Vascular Management in Rotationplasty

Craig R. Mahoney MD, Curtis W. Hartman MD,
Pamela J. Simon RN, B. Timothy Baxter MD,
James R. Neff MD

Received: 22 February 2007 / Accepted: 18 February 2008 / Published online: 18 March 2008
© The Association of Bone and Joint Surgeons 2008

Abstract The Van Nes rotationplasty is a useful limb-preserving procedure for skeletally immature patients with distal femoral or proximal tibial malignancy. The vascular supply to the lower limb either must be maintained and rotated or transected and reanastomosed. We asked whether there would be any difference in the ankle brachial index or complication rate for the two methods of vascular management. Vessels were resected with the tumor in seven patients and preserved and rotated in nine patients. One amputation occurred in the group in which the vessels were preserved. Four patients died secondary to metastatic disease diagnosed preoperatively. The most recent ankle brachial indices were 0.96 and 0.82 for the posterior tibial and dorsalis pedis arteries, respectively, in the

reconstructed group. The ankle brachial indices were 0.98 and 0.96 for the posterior tibial and dorsalis pedis arteries, respectively, in the rotated group. Outcomes appear similar using both methods of vascular management and one should not hesitate to perform an en bloc resection when there is a question of vascular involvement.

Level of Evidence: Level III, therapeutic study. See the Guidelines for Authors for a complete description of levels of evidence.

Introduction

Borggreve [4] first described rotationplasty in 1930 as a treatment for limb shortening and knee ankylosis secondary to tuberculosis. Van Nes, in the 1950s, popularized this procedure for correcting the location of the tumor and necessary bone resection. From the late 1970s to the present, the procedure has been popularized as a limb-preserving procedure for skeletally immature patients with distal femoral or proximal tibial sarcomas [18, 29]. There are numerous physical benefits to rotationplasty when compared with above-knee amputation. Cammisa et al. [6] compared the energy cost of ambulation in above-knee amputees with that of patients with a rotationplasty. They found ambulation by patients after rotationplasty required 38% of maximum aerobic capacity whereas above-knee amputees required 46% [6]. Rotationplasty maintains a functioning joint at the level of the knee. This results in a more efficient gait pattern and decreased oxygen consumption [2, 6, 29].

However, numerous complications have been reported with this procedure, including nonunion, malunion, local recurrence, compartment syndrome, superficial infection, and deep infection [2, 6, 9, 13, 19]. One of the most serious

James R. Neff—Deceased.

Each author certifies that he or she has no commercial associations (eg, consultancies, stock ownership, equity interest, patent/licensing arrangements, etc) that might pose a conflict of interest in connection with the submitted article.

Each author certifies that his or her institution has approved the human protocol for this investigation, that all investigations were conducted in conformity with ethical principles of research, and that informed consent was obtained.

Electronic supplementary material The online version of this article (doi:10.1007/s11999-008-0197-4) contains supplementary material, which is available to authorized users.

C. R. Mahoney, C. W. Hartman, P. J. Simon,
B. T. Baxter, J. R. Neff
The Department of Orthopaedic Surgery and Rehabilitation,
University of Nebraska Medical Center, Omaha, NE, USA

C. R. Mahoney (✉)
Iowa Orthopaedic Center, 411 Laurel Street, Suite 3300,
Des Moines, IA 50314, USA
e-mail: iowamahoneymd@aol.com

potential complications involves vascular compromise of the reconstructed limb [11, 17, 20–22, 27, 32, 33].

Currently, two methods of vascular management are reported. Patients may be treated by primary transection and reanastomosis, sparing only the sciatic nerve, when a tumor is suspected to involve the major vessels. This approach eliminates loops of redundant artery and vein and allows potentially improved resection margins. One report suggests resection of the vessels is obligatory when performing rotationplasty for tumors of the distal femur [35]. Alternatively, major vascular structures can be retained as dictated by tumor involvement, response to chemotherapy, and the ability to provide an adequate vascular bed distally. The vascular structures when mobilized are externally rotated 180° with the lower leg and looped with the sciatic nerve. Reports of complications in this group include pseudoaneurysm and prolonged distal ischemia eventually requiring vascular reconstruction [3]. Reported complications in the anastomosis group include thrombosis at the anastomosis, requiring vascular revision [9, 11, 17, 20, 21, 27, 32]. Currently, there is no consensus regarding whether one of the approaches results in a higher rate of complications.

We asked whether the ankle brachial index (ABI) or complication rate between the two groups would differ with the two methods of vascular management for rotationplasty.

