Knee arthrodesis using a vascularised fibular rotatory graft after tumor resection

H. Nouri a,*, M.H. Meherzi a, M. Jenzeri b, M. Daghfous c, R. Hdidane b, K. Zehi d, L. Tarhouni c, S. Karray a, S. Baccari c, M. Mestiri a, M. Zouari d

a Adult Orthopaedics Department, M.T. Kassab Orthopaedics Institute, Mannouba, Tunisia
b Paediatric Orthopaedics Department, M.T. Kassab Orthopaedics Institute, Mannouba, Tunisia
c Plastic and Reconstructive Surgery Department, M.T. Kassab Orthopaedics Institute, Mannouba, Tunisia
d Traumatology Department, M.T. Kassab Orthopaedics Institute, Mannouba, Tunisia

Accepted: 3 November 2009

Summary

Introduction: Knee arthrodesis is one of the reconstruction options for limb preservation after malignant tumor resection. Vascularised rotatory fibular transfer allows biological and, thus, definitive reconstruction. The goal of this work was to analyse the results of knee arthrodesis with vascularised fibular graft after tumor resection and to discuss the reliability of this technique.

Patients and methods: We report a retrospective series of 13 patients with an average age of 29.6 years. The pathological diagnosis was bone sarcoma in 12 cases and synovial chondrosarcoma in one case. Resection/arthrodesis was undertaken as the primary procedure in 11 cases. In two cases, arthrodesis was indicated after failure of an endoprosthesis. Reconstruction was achieved with a vascularised fibular rotatory transfer in all cases. For stabilisation, an external fixator was utilised in eight cases, a femorotibial nail in three cases, and a plate in two cases. Mean follow-up was 6 years.

Results: We encountered infection in 53% of cases, mechanical complications in 53% of cases, and nerve palsy in 23% of cases. Four patients died from metastases (only one had arthrodesis complete union). In the nine surviving patients, arthrodesis was fully united in seven cases, after an average period of 36 months. The functional score average (Enneking classification) was 20 points.

Discussion: Knee arthrodesis after tumor resection is a complex technique. Septic complications and mechanical failure are frequent regardless of the technique employed. They are related to the extent of bone sacrifice but also to that of soft tissues. The use of vascularised fibula alone and stabilisation by external fixation were the main shortcomings in this series.

Type of study Retrospective: Level IV

© 2009 Published by Elsevier Masson SAS.

DOI of original article:10.1016/j.rcot.2009.11.007.
* Corresponding author.
E-mail address: nourhibib@yahoo.fr (H. Nouri).

1877-0568/S - see front matter © 2009 Published by Elsevier Masson SAS.
doi:10.1016/j.otstr.2009.11.001
Introduction

In the era of endoprostheses, knee arthrodesis still plays a role in conservative treatment after malignant tumor resection. It is sometimes the only alternative to amputation. Immobilising the knee in a good position with proper alignment is presented to patients as an acceptable sacrifice to achieve stable, pain-free and durable reconstruction with time. However, it has been demonstrated that massive substance loss may reduce the chances of success with arthrodesis [1—5]. Despite the multiplicity of techniques, the complication rate remains high, and the time to consolidation is significant. Vascularised fibular rotatory grafting is one of the techniques used in bone reconstruction. It comprises biological material that is capable of bridging massive bone defects and of hypertrophying under the influence of mechanical constraints [6].

The goal of our work was to analyse the results of vascular fibular rotatory grafting in knee arthrodesis after malignant tumor resection and the factors conducive to failure of this technique.

Patients and methods

We retrospectively reviewed the medical records of 13 patients who underwent knee arthrodesis by vascularised free fibular transfer after malignant tumor resection in our institute. Benign bone tumors and other indications of knee arthrodesis were excluded from this study. All these tumors had spread into the epiphysis, and no epiphyseal preservation was possible. The epidemiological, clinical and evolutive data were analysed in all patients. The functional results were assessed in surviving patients with a minimum follow-up of 2 years according to the functional classification of Enneking et al. [7]. Arthrodesis was considered to be consolidated when it allowed full weight-bearing without assistance. Graft vitality was evaluated at last follow-up according to the method of De Boer and Wood [6].

