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ORIGINAL PAPER

Tain-Hsiung Chen · Yu-Ping Su · Wei-Ming Chen

Giant cell tumors of the knee: subchondral bone integrity affects the outcome

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Abstract From January 1992 to July 2001, we treated 38 patients with giant cell tumour in the knee region. Seventeen tumours were located in the distal femur and 21 in the proximal tibia .Twenty patients were classified as Campanacci grade II, 15 as grade III, and three as grade I. Patients' mean age was 34.5 (19–65) years, and the mean follow-up was 52 (24–134) months. Operative procedures were chosen according to the extent of bone and soft-tissue involvement. In 28 patients, intralesional curettage and bone grafting was performed and in ten patients a wide resection. We defined subchondral bone of the knee to be affected when the distance to the tumour was less than 3 mm. We then measured the area of affected subchondral bone radiographically using plain radiographs, CT, and MRI. In patients initially treated with curettage and bone grafting, the mean area of initially affected subchondral bone was 18.6 (0–81)%. The mean Enneking functional score at follow-up was 88 (66.6–100). There was a linear trend showing that the larger the area of affected subchondral bone, the worse the functional score. Among patients initially treated with wide resection, the mean area of affected subchondral bone was 68.2 (41–100)%. There was, however, no significant association between affected subchondral bone area and functional score.

Résumé De janvier 1992 à juillet 2001, nous avons traité 38 malades avec une tumeur à cellules géantes de la région du genou. Dix-sept tumeurs étaient localisées dans le fémur distal et 21 dans le tibia proximal. Vingt-huit malades ont été classés comme grade II de Campanacci, 15 comme grade III et trois comme grade I. L'âge moyen des malades était de 34.5 (19–65) ans et le suivi moyen de 52 (24–134) mois. Les procédures chirurgicales ont été choisies d'après l'extension osseuse et la participation des parties molles. Vingt-huit malades ont eu un curetage intralésionel et une greffe osseuse et dix malades une résection large. Nous avons considéré l'os sous-chondral du genou atteint quand la distance à la tumeur était de moins de 3 mm. Nous avons mesuré la superficie sous-chondrale affectée par radiographie en utilisant des radiographies ordinaires, la tomodensitométrie et l› IRM. Chez les malades initialement traités par curetage et greffe, la superficie moyenne d'os sous-chondral initialement affecté était de 18.6 (0–81)%. Le score fonctionnel moyen de Enneking au suivi étaitde 88 (66.6–100). Il y avait une tendance linéaire montrant que plus grande est la superficie d'os sous-chondral affecté, moins bon est le score fonctionnel. Parmi les malades initialement traités par résection large, la superficie moyenne d'os sous-chondral affecté était 68.2 (41–100)%. Cependant il n'y avait aucune association significative entre la surface d'os sous-chondral affecté et le score fonctionnel.

T.-H. Chen (✉) · Y.-P. Su · W.-M. Chen
Department of Orthopaedics and Traumatology,
Veterans General Hospital Taipei,
201, Sec. 2, Shih-Pai Road,
Taipei, 112, Taiwan
e-mail: su@pie.com.tw
Tel.: +886-2-28757557
Fax: +886-2-28757657

T.-H. Chen · Y.-P. Su · W.-M. Chen
Department of Surgery, School of Medicine,
National Yang-Ming University,
Taipei, Taiwan

Introduction

The purpose when treating giant cell tumors is to eradicate the tumor tissue, reconstruct the bone defect and restore a functional limb. Surgery includes intralesional curettage or wide excision as well as containment and stabilization of the remaining bone. The first priority is to preserve the joint, and because the knee is a weight-bearing joint, the integrity of the subchondral bone is essential. Several studies found that functional outcome was worse if patients were treated by wide resection [4, 6, 7, 9, 15, 17]. They also reported that the worst functional outcome resulted not only from the wide resection itself but also the wide destruction of tumour as well as from difficulties of reconstruction. The purpose of this retrospective study was to evaluate the relationship between the affected subchondral

bone area before treatment and the functional outcome at latest follow-up.

Materials and methods

Between January 1992 and July 2001, 45 consecutive patients with giant cell tumour in the knee region were treated at the authors' institution. We excluded two patients with lesions of the patella, four with lesions of the fibula and one who was lost to follow-up. Then we enrolled 38 patients of whom 19 were men and 19 women. Patients' mean age was 34.5 (19–65) years and mean follow-up was 58 (24–134) months. Three patients were classified as Campanacci grade I, 20 as grade II, and 15 as grade III. Five patients presented with pathological fractures including two intra-articular fractures.

