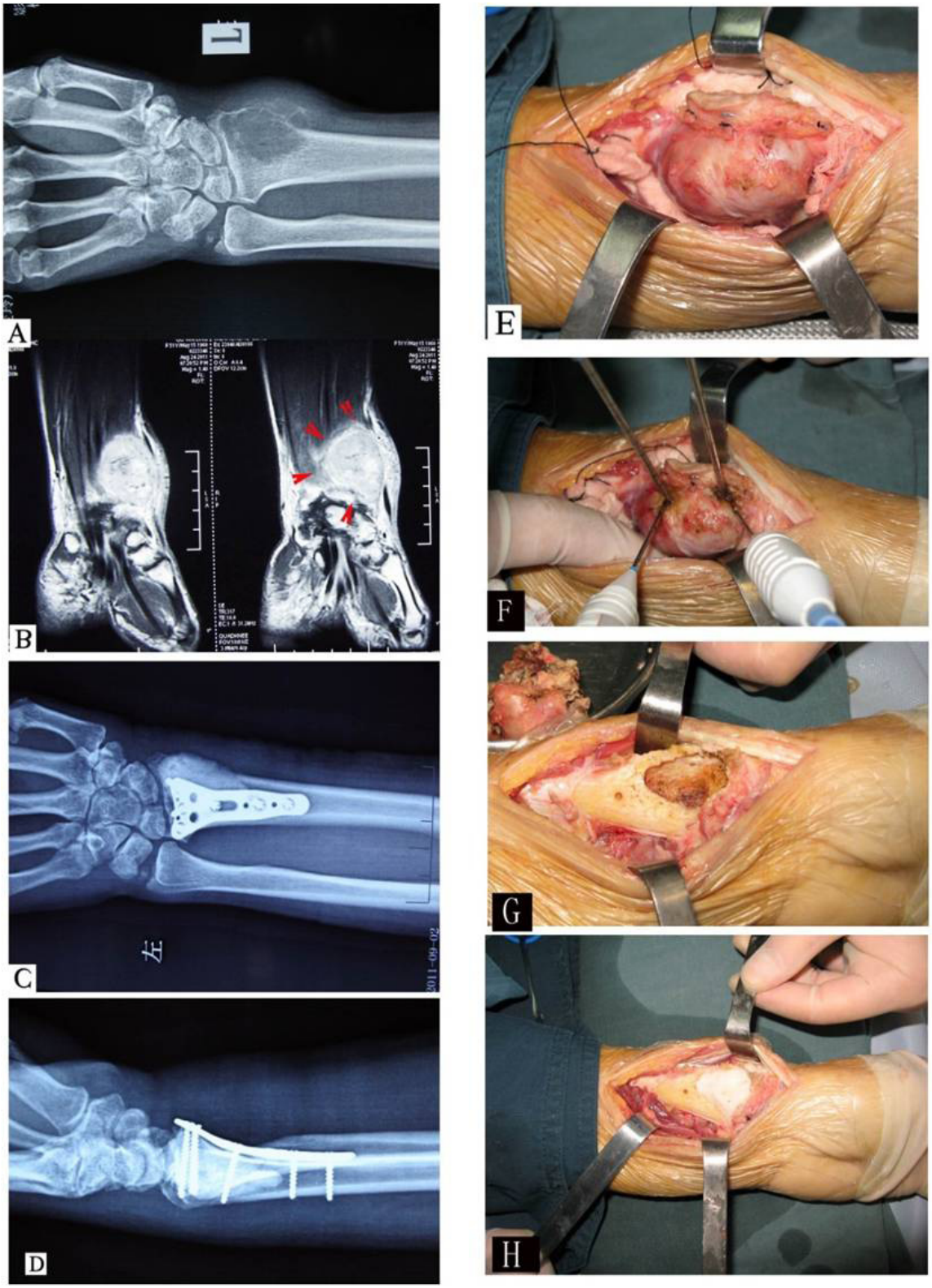


Figure 6: Procedure of MWA for a GCT of the distal radius (X-ray film taken at 8/31/2011).

