

Effectiveness of Salvage Knee Rotationplasty on Sarcoma Around the Knee in Adolescents and Young Adults

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Abstract. *Background/Aim:* This study aimed to investigate the effectiveness of knee rotationplasty (KRP) as salvage surgery for uncontrolled infection and implant failure of total knee arthroplasty (TKA) for sarcoma around the knee in adolescents and young adults (AYA). *Patients and Methods:* This retrospective cohort study included 33 patients who underwent KRP and were grouped based on the treatment received: initial surgery for sarcoma around the knee (n=18) or as salvage surgery (n=15). Musculoskeletal Tumor Society (MSTS) score, range of motion (ROM) and postoperative results were analyzed. *Results:* All 15 patients who underwent salvage KRP had TKA as an initial surgery. Although there were five infections in salvage KRP, which originated from the initial TKA, all cases were controllable, no implant failure occurred. MSTS score and ROM were deemed acceptable in both groups. *Conclusion:* Salvage KRP is an effective option for uncontrolled complications of initial TKA for sarcoma around the knee.

Sarcoma is a rare cancer that is most common in the adolescent and young adult (AYA) generation as well as older adults. Various surgeries are performed on sarcomas that develop around the knee, including total knee arthroplasty (TKA), lower limb amputations, and knee rotationplasty (KRP). In recent years, along with perioperative chemotherapy, limb-sparing surgery such as TKA has become more common (1). However, TKAs have various potential complications, including postoperative infection and durability, often leading the requirement of salvage surgery. In addition, postoperative infections after

combined surgery for both extensive tumor resection and TKA are often difficult to control and, in the worst cases, often require amputation, rather than implant replacement.

KRP is a type of surgery in which the rotated ankle serves as a new knee after the knee is removed due to an existing bone tumor. While KRP is often not accepted aesthetically, it is known to have good postoperative lower extremity function (2). Furthermore, KRP is considered to be better than TKA in terms of controlling postoperative infection and durability of function (3). Previously, we reported that KRP as initial surgery can be a useful method for reconstruction of the knee after wide excision of a malignant musculoskeletal tumor around the knee joint, for restoring function and avoiding full lower limb amputation (4). For these reasons, our institution has performed KRP as a salvage surgery for implant failure and uncontrolled postoperative infection after TKA for sarcoma around the knee for over 30 years. We believe that, whenever possible, limb-sparing surgery, such as TKA, should be performed as an initial procedure, and KRP is an option for salvage surgery due to high-risk complications, such as uncontrolled infection or implant failure. However, an unaesthetic KRP may be unacceptable to the AYA generation, which is most likely to receive this salvage surgery, decreasing the likelihood of postoperative satisfaction and lower limb function. Based on these observations, we considered the clinical question of whether salvage KRP is useful for postoperative complications of TKA in AYA sarcoma patients.

To investigate the effectiveness of salvage KRP for complications after initial TKA surgery for AYA sarcoma patients, we evaluated the clinical course after salvage KRP and compared the postoperative functions and outcomes between those who received KRP as initial surgery and those who received KRP as salvage surgery.

Patients and Methods

Study design. Approval from the ethics review board of Chiba Cancer Center and written informed consent from each patient were obtained prior to inclusion and before starting the current study. We

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Key Words: Knee rotationplasty (KRP), salvage surgery, total knee arthroplasty (TKA), adolescents and young adults (AYA), sarcoma.