All operations were performed by two experienced surgeons. The operative procedures were chosen according to the extent of bone and soft-tissue involvement and the surgeons preference. Intralesional curettage with bone grafting was performed in 28 patients. Protective weight bearing with or without casting was allowed. In ten patients, the subchondral bone was invaded extensively by tumour tissue, and a wide resection was performed. For reconstruction, a hemijoint allograft, a custom-made prosthesis, or an alloprosthetic composite was used.

The area of affected subchondral bone was measured on anteroposterior and lateral radiographs and confirmed by computed tomography or magnetic resonance image. The subchondral bone was defined as affected when there was less than 3-mm distance to the tumour. The medial and lateral compartments of the knee were evaluated separately. Because the lesions usually located eccentrically either medially or laterally, only one compartment was considered as the main area involved. The percentage of the affected subchondral bone in a compartment was calculated as the ratio of the affected length to the total length of the compartment's subchondral bone (Fig. 1).

The area of the affected subchondral bone of the proximal tibia was expressed as percentage and was calculated as $[c\times d/(C\times D)]\times 100\%$. Regarding the difficulty in measuring the length of curved subchondral line of the femoral condyle, we calculated its projected area on the plane parallel with the tibia plateau as $[a\times b/(A\times B)]\times 100\%$. The final functional outcomes were assessed at the latest clinical follow-up using Enneking's functional rating score [3], which ranges from 0% (worst functional outcome) to 100% (best functional outcome).

Independent variables included age, gender, Campanacci's >classification [1], tumour location (distal femur or proximal tibia) and type of surgery. Data were entered and analyzed with PC SAS (SAS Institute, Cary, NC, USA). Data were represented as mean ± standard deviation (for continuous variables) or percentage of proportion (for categorical variables). For this retrospective study, the area of the affected subchondral bone and the final Enneking's functional rating score were confounded by the two types of surgery. So we analyzed the data and reported the results separately based on the types of surgery (curettage with bone graft or wide resection). The association between the final Enneking's functional rating score and each continuous variable was analyzed with ordinary linear regression. The association between the final Enneking's functional rating score and each categorical variable was analyzed with a two-sample *t* test or one-way ANOVA. The significant level was set at 0.01 in advance for each univariate analysis.

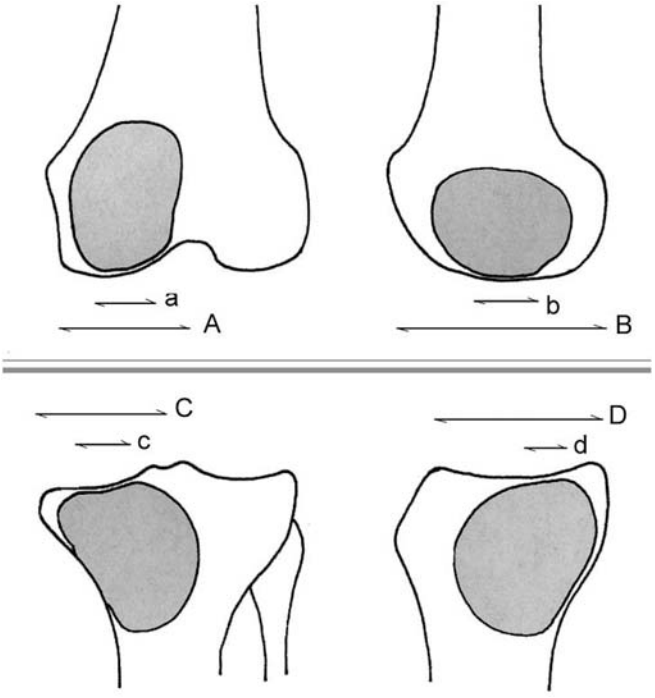

Fig. 1 The subchondral bone was defined as affected when less than 3-mm thickness remained. The area of the affected subchondral bone was calculated as $[a\times b/(A\times B)]\times 100\%$ for the distal femur, and $[c\times d/(C\times D)]\times 100\%$ for the proximal tibia.

Results

In the 38 patients, 17 tumours were located in the distal femur and 21 in the proximal tibia. The demographical data are summarized in Table 1.

In 28 patients initially treated with curettage and bone grafting, the mean area of the affected subchondral bone was 18.6% (range 0–81). The mean follow-up time was 52 (range 37–134) months. Five patients had local recurrence and one of them a concomitant pulmonary metastasis. All had a secondary surgical treatment, and at the most recent follow-up, they were free of local recurrence. Another five patients, although free of recurrence after the initial curettage, had severe osteoarthritis. The mean Enneking functional rating score was 88% (range 66.6–100). As seen in Fig. 2, there was a linear trend showing that the larger the area of affected subchondral bone, the worse the functional score.