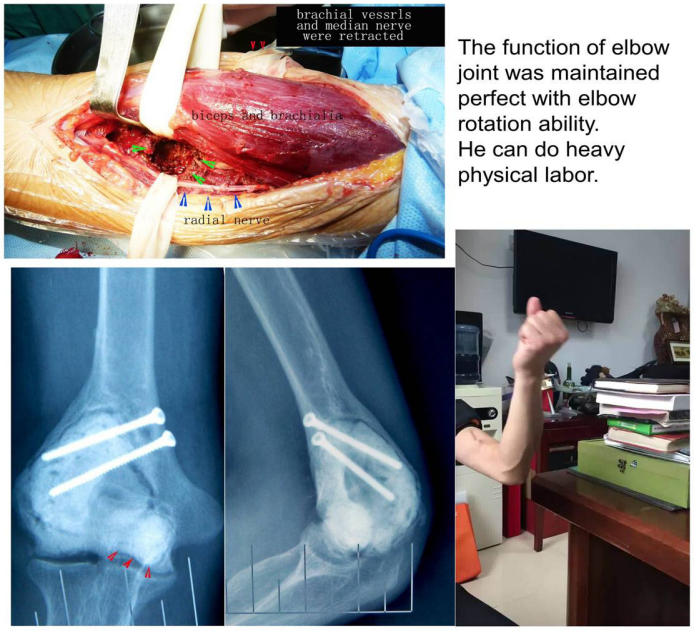


Figure 7: Procedure of MWA for a GCT of the distal humorus (X-film taken at 3/8/2014).

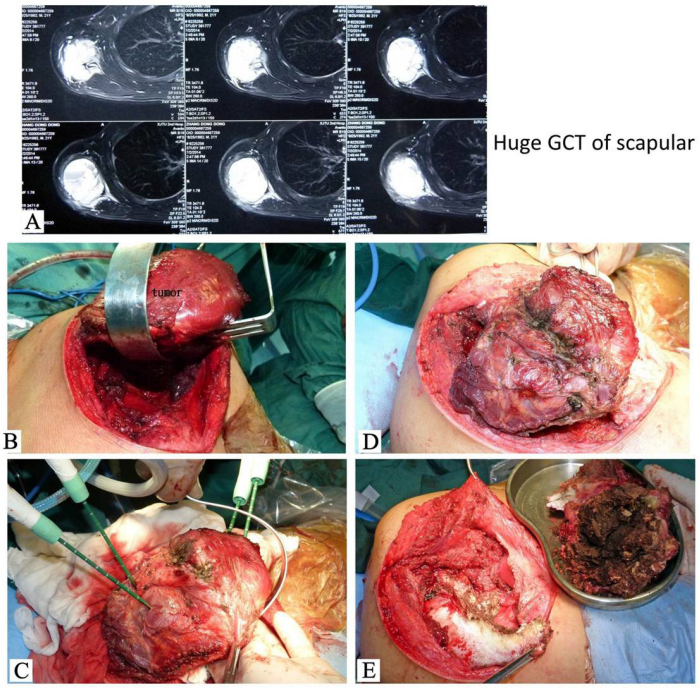


Figure 8: Procedure of MWA for a GCT of the scapula (X-film taken at 8/26/2002) MWA for a case with huge GCT of scapular. **A:** CT scan. **B:** Disect the scapular from the chest wall. **C:** Insert antenna array and thermometers in to the tumor bulk. **D:** After MWA. **E:** Remove the soften devitalized tussues, the shoulder joint was preserved.