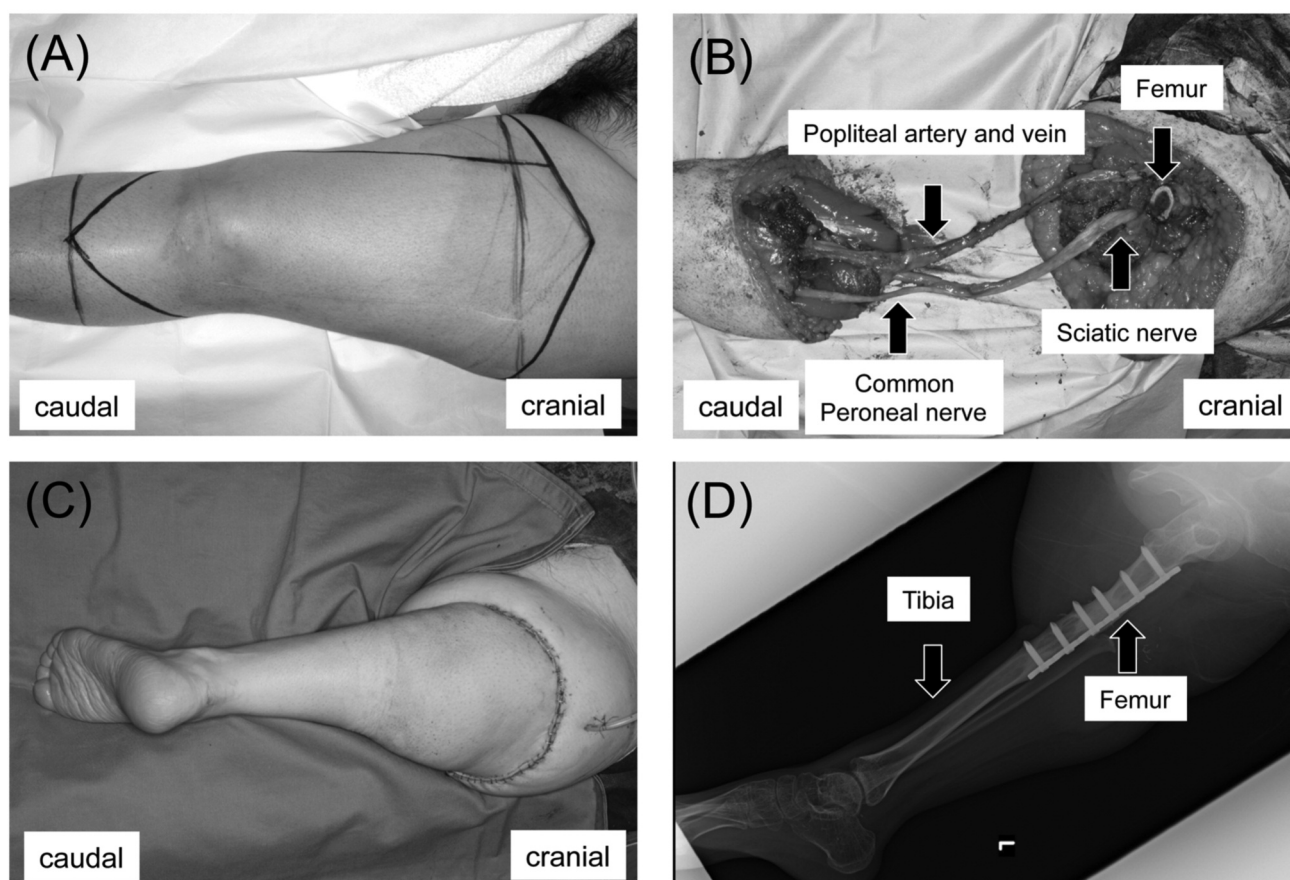


Figure 1. Intraoperative photographs and postoperative X-rays of knee rotationplasty (KRP). (A) Frontal view of preoperative skin incision line. (B) Intraoperative photograph of KRP. Popliteal artery, popliteal vein, common peroneal nerve, and sciatic nerve were conserved. (C) Reconstruction of the knee extension mechanism using the triceps surae. The ankle joint is rotated 180° and sutured to the thigh. (D) Postoperative X-rays of KRP. Tibia and femur were fixed by internal plate.

retrospectively reviewed our institution's database for AYA patients who underwent KRP from 1988 through 2018.

Surgical procedure and postoperative management. Informed consent was obtained from each patient before surgery. After the advantages and disadvantages of KRP, TKA, and arthrodesis were explained, each patient was given the opportunity to personally choose their surgical procedure. KRP followed a surgical procedure similar to that reported by Kots *et al.* (5). As shown in Figure 1, the popliteal blood vessels, common peroneal nerve, and sciatic nerve were conserved, the amputated lower leg was rotated, and the femur and tibia were fixed with implantation. In planning the length of osteotomy, the length of the affected thigh after surgery was designed to equal the length of the healthy thigh in the kneeling position, if the patient was a fully grown adult. In growing pediatric patients, the osteotomy length prior to completion of bone growth was decided in consideration of their bone growth in the future. The reserved growth capacity of the distal growth plate of the tibia was approximately 2/3 of that of the distal femur, thereby necessitating correction of only 1/3 growth capacity of the distal femoral growth plate. Accordingly, the affected thigh was lengthened approximately 4 cm at age 6 and 2 cm at age 10 in

Japanese pediatric patients. After an ischium-supporting, non-weight bearing prosthesis was fitted, walking rehabilitation was initiated at 3 months postoperatively in patients with KRP as an initial operation, and at 4 weeks postoperatively in patients who underwent KRP as salvage surgery. A below-the-knee prosthesis without ischium support was adapted after bone union completion in patients who underwent KRP as salvage surgery (6).