Materials and Methods

We retrospectively reviewed 15 patients (10 boys, five girls) ranging in age from 7 to 13 years, with an average age of 11.5 years, who underwent rotationplasty between April 1991 and May 1998. We resected the distal superficial femoral and popliteal vessels with the tumor in seven patients (Group A). In the remaining eight patients, the vessels were mobilized for rotation without transection (Group B). All seven patients in Group A had distal femoral tumors managed with a Type A1 rotationplasty as described by Winkelmann [35]. Five patients in Group B had proximal tibial tumors managed with a Type A2 rotationplasty [35]. Three patients in Group B had distal femoral tumors and were managed with a modified Type A1 rotationplasty in that the vessels were not transected [35]. Fourteen patients had osteosarcoma and one patient had synovial sarcoma. The patient with synovial sarcoma underwent rotationplasty as a salvage procedure to avoid above-knee amputation after an invasive *Aspergillus* infection developed after her initial tumor resection. All tumors were Stage IIB [10] at the time of initial evaluation. At the time of surgery, three patients had evidence of metastatic disease. Four patients died, all secondary to their

sarcomas, at an average of 46 months (range, 28–72 months) after their surgery. No living patient was lost to followup. The 15 patients were seen at a minimum followup of 28 months (mean, 95 months; range, 28–165 months).

Preoperative evaluation consisted of a history and physical examination, routine hematologic studies, routine radiographs and MRI of the involved extremity, and computerized axial tomography of the chest. Vascular studies included a limited arteriogram and a duplex scan of the deep and superficial venous systems. These studies were used to assess the extent of the tumor involvement and to plan the surgical procedure and vascular reconstruction. A biopsy-proven diagnosis was established in all patients preoperatively. We reviewed all radiographic data with a musculoskeletal radiologist (CWW), a vascular surgeon (BTB), and an orthopaedic oncologist (JRN).

All patients with osteosarcoma had completed a minimum of three courses of neoadjuvant chemotherapy before the anticipated surgical procedure. Patients typically completed chemotherapy 2 to 4 weeks before surgery. Hematologic parameters were followed closely by the pediatric oncology team and were normal at the time of surgery.

Patients with tumors showing maintenance of an otherwise normal fat plane between the sciatic nerve and the vessels were judged candidates to maintain continuity of the vessels. Patients having deviation of the vessels but maintenance of a normal fat plane also were presumed candidates to maintain vascular continuity. Patients with tumors showing the absence of a normal circumferential fat plane or encasement were considered candidates for vascular resection in continuity with the resection specimen to provide a minimum of a wide margin [10]. In all cases, the sciatic or tibial and peroneal nerves had to be uninvolved for a patient to remain a candidate for rotationplasty. The surgical approach was based on the approach described by Winkelmann [35] for Types A1 and A2 rotationplasties. The initial portion of the operation concerned the development of appropriate flaps and planes of dissection to adequately expose the peroneal nerve and sciatic nerve (Fig. 1). When appropriate, the vessels were mobilized, preserving the normal fat plane and keeping them isolated from the tumor. When vascular involvement was anticipated, the plane of dissection remained outside the vessels, thereby maintaining a wide margin of resection (Fig. 2). The average time to complete the surgery was 10.0 hours in Group A and 8.1 hours in Group B. During the case and postoperatively, a pulse oximeter was placed on the great toe and monitored closely (Fig. 3). Dextran (0.25 mL/kg/hour) was started at the end of the procedure and continued for 2 days to prevent thrombus of the venous anastomosis. To minimize swelling that can result from venous

Fig. 1 The initial portion of the operation concerns dissection and mobilization of the sciatic nerve. The nerve is localized by isolating the common peroneal nerve and dissecting proximally.

Fig. 2 Vascular shunts are used to maintain perfusion of the distal extremity during resection of the mass. After the resection is completed, the respective artery and vein are repaired by end-to-end anastomoses.

Fig. 3 A pulse oximeter is used on the distal portion of the ipsilateral extremity throughout the entire procedure with maintenance of oxygen saturation greater than 90%.

hypertension, the extremity was carefully dressed with a circumferential dressing, keeping the toes exposed for monitoring, and it was continuously elevated. Aspirin, 70 mg once daily, was initiated after the dextran was discontinued and continued until discharge from the hospital for 6 months.