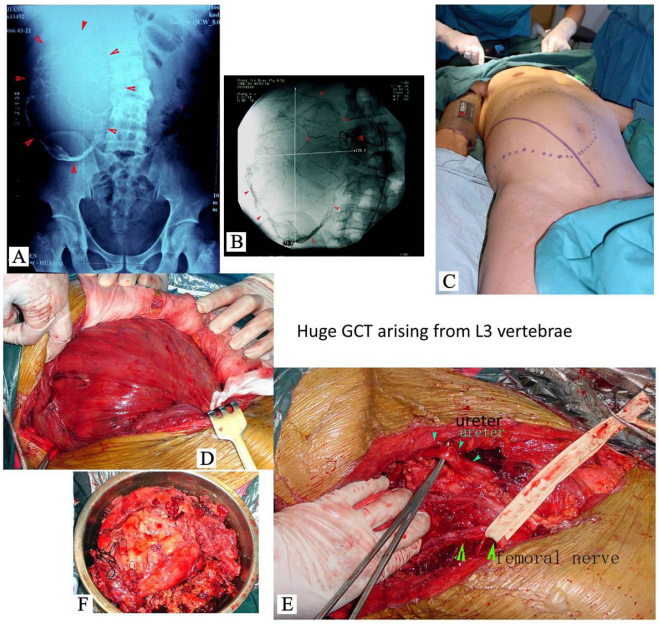


Figure 9: Resection of a huge GCT arising from L3 vertebra. **A,B:** image data showing a huge tumor aside the lumbar spine. **C:** Incision. **D:** Exposure of the tumor. **E:** Remove the tumor. Blood transfusion 2500 ml. Note the ureter and femoral nerve were intact.

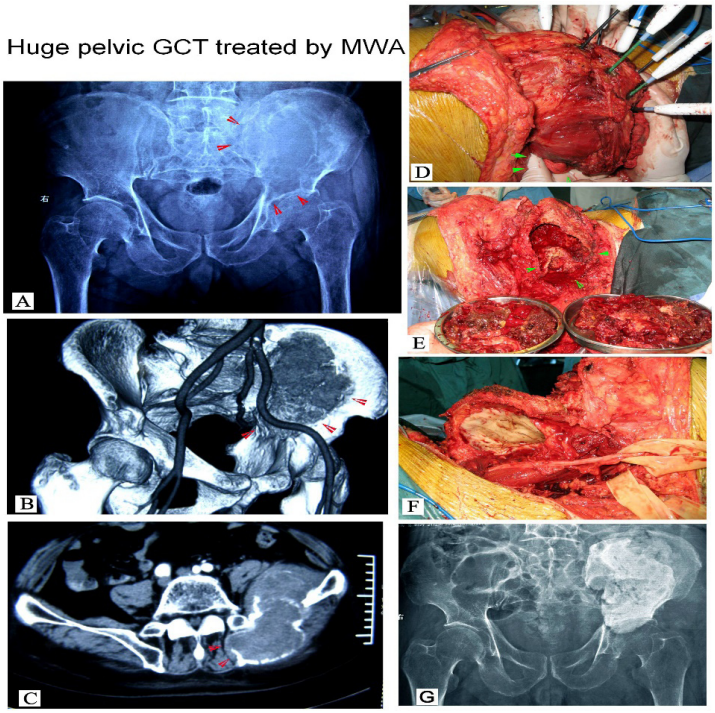


Figure 10: A very large pelvic GCT involved the iliosacral joint and very near to the hip joint. Microwave ablation made the surgery procedure safer, simpler, and more credible. A follow-up after 6 years revealed that the patient was doing well. **A,B,C:** Image data (taken at 9/4/2012). **D:** After completion of the intrapelvic and extrapelvic dissections of the soft tissues

with a proper margin, antenna array and thermocouples were inserted into the tumor bulk. **E:** After MWA, the tumor tissue was completely removed without heavy bleeding. **F:** The defect of the ilium could be repaired by bone graft and cement. **G:** Post-operative X-ray film.

