New Technique of Reconstruction after Resection of Tumors of the Distal Femur: Role of Inverted Pedicled Fibular Graft

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ABSTRACT

Background and purpose: The fibular bone has been widely used as a free vascularized graft in reconstruction of defects of the femur after bone tumour resection which is technically demanding and time consuming. In this study, we describe a technique of rotating the ipsilateral fibula 180° on its vascular pedicle to reconstruct lower femur defects after tumour resection aiming at avoiding the morbidity of microvascular anastomoses.

Patients and methods: A prospective non-randomized study on seven patients (mean age 16.8 years) with osteogenic sarcoma of the lower femur was conducted at the NCI, Cairo University between January 2000 and January 2003. Those patients underwent preoperative chemotherapy regimens followed by radical resection and reconstruction of the resulting defect with pedicled vascularized fibular graft based on the peroneal artery. Internal fixation of the recipient bones was done by broad plate and screws. Staging and resectability were determined by preoperative CT chest, bone scan and MRI of the region around the tumor. Patients with pathological fractures or neurovascular bundle involvement were excluded. Six patients were stage II B and one patient was stage II A. Those patients were followed up for a period ranging from 15 to 33 months with an average of 24.2 months.

Results: Most resections were wide (six patients), while one was marginal. The size of the defect ranged from 13 to 23 cm in length (average 16.5 cm). Radiological evidence of union was noted at an average of 4.2 months (range four to six months). One patient had nonunion at the proximal junction and required conventional bone grafting. Hypertrophy of the fibula was seen in two patients. The functional results were satisfactory (good in five patients, fair in one and poor in one). Postoperative complications included minor wound infection in one patient, lateral popliteal nerve palsy in two patients, one of whom recovered completely and local recurrence followed by lung metastasis in one patient.

Conclusion: Pedicled inverted fibular graft is a valuable reconstruction option after resection of tumors of the lower femur.

Key Words: Vascularized fibular graft - Bone tumor resection.

INTRODUCTION

Large skeletal defects of bone, resulting from excision of osseous tumors in the lower third of the femur, continue to be a problem for the surgeons. There is no standard technique for reconstruction of such defects.

Different modalities have been used such as endoprostheses, allografts and autogenous free bone grafts with knee arthrodesis. Custom made endoprostheses retain the function of the knee, however, they have the risk of loosening after some years due to forces exerted on the bone cement interface [1]. In addition, procuring a prosthesis that is appropriate for the needs of an individual patient may be difficult in developing countries, because of the prohibitive cost and irregular supply.

Allografts take a long time, up to two years, to heal by creeping substitutions. They carry a high risk of infection, nonunion and stress fracture. Also, preparation and maintenance of a bone bank is not an easy task [2]. Also, autogenous free grafts have high incidence of complications as fatigue fracture, failure of incorporation and nonunion, especially when a bone gap is greater than 6 cm [3]. Microvascular autogenous free bone grafting is a good substitute in such conditions. It provides solid union in a short time between the graft and the recipient bone similar to fracture healing. Compensatory bone hypertrophy is also fundamental for the vascularized graft which contributes more to the stability of the limb [4].
The fibula is the bone of choice to reconstruct large defects after bone tumor resection, because of its length, biomechanical stability, limited donor site morbidity and predictable vascular pedicle [5]. However, this requires two surgical teams experienced with microvascular surgical technique, which is technically demanding and time consuming. Secondary surgery may be needed [6].

In this study we describe a technique of rotating the ipsilateral fibula 180 degrees on its vascular pedicle to reconstruct the lower third of the femur after resection of bone sarcoma without the need for microvascular anastomoses, aiming at avoiding the morbidity of microvascular anastomoses, shortening the time of operation and reducing blood loss. To our knowledge, the operative details of this simple technique have not been published previously.

PATIENTS AND METHODS

Between January 2000 and January 2003, seven patients with a mean age of 16.8 years (range from 15 to 19 years) underwent resection of the lower femur and reconstruction with ipsilateral inverted pedicled fibular graft. All had primary osteogenic sarcoma of the lower end of the femur.

Selection of patients was based on the histological diagnosis of osteogenic sarcoma by open biopsy. The exact site was condylar and supracondylar areas of the femur. Biopsy sites were properly done so as not to endanger subsequent resection. Biopsy sites were not properly done in two patients who were referred to us after being biopsied outside our institute.

Preoperative staging studies, which should be done before open biopsy, included plain radiography, MRI or CT of the region around the tumor, full body isotopic bone scanning and CT of the chest (Figs. 1,2). Preoperative angiography was not done in our cases. The surgical stage was done according to the Enneking [7] staging system. Six patients were stage II B and one patient was stage II A.