Epidemiology

This series consisted of five men and eight women with an average age of 29.6 years (8 to 64 years) (Table 1). Four of them still had open growth plates during tumor resection (patients 1 to 4). The tumors were distal femoral in seven cases, proximal tibial in five cases, and synovial in one case. The histological type was conventional osteosarcoma in six cases, Ewing sarcoma in three cases, bone chondrosarcoma in two cases, fibrosarcoma in one case, and synovial chondrosarcoma in one case. All these tumors were stage IIB, and the fibular graft. She is currently in septic pseudoarthrosis. Patient 12 presented a recurrent infection at 9 years that necessitated ablation of the nail and sequestrectomy of the fibular graft. He is currently in septic pseudoarthrosis. In one case, an inert fibular graft was associated with a vascularised fibula (Fig. 2).

Arthrodesis was achieved with external fixation in eight cases. This was an external, monoplane fixator in four cases, with assembly mounting by a first-generation Hoffman® type fixator in four cases. In three cases, we used femorotibial nails. They were full nails, straight in all planes, locked at their extremities; their length and femoral and tibial diameters were custom made. In two cases, stability was provided by a plate.

In adults, the limb was shortened from 1 to 2 cm to allow foot clearance when walking. In children, the limb was lengthened between 2 and 3 cm.

The chemotherapy protocols initiated pre-operatively were followed post-operatively. One patient (patient 2) also underwent radiotherapy of the surgical site because of a poor response of Ewing sarcoma to pre-operative chemotherapy.

Results

Complications

Early complications essentially included wound necrosis or scar infection in seven cases (53%), and peroneal nerve paralysis in three cases (23%). Wound necrosis required repeat surgery for debridement. Four cases evolved favourably after excision of the necrosis (patients 3, 7, 10 and 13). One patient (patient 5) evolved to chronic osteitis and retained a fistula on arthrodesis consolidation. Patient 12 presented a recurrent infection at 9 years that necessitated ablation of the nail and sequestrectomy of the fibular graft. She is currently in septic pseudoarthrosis. In one case, extensive necrosis with deep infection required thigh amputation on the 15th day after the intervention (patient 1). One case (patient 13) recovered from nerve palsy in 3 months.

Late complications were often mechanical (Fig. 3). Graft fracture was noted in seven cases (53%). It occurred between...
Table 1 Clinical data on patients.