We attempted to predict the Enneking functional score from the area of affected subchondral bone using simple

Table 1 Demographical data of patients with surgery for giant cell tumour of the knee

	Curettage (n=28)	Wide resection (n=10)
Age (years, mean±SD)	35.8±12.2	32.1±9.8
Gender (male/female)	13/15	6/4m
Distal femur/proximal tibia	11/17	6/4
Campanacci classification:		
I	3	0
II	15	5
III	9	6
Affected subchondral bone (%, mean±SD)	18.6±23.0 (range 0–81)	68.2±22.8 (range 66.6–100)
Follow-up duration (months) (mean±SD)	52±4	71±5
Enneking's functional rating score (%, mean±SD)	88.2±9.1	84.6±6.8

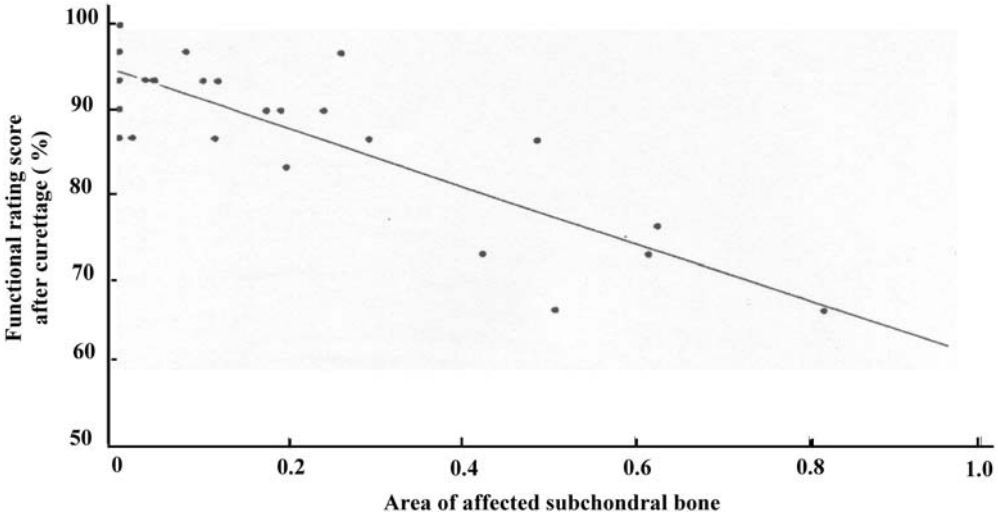

Fig. 2 The functional score after curettage as a function of the area of affected subchondral bone. There was a linear trend that the larger the area, the worse the score (P<0.001).

linear regression. We found that when the area of the affected subchondral bone increased by 10%, the Enneking functional rating score decreased by 3% (95% CI, 2.5–4.1%). For age, gender, Campanacci classification, and tumour locations, there was no significant association with the Enneking functional rating score.

Among the ten patients treated with wide resection, the mean area of the affected subchondral bone was 68.2% (range 41–100). The mean follow-up time was 71 (range 24–126) months. Six patients had reconstruction with hemijoint allografts, three had reconstruction with megaprosthesis, and one had an alloprosthetic composite. None of the patients had local recurrence or complications by infection. In this group, there was no significant linear association between the area of the affected subchondral bone and the Enneking functional rating score, neither was there any association for age, gender, Campanacci classification, and tumour location.

Discussion

The integrity of subchondral bone determines the durability of a weight-bearing joint, which in turn affects its functional result and suitability for salvage after trauma and surgery. The thickness distribution of the subchondral plate of the tibial plateau has been evaluated by computerized image analysis of serial sections [13]. The thinner zones (100–300 μm) are found in the peripheral region near the margin of the tibia plateau. Maximum thickness (≥1,500 μm) is seen at the center of the joint surfaces. If the giant cell tumour involvement is within 3-mm thickness from the joint line, the overlying cartilage would be damaged or exposed after the tumour was treated with intralesional curettage combined with the high-speed burring technique. Consequently, we defined the subchondral bone as affected when there remained less than 3-mm thickness. Magnetic resonance image and computerized tomography are more accurate to evaluate the integrity of the subchondral bone and were used to confirm the tumour extent if obscure on plain films. Although the calculated size by the current method is not the real size of the affected area, it is a simple and practical way to reflect the differences between limited and advanced lesions.