Patients were selected only if preoperative imaging had shown that a satisfactory surgical margin could be achieved and if no lung metastasis was detected. Patients with neurovascular bundle involvement, pathological fracture or diaphyseal disease were excluded. Patients should also have good cardiac, renal and hepatic functions by preoperative clinical assessment and laboratory investigations.

All patients received preoperative and postoperative chemotherapy.

Oncologic and reconstructive procedure:

The distal part of the femur was resected en bloc with a normal cuff of adjacent quadriceps muscles. If the tumor involved the knee joint, extra-articular resection including the proximal tibia was performed (Fig. 3). The accepted safety margin of the normal bone was at least three centimeters. The type of resection was estimated postoperatively as wide or marginal as described by Enneking [1]. Five patients had intra-articular resection and two patients had extra-articular resection. The mean size of the defect was 16.5 cm, ranging from 13 to 23 cm in length (Table 1).

After completion of the resection, the incision was extended to the lateral border of the fibula to be approached laterally as outlined by Gilbert [8]. The dissection included the upper part of the fibula. Care was taken to protect the lateral popliteal nerve curving around and adherent to the neck of the fibula.

The distal length of the fibula required was measured from the level where the peroneal artery originated from the posterior tibial artery, to be used as the level of rotation. The peroneal artery arises from the posterior tibial artery at an average 7.9 cm (range 5.7-11.9 cm) from the head of the fibula with a pedicle length ranging from 2 to 4 cm. It supplies the fibula through a nutrient artery and multiple periosteal branches [8]. So, we can measure the level of rotation approximately 8 cm from the head of the fibula. However, as the anatomy of the origin of the peroneal artery is highly variable, proximal branching helps to use a good length of fibula, while distal branching limits the proximal reach of the inverted fibula and may result in shortening of the limb, so we delayed the distal cut of the fibula until full exposure of the origin of the peroneal artery. The distal 8 cm of the fibula were left to preserve the ankle stability.

We had three precautions during inversion of the pedicled fibula. The first was that, in cases where the upper part of the tibia was not
included in the resection we had to remove the upper part of the fibula and part of the lateral condyle of the tibia to facilitate rotation of the fibula. As reported by McKee et al. [8], 96% of the foramina of the nutrient branch of the peroneal artery are found in the middle third of the fibula, so we could safely remove 8 cm measured from the head of the fibula without injury to the entry of the nutrient branch.

The second precaution was that if we rotated the fibula as such, the peroneal vessels would be stretched over the dissected lateral popliteal nerve. By doing more proximal dissection of the nerve and slight lateral rotation of the leg, the fibula and the peroneal vessels could be delivered behind the lateral peroneal nerve easily (Fig. 4).

The third precaution was that, some communicating veins between the vena commitants of the peroneal artery and the posterior tibial veins might be present. If we ligated these veins, this might add more length to the peroneal vessels and more proximal reach of the inverted fibula.

The transferred fibula was then examined for bleeding from the periostium and medullary canal. The vascular pedicle was examined for any possibility of being under tension, kinked, or presence of venous congestion.

It was better to insert the fibula into the medullary canal of the recipient bones after partial stripping of the periostium, so we usually took the fibula longer than the defect by two cm.

Internal fixation of the recipient bones was done using broad plate and screws (Fig. 5). During fixation, we made the affected limb shorter than the healthy one by two cm in two patients (cases no. 1,6).

The mean operative time was four hours and the mean blood loss was 850 ml.

Follow up was established bimonthly for physical examination, radiological evaluation of bone union, hypertrophy, recurrent or metastatic disease. All patients were followed up for a period that ranged from 15 to 33 months, with an average of 24 months.

The functional results were broadly evaluated on the basis of pain, walking ability, working capacity and shortening, as described by Yadav [9] (Table 2).

Mobilization was started early by non weight bearing exercises using axillary crutches. Partial weight bearing was allowed with the radiological evidence of bone union and full weight bearing was applied when the radiographs showed evidence of solid union or hypertrophy of the fibular graft.

**RESULTS**

(Table 3)

_Graft union and hypertrophy:_ Radiological evidence of graft union at both sides was evident in six patients at an average of 4.2 months (range four to six months). Hypertrophy developed in two patients (cases no. 2,3) one year after surgery. It was still early and did not match the size of the femur (Fig. 6).

_Oncological evaluation:_ Postoperative evaluation of the resection margins showed that they were wide in six patients and marginal in one patient (case no 1). Six patients remained free of disease at a mean of 24 months after surgery. One patient (case 1) developed local recurrence one year after surgery. He was subjected to hip disarticulation and second course chemotherapy. Despite chemotherapy, this patient developed multiple distant metastases to the lung over six months and died of his disease.