<table>
<thead>
<tr>
<th>Sex/age</th>
<th>Site</th>
<th>Histology</th>
<th>Prior treatment</th>
<th>Reconstruction technique</th>
<th>BLR (cm)</th>
<th>Adjuvant treatment</th>
<th>Complications</th>
<th>Number of re-interventions</th>
<th>Oncological results</th>
<th>Graft status</th>
<th>Time to consolidation (months)</th>
<th>Follow-up(^a)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 M/8</td>
<td>DF</td>
<td>EW</td>
<td>—</td>
<td>VF+EF</td>
<td>14</td>
<td>CT</td>
<td>Wound necrosis</td>
<td>1</td>
<td>LR on stump</td>
<td>Thigh amputation at day 15 post-op</td>
<td>—</td>
<td></td>
</tr>
<tr>
<td>2 F/9</td>
<td>PT</td>
<td>EW</td>
<td>—</td>
<td>VF+EF</td>
<td>15</td>
<td>CT+RT</td>
<td>Wound necrosis</td>
<td>1</td>
<td>DFS at 4 years</td>
<td>Hypertrophy</td>
<td>18</td>
<td>48</td>
</tr>
<tr>
<td>3 M/14</td>
<td>DF</td>
<td>OS</td>
<td>—</td>
<td>VF+plate</td>
<td>17</td>
<td>CT</td>
<td>Wound necrosis</td>
<td>2</td>
<td>PM at 18 months</td>
<td>No hypertrophy</td>
<td>—</td>
<td>24</td>
</tr>
<tr>
<td>4 F/13</td>
<td>PT</td>
<td>OS</td>
<td>—</td>
<td>VF+EF</td>
<td>15</td>
<td>CT</td>
<td>Wound necrosis</td>
<td>1</td>
<td>DFS at 2 years</td>
<td>Hypertrophy</td>
<td>36</td>
<td>96</td>
</tr>
<tr>
<td>5 M/39</td>
<td>PT</td>
<td>OS</td>
<td>—</td>
<td>VF+EF</td>
<td>16</td>
<td>CT</td>
<td>Infecion</td>
<td>9</td>
<td>DFS at 2 years</td>
<td>Graft lysis</td>
<td>72</td>
<td>96</td>
</tr>
<tr>
<td>6 M/64</td>
<td>Synovial</td>
<td>CS</td>
<td>—</td>
<td>VF+EF</td>
<td>20</td>
<td>—</td>
<td>Graft fracture</td>
<td>7</td>
<td>DFS at 7 years</td>
<td>Aseptic pseudoarthrosis</td>
<td>48</td>
<td></td>
</tr>
<tr>
<td>7 F/24</td>
<td>PT</td>
<td>EW</td>
<td>—</td>
<td>VF+NVF+nail</td>
<td>18</td>
<td>CT</td>
<td>Wound necrosis</td>
<td>Nerve palsy</td>
<td>DFS at 2 years</td>
<td>No hypertrophy of 2 grafts</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>8 F/50</td>
<td>DF</td>
<td>CS</td>
<td>Cortical graft + nail</td>
<td>VF+plate</td>
<td>19</td>
<td>—</td>
<td>Infecion</td>
<td>1</td>
<td>DFS at 4 years</td>
<td>No hypertrophy</td>
<td>48</td>
<td>48</td>
</tr>
<tr>
<td>9 F/30</td>
<td>DF</td>
<td>CS</td>
<td>—</td>
<td>VF+EF</td>
<td>22</td>
<td>—</td>
<td>Graft fracture</td>
<td>5</td>
<td>DFS at 7 years</td>
<td>Consolidation at 5 years</td>
<td>60</td>
<td></td>
</tr>
<tr>
<td>10 F/21</td>
<td>DF</td>
<td>OS</td>
<td>—</td>
<td>VF+EF</td>
<td>20</td>
<td>CT</td>
<td>Wound necrosis</td>
<td>2</td>
<td>LR at 18 months</td>
<td>No hypertrophy</td>
<td>Amputation at 18 months</td>
<td>—</td>
</tr>
<tr>
<td>11 M/35</td>
<td>DF</td>
<td>OS</td>
<td>Endoprosthesis</td>
<td>VF+nail</td>
<td>22</td>
<td>—</td>
<td>Graft fracture</td>
<td>1</td>
<td>DFS at 2 years</td>
<td>Septic pseudoarthrosis</td>
<td>12</td>
<td></td>
</tr>
<tr>
<td>12 F/20</td>
<td>DF</td>
<td>OS</td>
<td>Endoprosthesis</td>
<td>VF+nail</td>
<td>20</td>
<td>—</td>
<td>Infecion</td>
<td>12</td>
<td>DFS at 16 years</td>
<td>—</td>
<td>156</td>
<td></td>
</tr>
<tr>
<td>13 F/58</td>
<td>PT</td>
<td>FS</td>
<td>—</td>
<td>VF+EF</td>
<td>19</td>
<td>—</td>
<td>Early infection</td>
<td>2</td>
<td>BM</td>
<td>Aseptic pseudoarthrosis</td>
<td>—</td>
<td></td>
</tr>
</tbody>
</table>

M: male; F: female; DF: distal femur; PT: proximal tibia; EW: Ewing sarcoma; OS: osteosarcoma; CS: chondrosarcoma; FS: fibrosarcoma; VF: vascularised fibula; EF: external fixator; NVF: non-vascularised fibula; BLR: bone loss to be reconstructed; CT: chemotherapy; RT: radiotherapy; LR: local recurrence; PM: pulmonary metastasis; BM: bone metastasis; DFS: disease-free survival; DCD: deceased.