In this retrospective study, we found that there is a significant linear association between the area of affected subchondral bone before surgery and the functional outcome at final follow-up for patients treated with curettage and bone grafting. From the simple linear regression, it results that when the area of the affected subchondral bone increased by 10%, the final Enneking functional score decreased by 3% (95% CI, 2.5–41%). On the other hand, the Campanacci stage had no significant effect on the outcome. In consideration of the bias of the scoring system, it

does not necessarily mean that we can use it to predict the final outcome if curettage was chosen in the beginning. However, it is obvious that the smaller extent of invasion of the subchondral bone, the better the outcome—no matter whether there is extraosseous involvement or not. Most patients treated with curettage obtained good functional results, except those with advanced lesions. We had five patients whose functional outcome was less than 80%; all of them had a lesion endangering more than 40% of the subchondral bone. One patient developed infection after a salvage total knee arthroplasty, which was performed for acute subchondral bone collapse following curettage. Another two patients suffered from osteoarthritis. One patient was treated with arthrodesis after a wide resection for tumour recurrence. Another patient had a loosened femoral prosthesis and a stiff knee after repetitive surgery for recurrence.

Lausten et al. [11] studied 31 recurrences of giant cell tumour in variable sites, including the foot, knee, hip, spine, pelvis, distal radius, and proximal humerus. He suggested wide excision for recurrence due to the much higher re-recurrence rate after curettage (56%) compared to 0% after wide excision. However, we think the management of recurrence should be individualized and site specific. As for the knee, the joint still has to be saved if the bearing surface is good. The primary recurrence rate after curettage for the knee was 17.8% (5/28) in our series. Three of the five recurrent lesions were treated with repetitive curettage due to less subchondral involvement. These knees were free of recurrence after more than 5 years of follow-up. The other two recurrent lesions invaded subchondral bone and were treated with wide resection.

Although the reconstruction methods were variable, the functional outcome after wide resection was more predictable. There was no recurrence for patients treated with wide excision, and there was no secondary oncological procedure for them. In the ten patients treated with wide resection, six had hemijoint allografts, three had megaprosthesis, and one had an alloprosthetic composite. Those patients with hemijoint allografts regained nearly full range of motion 3 months after surgery. There was no nonunion or graft fracture. None of these allografts have been revised to date. Four patients who initially received reconstruction with prosthesis after a wide resection had limitation in the range of motion of the knees, but they lived well in a sedentary lifestyle. In our series, hemijoint arthroplasty with osteoarticular allograft was promising. The joint surface of the allografts began to show more or less irregularity on radiographs 2 years after surgery, but it was asymptomatic until the opposite side was affected (usually more than 5 years after surgery). Two patients having had surgery more than 10 years ago still actively worked at the most recent follow-up.

Much research shows that wide resection provides a better local control than intralesional curettage. However, the latter regains a better functional outcome [6, 7, 9, 15], which is comparable to our own series [16]. However, for an advanced lesion, wide resection provided predictable results with better local control and less secondary procedures. Ward and Li [19] recommended taking a wide resection of the knee joint with approximately 50% of articular surface compromised. However, to our knowledge, most of the reports, no matter whether supporting a conservative or an aggressive resection for an advanced lesion, had not stated definite criteria that can be objectively measured and followed [1, 2, 4, 6, 7, 12, 14, 17]. By the current method that indirectly reflects the extent of subchondral bone involvement, we can identify patients who are at risk of complications from curettage and bone grafting, especially for those exceeding 40%.

Our series seems to show promising results with reconstruction of the knee using hemijoint osteochondral allograft. However, the source of allograft is limited in our country, and patient selection is also restricted. Of the other choices, reconstruction with a custom-made prosthesis also had satisfactory early results. However, bone loss for that procedure is tremendous. Since the majority of patients with giant cell tumours are relatively young and active, we leave this surgical option as the last resort.

For age, gender, Campanacci classification and tumour locations, there is no significant association with the Enneking functional rating score. The distribution of Campanacci grading in our series was also uneven, and there was no apparent association between them and the functional results in each group. There are many factors besides integrity of subchondral bone that should be taken into account when choosing a surgical modality, such as the presentation of pathological fracture, support of cortical bone, tumour infiltration of the soft tissue, and the aggressiveness of the tumour. Presentation of pathological fracture, which had not shown definite association with the recurrence, is not a contraindication to treatment by curettage and adjuvant therapy [2, 12]. The destruction of cortical bone can be augmented by bone grafting. The soft tissue infiltration can be managed by wider resection without sacrifice of the joint unless the stability of the whole reconstruction cannot be restored. Although there is some progress in the identification of histopathological factors and genomic expression to correlate with the tumour's aggressiveness, it is still not clinically practical [5, 8, 10].

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