Chemotherapy typically was resumed 2 to 4 weeks postoperatively when hematologic parameters had returned to normal. All patients had been familiarized with the expected cosmetic and functional outcome either by personal interaction with other patients or using videotapes of interviews with other patients.

Patients were seen in followup by the operating surgeon (JRN) at 2 weeks and then monthly for 3 months. Followup was more frequent for patients with wound complications. An ABI was obtained when the wounds were healed. Patients typically were seen every 3 months for the first year, every 4 months for the second and third years, every 6 months for the fourth and fifth years, and on a yearly basis thereafter. Routine radiographs of the involved extremity were obtained at each followup to evaluate the osteotomy site. Metastatic surveillance included a computed tomographic scan of the chest at each followup and an annual radionuclide bone scan.

The differences in the ABI between the two groups were determined using Student's *t* test with the level of significance set at $p < 0.05$. Survival was determined by calculating the percent of patients living at 5 years followup.

Results

Four patients died, all secondary to their sarcomas, at an average of 46 months after their surgery. Three deceased patients were in Group A and one was in Group B. Two of these patients were known to have systemic disease before their operation. Of the remaining patients, 10 have no evidence of residual neoplastic disease. One patient has evidence of metastatic disease 39 months after surgery. There have been no local recurrences. The average 5-year survival rate for the entire cohort was 81%. The 5-year survival rate for Group A was 71%, and the 5-year survival rate for Group B was 89%.

The mean ABIs for both groups for the posterior tibial and dorsalis pedis arteries were similar preoperatively and just over 2 months postoperatively (Table 1). The most recent ABIs for Group A at an average of 23 months postoperatively and Group B at an average of nearly 8 months also were similar (Table 2). The mean change from the preoperative to postoperative ABIs for both arteries in both groups was similar (Table 3), as was mean change from preoperative to final values (Table 4).

Table 1. Mean change in ankle brachial index

Group/Artery	Preoperative	Postoperative	p Value
Group A			
Posterior tibial	0.96 (0.89–1.00)	0.80 (0.64–1.05)*	0.28
Dorsalis pedis	0.98 (0.93–1.00)	0.57 (0.00–1.13)*	0.27
Group B			
Posterior tibial	1.03 (0.93–1.10)	1.00 (0.78–1.31) [†]	0.09
Dorsalis pedis	0.97 (0.91–1.00)	0.97 (0.81–1.22) [†]	0.09

* 2.4 months postoperatively; [†]7.2 months postoperatively.

Table 2. Mean change in ankle brachial index

Group/Artery	Preoperative	Last	p Value
Group A			
Posterior tibial	0.96 (0.89–1.00)	0.96 (0.64–1.35)*	0.17
Dorsalis pedis	0.98 (0.93–1.00)	0.82 (0.00–1.13)*	0.27
Group B			
Posterior tibial	1.03 (0.93–1.10)	0.98 (0.93–1.31) [†]	0.17
Dorsalis pedis	0.97 (0.91–1.00)	0.96 (0.81–1.22) [†]	0.16

* 23 months postoperatively; [†]7.7 months postoperatively.

Table 3. Mean change in preoperative to postoperative ankle brachial index

Artery	Group A	Group B	p Value
Posterior tibial	0.11	0.19	0.48
Dorsalis pedis	0.07	0.22	0.10

Table 4. Mean change in preoperative to final ankle brachial index

Artery	Group A	Group B	p Value
Posterior tibial	0.26	0.10	0.24
Dorsalis pedis	0.43	0.12	0.27

Duplex scanning was performed in two of the patients who had reconstruction during their routine followup. Notably, there was no evidence of intimal hyperplasia of the anastomosis.

There were 12 complications (five in Group A and seven in Group B) requiring an additional 36 operations (18 in both groups) in eight patients. Nineteen of the operations were performed on two patients. One patient in Group B experienced vascular insufficiency after discharge from the hospital. On return for the first postoperative visit, examination in the clinic revealed a largely necrotic, nonunited limb. Further inspection in the operating room confirmed the findings and the decision was made to amputate. Two patients, one from each

group, required vascular exploration within 24 hours of the operation secondary to venous congestion in the first and arterial thrombosis in the second. Both of these patients eventually required split-thickness skin grafting for necrotic areas around their respective wounds. Two of the patients in Group A had infections requiring irrigation and débridement. One patient initially was treated for synovial sarcoma with soft tissue resection and a medial gastrocnemius flap. Postoperatively, the wound became infected with *Aspergillus*, and despite numerous débridements, it remained infected. The limb was salvaged with a rotationplasty. The second patient had a postoperative infection and twice underwent irrigation and débridement to aid wound healing. This patient ultimately required hardware removal to achieve wound healing. The remaining additional operations were for soft tissue coverage secondary to wound-healing complications. These were equally divided between the two groups.