\(^a\) Follow-up of arthrodesis.
the 12th and 14th day, always after removal of the external fixator. All these patients required at least one surgical re-intervention with replacement of the external fixator and cancellous bone grafts.

In total, all patients had repeat surgery at least once. Infections were more difficult to manage and required several operations. The number of re-interventions averaged four per patient (one to 12).

Oncological results

Local recurrence was observed in two cases at 18 months of follow-up, one (patient 1) on the amputated thigh stump, and the second (patient 11) on the non-consolidated arthrodesis. The thigh was amputated. Three patients developed lung metastases (patients 1, 3 and 10), and another (patient 13) incurred bone metastases in an average period of 22 months. All these patients died from their disease at an average 2 years of follow-up.

Nine patients were alive with an average follow-up of 8.6 years (2 to 22 years).

Anatomical results

Among the deceased patients, one (patient 13) had a consolidated arthrodesis. Two patients (patients 1 and 10) were amputated and another (patient 3) still bore external fixation.

Among the nine alive patients, seven had arthrodesis consolidation. The average period of consolidation was 36 months (6 to 72 months). Faster consolidation was
observed in arthrodesis stabilised by nail. One patient (patient 6) was in aseptic pseudoarthrodesis at 6 years of follow-up. He always retained a compression type Orthofix® external fixator despite many cancellous bone contributions. Another patient (patient 12) was in septic pseudoarthrodesis at 13 years of follow-up and refused amputation.

Significant hypertrophy of the vascularised graft was observed in two cases (patients 2 and 4). Lysis occurred in three cases, including two after chronic infection. In the other cases, the fibular graft ensured bone continuity, but without significant hypertrophy. Consolidation was essentially provided by iterative cancellous bone grafting.

Functional results

The functional outcome was evaluated in alive patients (nine cases) with an average follow-up of 6 years (2 to 13 years) (Table 2). The average functional score was 20 (3 to 27). Consolidated arthrodeses had a functional score of 24.8. They resulted in a pain-free limb with acceptable function without help, but walking was affected by limb shortening, which averaged 2.8 cm (1 to 4 cm). In two cases, limbs stabilised by nail retained their originally-fixed length. The others were reduced during evolution. Most patients accepted the results obtained. A fair result (score of 21) was associated with paralysis of foot muscles. The two patients with non-consolidated arthrodesis had a poor outcome (score of 3 points).

Discussion

Knee resection/arthrodesis has been adopted with success in tumor surgery since 1970 [10–15]. In 1977, Enneking and Shirley [11] demonstrated that arthrodesis for malignant knee tumors gave the same results as thigh amputation in terms of local disease control.

Currently, knee endoprostheses are the method of choice after tumor resection because joint mobility is preserved but mostly because of improved longevity. However, arthrodesis still essentially keeps its place in large resections of the extensor system. Other related indications are young age or financial conditions of patients. It also provides a rescue solution after the failure of endoprostheses.

The proposed techniques are multiple and differ according to the nature of the material used for bone reconstruction, but commonly retain the complex character of the intervention and frequent consolidation failures (Table 3).

Vascularised fibular grafts have been adopted with success in knee arthrodesis [13–16]. They offer a biological solution that is capable of bridging a large loss of bony substance and hypertrophy under the influence of mechanical constraints [6]. Rasmussen et al. [15] reported 12 cases of consolidation among 13 patients with a vascularised fibula in an average of 51 months. Usui et al. [14] likewise described 16 cases of consolidation in 17 patients. However, a major drawback of the graft is its small caliber in relation to that of the femur and the tibia, which often results in mechanical failure when it is used alone.