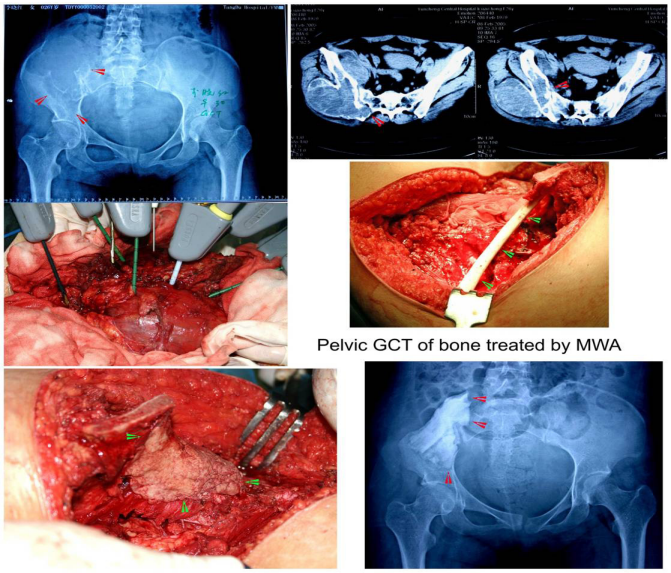


Figure 11: The lesion also invaded the iliosacral joint (Image data taken at 5/26/2008). Allograft fibular was used to reconstruct. There was no recurrence 10 years after operation. The function was fair.

As for the sacral GCTs, due to the cauda equina, it was entangled with tumor tissue; therefore, MWA could not be carried out safely. Therefore, curettage plus local chemotherapy was used to address the sacral GCTs. During curettage, heavy bleeding could be problematic. After curettage, gelatin sponges with cisplatin powder were used to fill the remaining dead space. The procedure of locally delivered chemotherapy did not lead to detected injury of the normal cauda equina (Figure 12).

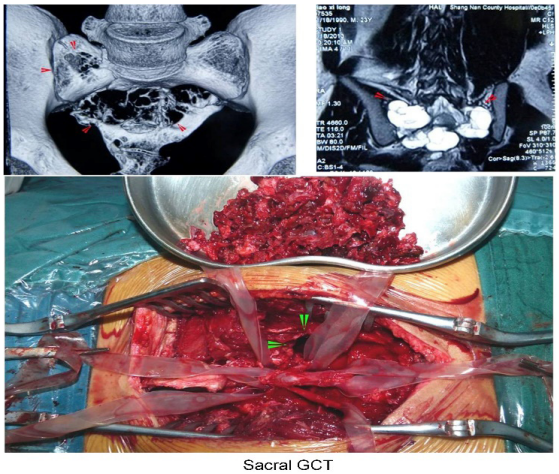


Figure 12: A sacral GCT (CT film taken at 1/25/2013) treated by curettage. The cauda equina was preserved well. After curettage, gelatin sponges with cisplatin powder were used to fill the remained dead space.

In five cases, the iodoform gauze strips were used to pad the cavity tightly to deal with the uncontrollable bleeding. Five to seven days late, the strips were removed, and thorough curettage can be carry out once more. Finally, gelatin sponges with cisplatin powder also were used to fill the remaining dead space (Figure 13).