Discussion

Two methods are available for management of the vascular structures during a rotationplasty. These involve transection and reanastomosis of the vessels or retaining and rotating the vessels with the leg. It is not clear if one method results in superior outcomes. We asked whether the two methods of vascular management differ regarding ABI and rate of complications.

Two limitations of this study include the retrospective nature and the small sample size. A retrospective study design cannot be randomized and can be subject to bias. With a small variable cohort, one should exercise caution when generalizing the results.

The ABI is a well-described tool to indirectly measure the adequacy of arterial circulation of the lower extremity [24]. We used the ABI to evaluate the health of the vascular system with two methods of vascular management. Although the mean preoperative to postoperative changes in ABI were similar in Group A, there was a trend toward a lower ABI in the postoperative period, which partially recovered with time. This likely was attributable to a considerable decline in the ABI of two patients during the early postoperative period. We cannot be certain of the reasons for these findings, but we presume they were related to swelling around the anastomosis. Only one patient with a noticeable change in the ABI had a complication. All other complications were in patients with normal ABIs. A review of the literature finds other reports of this method of vascular management. Sidiropoulos et al. [31] reported finding no vascular complications in a series of 34 patients managed with vascular resection and reanastomosis. They recommend this method of vascular

management because of the improved resection margins, surgical time, and low rate of complications. We found no difference in complication rate between the two methods but did find the vascular reconstruction took slightly more time to perform.

Duplex ultrasound was performed in two patients to evaluate the anastomosis for intimal hyperplasia after a substantial interval decrease in the ABI. Surprisingly, we did not observe a single case of hyperplasia. We postulate the perioperative chemotherapy may have inhibited the cellular proliferation required for hyperplasia. This hypothesis is supported by the experience of using drug-eluting stents to prevent restenosis after percutaneous intervention for coronary artery disease [7, 26, 30].

We did experience some wound-healing problems at the site of the rotation. The rate and type of complications we found were similar to those described in other reports of limb-sparing surgery [12, 14]. It could be theorized the wound complications were secondary to a decrease in the peripheral blood flow to the skin resulting from our

vascular ligation and reanastomosis; however, patients had wound-healing problems in the group without shunting procedures as well. Furthermore, the problems encountered occurred in earlier cases, indicating a possible learning curve associated with the procedure, an idea both senior authors (BTB, JRN) support.

Several authors have reported using rotationplasty as a successful treatment option for a failed limb salvage procedure, albeit with higher complication rates than primary rotationplasty [5, 15]. The only patient in our cohort who did not have osteosarcoma underwent rotationplasty after failure of the primary resection for synovial sarcoma. After the rotationplasty, the patient had no additional complications.

There are some drawbacks to the rotationplasty. There is a long and intensive period of physical therapy that should be completed to ensure the limb is functional. This requires commitment from not only the patient but also the patient's family because nearly all of these patients are juveniles. Much has been written about the self-image of these

Fig. 4A–C A patient is shown 57 months after rotationplasty (**A**) wearing his prosthesis, (**B**) sitting and (**C**) standing without his prosthesis. He is clinically and radiographically free of disease. His wound healed with no skin loss and his prosthesis is well fitting and highly functional. He is extremely active and enjoys inline skating and bicycle riding (Videos 1 and 2, Supplemental Website Materials; supplemental materials are available with the online version of CORR).

patients after they have their surgeries [25]. It is no doubt hard to undergo major surgery for an illness, especially a serious illness like cancer, only to have the residual be an extremity that is deformed and initially not functional (Fig. 4). However, published reports suggest patients are well adjusted (in terms of SF-36 mental health scores) to the final outcome [1, 16]. One concern more recently has been the long postoperative hospital stay compared with amputation. In the age of managed care, prolonged hospital stays may become harder to justify; however, it is our opinion that a patient's well-being should never be compromised secondary to cost. Finally, the surgeon must consider, if the rotationplasty fails, the patient will be left with a considerably shorter residual limb than if transfemoral amputation had been the primary procedure.

Reconstruction with an expandable endoprosthesis could be considered an alternative option for many of these patients. Patients with intraarticular extension of the tumor and those with failed resection of a synovial sarcoma were not candidates for an expandable prosthesis. In addition, numerous orthopaedic oncologists, including the senior author (JRN), have expressed concern regarding the reported long-term durability and revision rates of the expandable prosthetic reconstructions [8, 28, 29].