Mechanical complications were observed in 53% of cases from our series. They were related, on the one hand, to the

<table>
<thead>
<tr>
<th>Patient</th>
<th>Pain</th>
<th>Function</th>
<th>Acceptance</th>
<th>Support</th>
<th>Walking</th>
<th>Load</th>
<th>Score</th>
<th>LLI (cm)</th>
<th>Anatomical results</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>5</td>
<td>4</td>
<td>4</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>25</td>
<td>4</td>
<td>Consolidated</td>
</tr>
<tr>
<td>4</td>
<td>4</td>
<td>4</td>
<td>3</td>
<td>5</td>
<td>4</td>
<td>4</td>
<td>24</td>
<td>2</td>
<td>Consolidated</td>
</tr>
<tr>
<td>5</td>
<td>5</td>
<td>4</td>
<td>5</td>
<td>5</td>
<td>3</td>
<td>3</td>
<td>25</td>
<td>4</td>
<td>Consolidated</td>
</tr>
<tr>
<td>6</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>3</td>
<td>5</td>
<td>Aseptic pseudoarthrodesis</td>
</tr>
<tr>
<td>7</td>
<td>5</td>
<td>3</td>
<td>4</td>
<td>3</td>
<td>3</td>
<td>4</td>
<td>26</td>
<td>2</td>
<td>Consolidated</td>
</tr>
<tr>
<td>8</td>
<td>5</td>
<td>4</td>
<td>5</td>
<td>5</td>
<td>4</td>
<td>4</td>
<td>27</td>
<td>3</td>
<td>Consolidated</td>
</tr>
<tr>
<td>9</td>
<td>5</td>
<td>4</td>
<td>5</td>
<td>5</td>
<td>4</td>
<td>4</td>
<td>27</td>
<td>3</td>
<td>Consolidated</td>
</tr>
<tr>
<td>11</td>
<td>5</td>
<td>4</td>
<td>5</td>
<td>5</td>
<td>3</td>
<td>4</td>
<td>26</td>
<td>4</td>
<td>Consolidated</td>
</tr>
<tr>
<td>12</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>3</td>
<td>6</td>
<td>Septic pseudoarthrodesis</td>
</tr>
</tbody>
</table>

LLI: Limb length inequality.

<table>
<thead>
<tr>
<th>Authors</th>
<th>Type of graft</th>
<th>Number of patients</th>
<th>Patients with major complications</th>
<th>Follow-up (months)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Enneking and Shirley [11]</td>
<td>Cortical autograft</td>
<td>20</td>
<td>7</td>
<td>1 (14%)</td>
</tr>
<tr>
<td>Tomeno and Istria [12]</td>
<td>Cortical autograft</td>
<td>38</td>
<td>18</td>
<td>8 (44%)</td>
</tr>
<tr>
<td>Campanacci and Costa [10]</td>
<td>Cortical autograft</td>
<td>26</td>
<td>6</td>
<td>1 (17%)</td>
</tr>
<tr>
<td>Wada et al. [13]</td>
<td>Vascularized fibula</td>
<td>12</td>
<td>12</td>
<td>1 (8%)</td>
</tr>
<tr>
<td>Rasmussen et al. [15]</td>
<td>Vascularized fibula</td>
<td>13</td>
<td>5</td>
<td>0</td>
</tr>
<tr>
<td>Our series</td>
<td>Vascularized fibula</td>
<td>13</td>
<td>13</td>
<td>8 (61%)</td>
</tr>
</tbody>
</table>

a Complications affecting evolution.
small caliber of the fibula, but mostly to insufficient stability of the fixation on the other hand. According to Zaretski et al. [16], indications for a fibula alone are reconstruction of the upper limb, of the tibia or when there is a bone defect with continuity on one of the corticals and among children under 10 years of age.