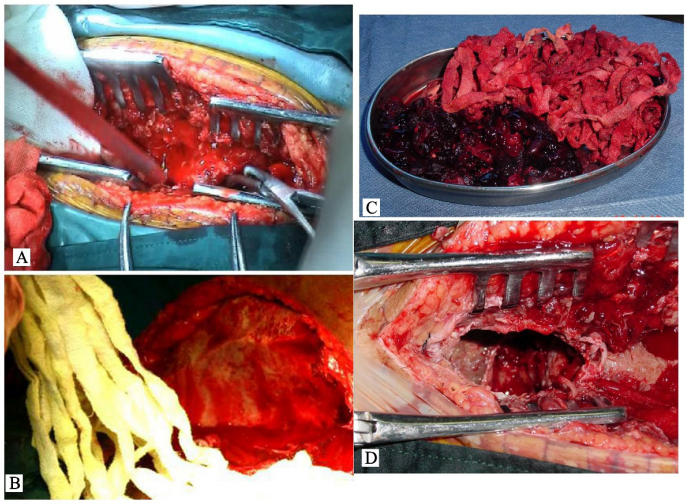


Figure 13: Iodoform gauze strips were used to pad the cavity to deal with the uncontrollable bleeding.

Results

Survival rate: Only four patients, all of them diagnosed with a grade-III GCT of the pelvis, died from disease. The survival rate was 98.5%.

Recurrence

For long tube bones: For 199 patients with long tube bones GCT (including 18 cases transferred from other hospitals due to recurrence), three patients who are firstly operated received revision operations for recurrence; (3/181=1.65%) two patients who are transferred to our hospital due to recurrence received secondary revision operations for recurrence (2/18=11.1%).

Pelvis: Recurrence occurred in three cases, one received revision surgery and were no longer recurrent. Two amputations were performed due to recurrence (3/34=8.8%).

Sacrum: All achieved local control, but 4 cases received revision surgery 2 or even 3 times; all the revision surgeries were simpler than the first operation due to direct access to the tumor and curettage. (4/28=14.2%) The final local control rate was 99.2% (259/161).

Complication: Two patients experienced plate breakages, both required revision surgery. Two patients had mild infection and smoothly controlled.

Discussion

For the long-tube bones, GCTs have a typical epiphyseal location, but the joint and/or its capsule are rarely invaded. It may be associated with severe, substantial destruction of the local bony architecture, and thus it can be particularly difficult to reconstruct after MWA and curettage, especially for the cases that are diagnosed late. In that situation, prosthesis replacement could be a choice. The risk of subchondral cement causing cartilage damage and subsequently causing degenerative arthritis has been cited in the literature, but remains unproven. [10,11]. A modified reconstruction method was used (Figures 14,15).

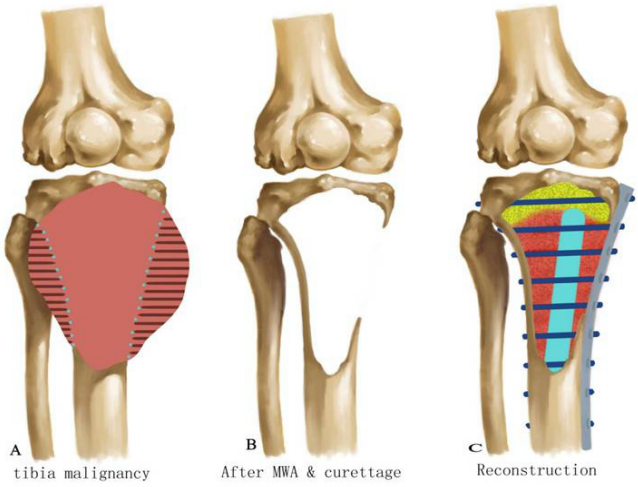


Figure 14: Schematics show the procedure of reconstruction of the cavity after curettage.