_Functional results:_ Six patients had satisfactory functional results (five good 2,3,4,5,7; one fair, 6) (Fig. 7). One patient developed local recurrence after one year and required amputation, i.e. poor functional result (case no 1).

_Complications:_

_Nonunion:_ One patient had a nonunion at the proximal end of the graft, between the femur and the fibula and he required grafting with cancellous bone to achieve union (Case no. 4).

_Infection:_ One patient developed partial necrosis of the skin without exposure of the plate and the graft. Infection was controlled by antibiotic and repeated dressing (case no. 3).

_Nerve palsy:_ Two patients had signs of postoperative peroneal nerve palsy (cases no. 6,7). One patient recovered completely after five months (case no. 7).
Reconstruction after Resection of Tumors of the Distal Femur

Fig. (1): Plain X ray of a case of osteosarcoma of lower femur.

Fig. (2): Preoperative MRI showing the intramedullary extension of the tumor.

Fig. (3): Post operative specimens of resected osteosarcoma (Intra-articular resection).

Fig. (4-A): Fibular graft pedicled on the peroneal vessels is dissected and inverted behind the common peroneal nerve.

Fig. (4-B): Fibular graft pedicled on the peroneal vessels is dissected and inverted behind the common peroneal nerve.

Fig. (5): Fibular graft in place, guttered into the femoral shaft and the tibia. The recipient bones were fixed with broad plate and screws.
Fig. (6-A): Extra-articular resection, immediate postoperative X-ray.

Fig. (6-B): X ray of the same patient after two years showing the callus and hypertrophy of the fibular graft.

Fig. (6-C): Plain X ray after 9 months showing union, example of intraarticular resection.

Fig. (7-A): Pictures of different patients. A. B. Note, no shortening.

Table (1): Patients and methods.

<table>
<thead>
<tr>
<th>No.</th>
<th>Age, yr</th>
<th>Sex</th>
<th>Stage</th>
<th>Type of resection</th>
<th>Extent of the defect</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>19</td>
<td>M</td>
<td>II B</td>
<td>Intraarticular</td>
<td>13 cm</td>
</tr>
<tr>
<td>2</td>
<td>17</td>
<td>M</td>
<td>II B</td>
<td>Extraarticular</td>
<td>23 cm</td>
</tr>
<tr>
<td>3</td>
<td>17</td>
<td>M</td>
<td>II B</td>
<td>Extraarticular</td>
<td>23 cm</td>
</tr>
<tr>
<td>4</td>
<td>15</td>
<td>M</td>
<td>II B</td>
<td>Intraarticular</td>
<td>15 cm</td>
</tr>
<tr>
<td>5</td>
<td>16</td>
<td>F</td>
<td>II B</td>
<td>Intraarticular</td>
<td>15 cm</td>
</tr>
<tr>
<td>6</td>
<td>18</td>
<td>M</td>
<td>II B</td>
<td>Intraarticular</td>
<td>14 cm</td>
</tr>
<tr>
<td>7</td>
<td>16</td>
<td>M</td>
<td>II A</td>
<td>Intraarticular</td>
<td>13 cm</td>
</tr>
</tbody>
</table>

Fig. (7-B): Pictures of different patients. A. B. Note, no shortening.
Because of its length, biomechanical stability, limited donor site morbidity and predictable vascular pedicle, the fibula has proved to be an excellent donor site for microvascular bone graft reconstructions of skeletal defects in long bones [10].

In reconstruction of the lower femur defects, it has been used as a free microvascular graft either as a single strut, double fibulae or double barrel, which is technically demanding and time consuming. The average operative time is eight hours and the average blood loss is two liters. [9,11-14]. When used as a pedicled graft, the fibula was used in reconstruction of defects of the tibia by simple transposition after retaining its endosteal and periosteal blood supply [15].

We studied the possibility of inversion of the fibula as a pedicled graft to bridge lower femur defects after tumor resection without kink to the pedicle. We made the arc of rotation of the fibula at the level of origin of the peroneal artery. The peroneal artery arises from the posterior tibial artery at an average 7.9 cm (range 5.7-11.9 cm) from the head of the fibula with a pedicle length ranging from 2 to 4 cm. This is variable among patients and it is difficult to detect the distal cut of the fibula without preoperative angiography [12]. We did not use preoperative angiography in our patients so, we delayed measuring the distal cut of the fibula until full exposure of the origin of the peroneal artery.