Several techniques have been proposed to overcome this disadvantage. The method of Capanna et al. [17] consists of applying a sleeve on the vascularised graft with an allograft. Another solution is to separate the fibula in two while keeping a tissue flap carrying the vessels to obtain two vascularised grafts, but this technique is limited by the amount of bony substance lost. We could also associate the vascularised fibula with a non-vascularised, free fibula. In our series, the latter technique was used only once with consolidation in 6 months. At 2-year of follow-up, we saw no difference in vitality of the two grafts. De Boer and Wood [6], on the other hand, observed lysis of the non-vascularised graft and hypertrophy of the vascularised graft after limb loading.

In our opinion, external fixation was the main flaw in our technique. It was chosen to insert the fibular graft according to the inlay technique. However, cortical contact probably provides better graft consolidation and mechanical load transmission. In addition, the external fixator does not deliver good mechanical stability given the cantilever involved with knee arthrodesis. [18,19]. In the literature, its use is very limited after tumor resection. It is often reserved for arthrodesis due to tuberculosis sequelles and failure of total knee arthroplasties [1—5,18—20]. Knutson et al. [20] examined the stability of the external fixator in knee arthrodesis after infection and found better stability with sagittal pins connected by an anterior fixator. A frontal monoplane fixator has low stability in the flexion/extension plane. Conway et al. [18] inserted bi-plane external fixators for knee arthrodesis that allowed fixation from the small trochanter up to the distal tibial metaphysis in two frontal and sagittal planes for maximum stability.

The centromedullary nail is the best way of fixing knee arthrodesis [18,19]. Used by most authors [1,3,5,11,12], it offers excellent stability in limb flexion/extension. It also provides fixation of limb length and alignment. And its elasticity allows mechanical demands on the graft. According to De Boer and Wood [6], rigid assemblies, which exclude mechanical graft loading, weaken it and are responsible for a high rate of stress fractures (59%).

The rate of wound necrosis and infection, 53% in our series, was a feared complication, which can compromise consolidation and even limb preservation. Tomeno and Istria [12] reported an infection rate of 42% in 38 knee arthrodesis by cortical grafting. Five cases required amputation and six cases presented consolidation problems. In a series of 12 knee arthrodeses by vascularised fibula, Wada et al. [13] described three cases of wound necrosis and one case of late infection leading to limb amputation. This complication is essentially related first to significant sacrifice of soft tissues and second to a more extensive approach necessary for fibular graft harvesting. This undermines local vascularisation and creates dead spaces that promote infection.

Nerve palsy is also a frequent complication (23% of cases in our series). We believe that it is linked more to tumor resection than to fibular graft harvesting. It has been observed in 23% of cases in the series of Tomeno and Istria [12] and in 41% of the series of Wada et al. [13]. Krieg and Hefti [21] reported two cases of nerve palsy associated with fibula harvesting in 31 patients. They recommended a limit of 4 cm proximal to the graft to control this complication.

The success of bone grafts can also be compromised by adjuvant treatments. Friedlander et al. [22] examined the deleterious effect of chemotherapy on osteoblasts and suggested that it hindered the consolidation of fractures and allograft incorporation. At the end of their study, they observed no statistically significant difference between two groups of patients receiving or not peri-operative chemotherapy. Similarly, it is recognised that high-dose irradiation inhibits osteogenesis [23]. Shea et al. [24] and El-Gammal et al. [25] did not find differences in bone fusion after chemotherapy, but noted a significant negative effect of irradiation. Zaretski et al. [16] recommended provisional reconstruction with a cement spacer in patients with Ewing sarcoma, who are candidates for post-operative irradiation, with final biological reconstruction after 2 years for those who have a good prognosis.

Conclusion

Knee arthrodesis with vascularised fibula rotatory grafting seems to be fraught with complications, particularly mechanical accidents and infections. However, in some cases, we prefer it to knee endoprosthesis as it offers a definitive solution in young, active patients and whose survival has increased significantly. It is sometimes the only alternative to limb amputation. The outcome can be improved with a more rigorous technique and the use of two fibular grafts stabilised by a centromedullary nail.

Conflict of interest

None.

References

Knee arthrodesis using a vascularised fibular rotatory graft after tumor resection