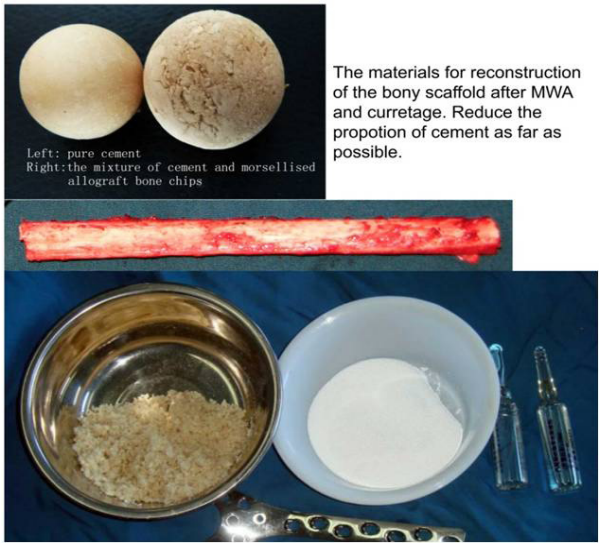
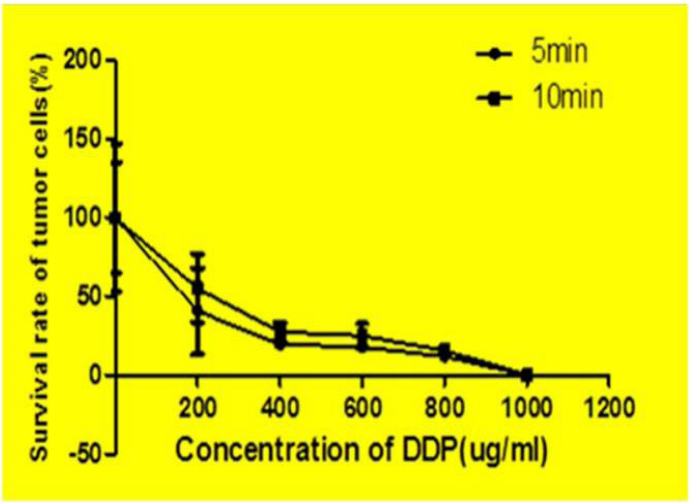


Figure 15: The material used for bone reconstruction.

Giant cell tumour of pelvis is extremely rare. Intra-lesional curettage can preserve of pelvic integrity, but it is also deemed to increase the risk of heavy bleeding during surgery and local recurrence. Reconstruction after resection involving acetabulum and peri-acetabular region is a very challenging subject. Microwave ablation made the surgery procedure safer, simpler, and more credible [13]. Sacrum is the most common location of Giant cell tumors of bone with incidence between 6.7% to 9.4% [1,2]. If curettage can be carried out, a total sacrectomy should not be attempted because the valuable functions of the cauda equina could be sacrificed. After a total sacrectomy, some types of spinopelvic reconstruction have to be applied. However, complications associated with reconstruction are not uncommon and usually result in further surgical interventions. Loss of neuro-function is another problem [14-16].

In the sacrum, complete curettage is hardly possible because of the spinal nerve roots. After a tumor was curetted, the cavity can be filled with gelatin sponges with cisplatin powder. The so-called insensitivity of a kind of cancer cells to chemotherapy refers to the concept of systemic chemotherapy. In such a case, the disparity between the lethal dose (toxic dosage), or tolerance dosage, and the effective dose (effective dosage) is very small. A local "soaked" type of chemotherapy has a very high local concentration (carboplatin 2 g/L, cisplatin, 400 ~ 600 mg/L) without whole-body poisoning. It can effectively kill local tumor cells, including chordoma, giant cell tumors and other malignancies (Figure 16-18).



After incubation in cisplatin solution with concentration 1000ug/ml (1mg/ml) for 5 or 10 min, the survival rate of osteosarcoma cell line MG-63 decreased to the minimum.

Figure 16: The anti-tumor effect of high concentration of cisplatin.