As the adult fibula is up to 40 cm in length, leaving 8 cm at the lower end to reserve ankle stability and 8 cm above the level of origin of the peroneal artery, approximately 24 cm are available for transfer [5]. Including the upper part of the fibula proximal to the level of origin of the peroneal artery helped to replace the upper tibia when extra-articular resection was performed as seen in cases no. 2,3. In all our patients, the proximal reach of the fibula could replace all the defects without shortening. However, 2 cm shortening was induced in case no. (1,6) because those patients had nearly mature epiphyses. Shortening of 2 cm did not cause marked leg length discrepancy and was well tolerated by those patients.

Addition of skin island to serve as a monitor for the vascularity of free vascularized fibular graft in reconstruction of femur defects is of limited value. The depth of the recipient femur requires the island to be inset to the overlying skin under excess tension. This makes the flap cyanotic and misleading [6]. In our technique, the vascularity of the fibula could be reliably assessed intraoperatively. Any tension, kink or congestion of the pedicle could be corrected before closure of the wound.

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**DISCUSSION**

Table (2): Functional evaluation of limb salvage of lower extremity [9].

<table>
<thead>
<tr>
<th>No.</th>
<th>P, D union</th>
<th>Hypertophy</th>
<th>Complications</th>
<th>Shortening</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>5-4 ms</td>
<td>–</td>
<td>Local, distant rec.</td>
<td>2 cm</td>
<td>Poor</td>
</tr>
<tr>
<td>2</td>
<td>4-4 ms</td>
<td>+</td>
<td>–</td>
<td>–</td>
<td>Good</td>
</tr>
<tr>
<td>3</td>
<td>5-4 ms</td>
<td>+</td>
<td>Minor wound inf.</td>
<td>–</td>
<td>Good</td>
</tr>
<tr>
<td>4</td>
<td>-4 ms</td>
<td>–</td>
<td>Proximal nonunion</td>
<td>–</td>
<td>Good</td>
</tr>
<tr>
<td>5</td>
<td>6-4 ms</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>Good</td>
</tr>
<tr>
<td>6</td>
<td>5-4 cm</td>
<td>–</td>
<td>Lat pop n palsy</td>
<td>2 cm</td>
<td>Fair</td>
</tr>
<tr>
<td>7</td>
<td>6-5 cm</td>
<td>–</td>
<td>Lat pop n palsy</td>
<td>–</td>
<td>Good</td>
</tr>
</tbody>
</table>
Six patients showed union at both ends of the graft after an average of 4.2 months. This was nearly the same time of union of free vascularized fibular graft according to the results of other authors [6,11,13,14]. Despite rigid fixation of the recipient bones, one patient (case no. 4) developed nonunion at the proximal junction. This patient required a conventional bone grafting to achieve union.

Compensatory hypertrophy seen in two patients (case no. 2, 3) started to appear one year after surgery. Rigid internal fixation supported the bone until bone union was established and protected the graft from the stresses that occurred during this hypertrophic phase. However, it causes stress shielding and delay the time of onset and progression of hypertrophy [16]. Amr et al. [14] reported that early removal of the fixation plate may result in stress fracture, so removal of the fixation plate should not be guided by union or periosteal hypertrophy as previously reported by De Boer and Wood [4], but by true widening of the medullary canal. We did not remove the fixation plate in the two cases who developed hypertrophy because those patients were active workers and the hypertrophy was still early.

All our patients had arthrodesis of their knees. Arthrodesis in the presence of painless and stable limb was accepted by all our patients in view of the seriousness of their medical problem. Early union and compensatory hypertrophy seen in two patients contributed to the stability of the limb and allowed a rapid program of rehabilitation. In comparison, other authors (1,2,3), who used different modalities as nonvascularized autogenous grafts and allogenic grafts to do knee arthrodesis after resection of tumors of the lower femur, reported a high incidence of complications as fatigue fracture, failure of incorporation and nonunion, especially when a bone gap was greater than 6 cm. Repeated operations and prolonged immobilization were often necessary for successful healing.

Gore et al. [17] and Lee et al. [18] reported that most patients who underwent removal of a portion of the fibula had subjective complaints and muscular weakness. The two patients (cases no. 6, 7) developed lateral popliteal nerve palsy and were managed conservatively with posterior slab. One patient (case no. 7) recovered completely after five months, while the other still had residual weakness. The problem during applying our technique was that we had to dissect the nerve more proximally to facilitate rotation of the fibula behind the nerve. This may explain the relatively higher incidence of lateral popliteal nerve palsy in our cases.

**Conclusion:** Our results indicate that inverted pedicled fibular graft is able to replace the defects of lower femur, condylar and supracondylar areas, after excision of neoplasms, while retaining the advantages of vascularized bone grafts but sparing a microvascular procedure.

**REFERENCES**

12- Jones N.F., Williams M.S., Donal C.M., Jesse B. and Jupiter J.B.: The double barrel free vascularized fibular