We evaluated two methods of vascular management with the Van Nes rotationplasty and were unable to show a difference in the ABI or rate of complications between the two methods of vascular management. From this, we conclude resection of the vessels with reanastomosis is a surgically sound alternative to coiling of the vessels when the tumor dictates en bloc vascular resection.

Acknowledgments We thank Dr. Craig Walker for assistance in interpretation of the MRIs, Kerby Selmer for assistance with the patient database, and Dr. Kaleb Michaud for assistance with the statistical analysis.

References

1. Akahane T, Shimizu T, Isobe K, Yoshimura Y, Fujioka F, Kato H. Evaluation of postoperative general quality of life for patients with osteosarcoma around the knee joint. *J Pediatr Orthop B*. 2007;16:269–272.
2. Alman BA, Krajchich JJ, Hubbard S. Proximal femoral focal deficiency: results of rotationplasty and Syme amputation. *J Bone Joint Surg Am*. 1995;77:1876–1882.
3. Blewitt N, Pooley J, Berridge D, Chamberlain JC. Pseudoaneurysm of the superficial femoral artery: an unusual complication following rotationplasty. *Clin Orthop Relat Res*. 1994;306:171–174.
4. Borggreve J. Kniegelenkseratz durch das in der Beinlängsachse um 180 Degree gedrehte Fussgelenk. *Arch Orthop Unfall Chir*. 1930;28:175.
5. Brigman BE, Kumagai SG, McGuire MH. Rotationplasty after failed limb-sparing tumor surgery: a report of two cases. *Clin Orthop Relat Res*. 2003;415:254–260.
6. Cammisa FP Jr, Glasser DB, Otis JC, Kroll MA, Lane JM, Healey JH. The Van Nes tibial rotationplasty: a functionally viable reconstructive procedure in children who have a tumor of the distal end of the femur. *J Bone Joint Surg Am*. 1990;72:1541–1547.
7. Degertekin M, Regar E, Tanabe K, Smits PC, van der Giessen WJ, Carlier SG, de Feyter P, Vos J, Foley DP, Lighthart JM, Popma JJ, Serruys PW. Sirolimus-eluting stent for treatment of complex in-stent restenosis: the first clinical experience. *J Am Coll Cardiol*. 2003;41:184–189.
8. Eckardt JJ, Safran MR, Eilber FR, Rosen G, Kabo JM. Expandable endoprosthetic reconstruction of the skeletally immature after malignant bone tumor resection. *Clin Orthop Relat Res*. 1993;297:188–202.
9. Eilber FR, Morton DL, Eckardt J, Grant T, Weisenburger T. Limb salvage for skeletal soft tissue sarcomas: multidisciplinary preoperative therapy. *Cancer*. 1984;53:2579–2584.
10. Enneking WF. A system of staging musculoskeletal neoplasms. *Clin Orthop Relat Res*. 1986;204:9–24.
11. Fortner JG, Kim DK, Shiu MH. Limb-preserving vascular surgery for malignant tumors of the lower extremity. *Arch Surg*. 1977;112:391–394.
12. Futani H, Minamizaki T, Nishimoto Y, Abe S, Yabe H, Ueda T. Long-term follow-up after limb salvage in skeletally immature children with a primary malignant tumor of the distal end of the femur. *J Bone Joint Surg Am*. 2006;88:595–603.
13. Gottsauer-Wolf F, Kotz R, Knahr K, Kristen H, Ritschl P, Salzer M. Rotationplasty for limb salvage in the treatment of malignant tumors at the knee: a follow-up study of seventy patients. *J Bone Joint Surg Am*. 1991;73:1365–1375.
14. Hanlon M, Krajchich JJ. Rotationplasty in skeletally immature patients: long-term followup results. *Clin Orthop Relat Res*. 1999;358:75–82.
15. Hillmann A, Gosheger G, Hoffmann C, Ozaki T, Winkelmann W. Rotationplasty: surgical treatment modality after failed limb salvage procedure. *Arch Orthop Trauma Surg*. 2000;120:555–558.
16. Hopyan S, Tan JW, Graham HK, Torode IP. Function and upright time following limb salvage, amputation, and rotationplasty for pediatric sarcoma of bone. *J Pediatr Orthop*. 2006;26:405–408.
17. Imparato AM, Roses DF, Frances KC, Lewis MM. Major vascular reconstruction for limb salvage in patients with soft tissue and skeletal sarcomas of the extremities. *Surg Gynecol Obstet*. 1978;147:891–896.
18. Jacobs PA. Limb salvage and rotationplasty for osteosarcoma in children. *Clin Orthop Relat Res*. 1984;188:217–222.
19. Karakousis CP, Emrich LJ, Rao U, Krishnamsetty RM. Feasibility of limb salvage and survival in soft tissue sarcomas. *Cancer*. 1986;57:484–491.
20. Kawai A, Hashizume H, Inoue H, Uchida H, Sano S. Vascular reconstruction in limb salvage operation for soft tissue tumors of the extremities. *Clin Orthop Relat Res*. 1996;332:215–222.
21. Koperna T, Teleky B, Vogl S, Windhager R, Kainberger F, Schatz KD, Kotz R, Polterauer P. Vascular reconstruction for limb salvage in sarcoma of the lower extremity. *Arch Surg*. 1996;131:1103–1107; discussion 1108.
22. Krajchich JJ. Modified Van Nes rotationplasty in the treatment of malignant neoplasms in the lower extremities of children. *Clin Orthop Relat Res*. 1991;262:74–77.
23. Krajchich JJ, Carrol NC. Van Nes rotationplasty with segmental limb resection. *Clin Orthop Relat Res*. 1990;256:7–13.
24. McGee SR, Boyko EJ. Physical examination and chronic lower-extremity ischemia: a critical review. *Arch Intern Med*. 1998;158:1357–1364.
25. Merkel KD, Gebhardt M, Springfield DS. Rotationplasty as a reconstructive operation after tumor resection. *Clin Orthop Relat Res*. 1991;270:231–236.