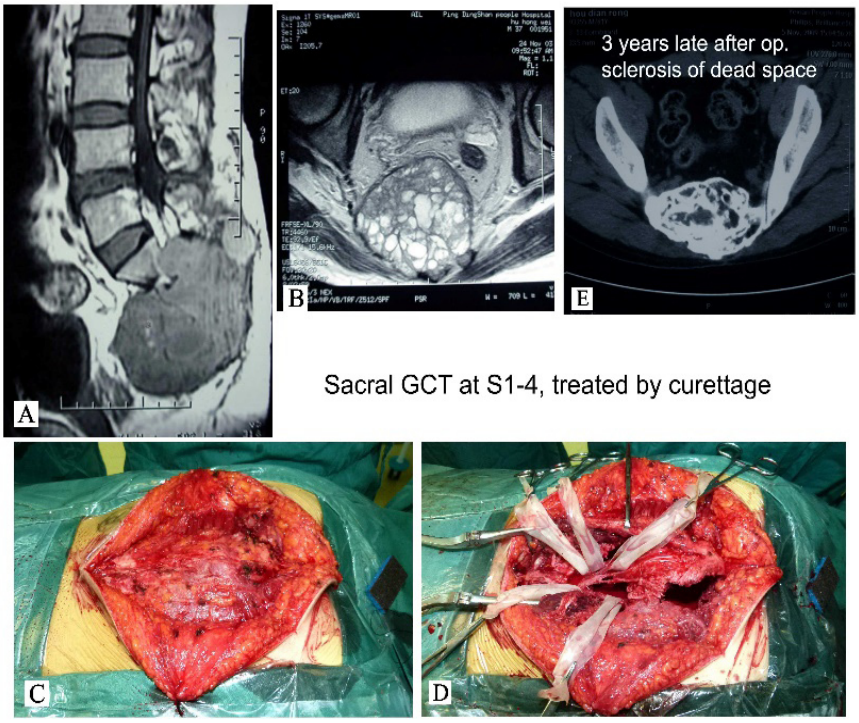


Figure 17: Sacral GCT reaching S1 level was treated by curettage and packing with gelatin sponges and cisplatin powder.

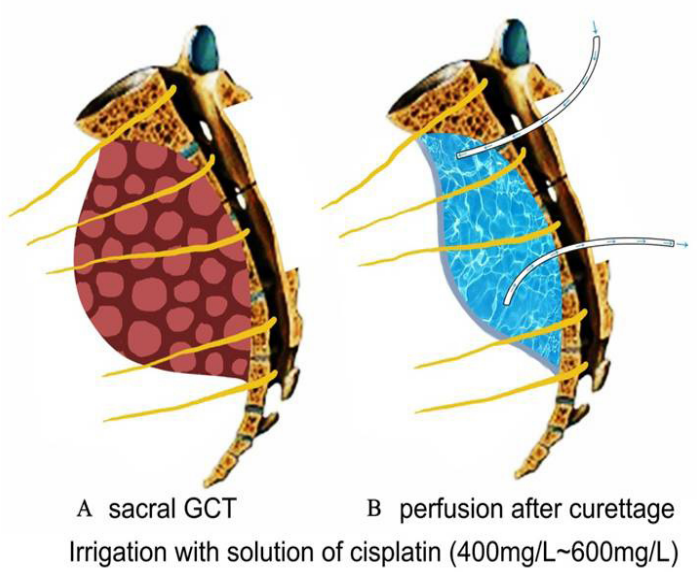


Figure 18: At the early stage of the study, irrigation using solution of cisplatin was employed. Packing cavity with gelatin sponge mixed with cisplatin was more convenient.

Upon diagnosis, approximately 12% of patients with GCTs presented with a pathologic fracture[1]. Some authors have suggested immobilizing the affected limb and waiting for the fracture to heal before performing surgery. Direct treatment was performed without waiting in our series, but the pathological fracture incidence rate was not very high (Figure 19).