26. Morice MC, Serruys PW, Sousa JE, Fajadet J, Ban Hayashi E, Perin M, Colombo A, Schuler G, Barragan P, Guagliumi G, Molnar F, Falotico R, RAVEL Study Group. RAnDomiZed study with the sirolimus-coated Bx VELOCITY balloon-expandable stent in the treatment of patients with de novo native coronary artery lesions. A randomized comparison of a sirolimus-eluting stent with a standard stent for coronary revascularization. *N Engl J Med*. 2002;346:1773–1780.
27. Nambisan RN, Karakousis CP. Vascular reconstruction for limb salvage in soft tissue sarcomas. *Surgery*. 1987;101:668–677.
28. Neel MD, Wilkins RM, Rao BN, Kelly CM. Early multicenter experience with a noninvasive expandable prosthesis. *Clin Orthop Relat Res*. 2003;415:72–81.
29. Rougraff BT, Simon MA, Kneisl JS, Greenberg DB, Mankin HJ. Limb salvage compared with amputation for osteosarcoma of the distal end of the femur: a long-term oncological, functional, and quality-of-life study. *J Bone Joint Surg Am*. 1994;76:649–656.
30. Serruys PW, Degertekin M, Tanabe K, Abizaid A, Sousa JE, Colombo A, Guagliumi G, Wijns W, Lindeboom WK, Ligthart J, de Feyter PJ, Morice MC, RAVEL Study Group. Intravascular ultrasound findings in the multicenter, randomized, double-blind RAVEL (RAnDomiZed study with the sirolimus-eluting VELOCITY balloon-expandable stent in the treatment of patients with de novo native coronary artery lesions) trial. *Circulation*. 2002;106:798–803.
31. Sidiropoulos A, Tjan TD, Soeparwata R, Wuisman P, Winkelmann W, Scheld HH. Reconstructive vascular surgery in rotationplasty for malignant tumors of the femur. *Int Angiol*. 1994;13:327–330.
32. Steed DL, Peitzman AB, Webster MW Jr, Ramasastry SS, Goodman MA. Limb sparing operations for sarcomas of the extremities involving critical arterial circulation. *Surg Gynecol Obstet*. 1987;164:493–498.
33. Tamini AH, Arndt JW, van Bockel JH, Steenhoff JR, Pauwels EK. Evaluation of the lymph flow with lymphoscintigraphy after rotationplasty for the treatment of bone tumors. *J Bone Joint Surg Am*. 1992;74:101–105.
34. Torode IP, Gillespie R. Rotationplasty of the lower limb for congenital defects of the femur. *J Bone Joint Surg Br*. 1983;65:569–573.
35. Winkelmann WW. Rotationplasty. *Orthop Clin North Am*. 1996;27:503–523.