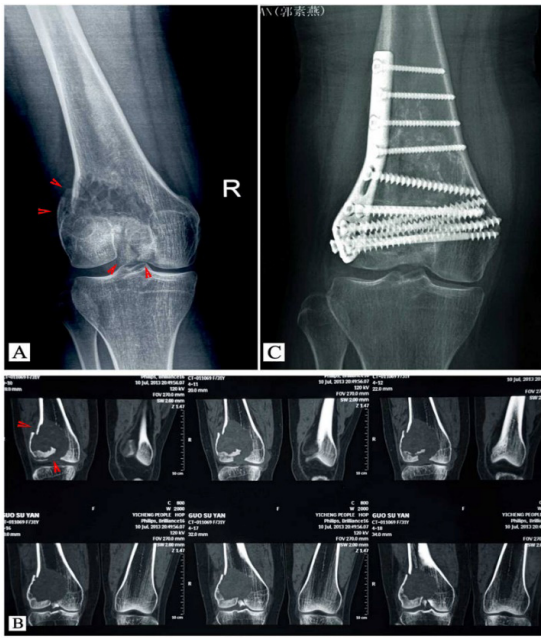


Figure 19: Treatment of GCT of bone of distal femur with fracture into knee joint.

Finally, a special case is described. The patient was a young navy soldier with a sacral GCT who was transferred to our hospital after a failed operation. The patient's general condition was very poor, and revision surgery was the only choice for saving life. So, don't give up easily because the tumor basically is a benigh lesion (Figure 20)

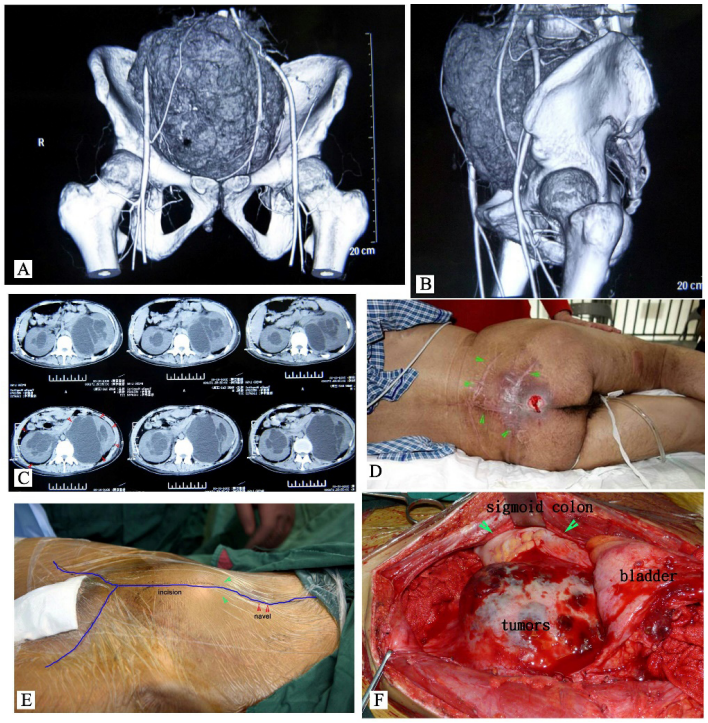


Figure 20: Treating the patient with recurrent GCT of sacrum was a great challenge. The patient was a young navy soldier with a sacral GCT who was transferred to our hospital after a failed operation. The result was very satisfied. **A,B:** Image data (taken at 3/6/2013) show the recurrent tumor was so large that the pelvic viscera and the vessels were tightly pressured. **C:** There were hydronephrosis at both sides due to the pressure of the tumor on the ureters. Kidney function was damaged such that renal dialysis was needed. **D:** There was a bedsore after failed radiation therapy. **E:** A reversed "Y"

incision of the abdomen was used. **F:** Heavy bleeding occurred during dissection of the severe adhesion, and blood transfusion more than 5000 ml. The tumor tissues were removed completely and gelatin sponges with cisplatin powder were used to fill the remaining dead space of the sacral. No recurrence had occurred five years after surgery. Sphincter function remains intact.

Microwave ablation is a reliable, effective and easy-to-use local tumor control technique for treating GCT of bone. It deserves more attention than it has received until now. We will continue to use it, evaluate it, and improve it.

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