Patients and clinical characteristics. We identified 33 AYA patients (age <40 years old) who had received KRP due to sarcoma around the knee at the Chiba Cancer Center. Patients were divided into two groups: an initial group consisting of 18 patients in which the operations were performed as initial surgery and a Salvage group consisting of 15 patients in which the operations were performed as salvage surgery for complications after TKA, such as implant failure and infection. Patient demographics including sex, age at operation, periods of follow-up, histology, tumor location, and previous surgery are presented in Table I.

Parameters for investigation. Intraoperative and postoperative results include operation time, amount of bleeding, postoperative complications,

Table I. Patient demographics and disease characteristics, including gender, age at operation, follow-up period, histology, tumor location, and previous surgery.

Characteristics	Overall (n=33)	Initial (n=18)	Salvage (n=15)	p-Value
Gender (n)				0.2
Male	26	16	10	
Female	7	2	5	
Age at operations (mean, years)	21.2	15.7	27.8	0.0001*
Follow-up period (mean, years)	13.4	13.3	13.4	0.98
Histology (n)				
Osteosarcoma	28	16	12	0.64
Synovial sarcoma	2	2	0	0.49
Fibrosarcoma	1	0	1	0.45
Liposarcoma	1	0	1	0.45
UPS	1	0	1	0.45
Tumor Location (n)				0.14
Femur	21	9	12	
Tibia	12	9	3	
Previous surgery (n)				
Total knee arthroplasty	15	0	15	
None	18	18	0	

UPS: Undifferentiated pleomorphic sarcoma. *Statistically significant.

reoperation, and disease status (Table II). Postoperative functions include Musculoskeletal Tumor Society (MSTS) score and range of motion (ROM) of the reconstructed knee joint (Table III). The MSTS score consists of six items: pain, function, emotional acceptance, support, walking ability, and gait. Points for each item of the MSTS score were totaled and an overall evaluation was made with 26-30 points as excellent, 21-25 points as good, 16-20 points as moderate, and 15 points or less as poor. Furthermore, we analyzed the overall survival rate of these two groups (Figure 2A and B).

Statistical analysis. Patient data were entered into our database in a consecutive manner. All data were collected from the central electronic medical record at our institution. All analyses were performed using SAS software, version 14.2 (SAS Institute, Inc., Cary, NC, USA). Differences between groups were assessed with Student's *t*-test, Fisher's exact test, chi-square test. Survival was evaluated with Kaplan-Meier analysis and differences were assessed using the log-rank test. A *p*-value less than 0.05 was considered statistically significant.

Results

Patient demographics. A total of 33 patients (aged <40 years) with a diagnosis of sarcoma around the knee joint who underwent KRP were included in the current study. Of these, 18 patients underwent KRP as initial surgery and 15 patients underwent KRP as salvage surgery after complications due to TKA. The complete patient demographics and clinical characteristics are presented in Table I. Of the 33 patients,

Table II. Intraoperative and postoperative results, including operation time, bleeding, complications, reoperation, and disease status.

Variables	Overall (n=33)	Initial (n=18)	Salvage (n=15)	p-Value
Intraoperative outcomes				
Operation time (min, mean)	506	470	553	0.048*
Bleeding (ml, mean)	1448	945	2105	0.006*
Postoperative complications (n)				
Infection	5	0	5	0.012*
Nerve palsy	5	4	1	0.34
Ischemia	3	2	1	0.65
Non union	3	3	0	0.23
Reoperation (n)				
Neurovascular anastomosis	2	2	0	0.48
Hip disarticulation	2	0	2	0.19
Above knee amputation	1	0	1	0.45
Debridement	1	0	1	0.45
Bone implantation	1	1	0	0.35
Disease status (n)				
CDF	17	7	10	0.16
NED	8	3	5	0.41
DOD	8	8	0	0.003*

CDF: Continuous disease free; NED: no evidence of disease; DOD: died of disease. *Statistically significant.

26 were male (79%) and patients' mean age at operation was 21.2 years (range=7-39 years). Patients in the Salvage group (27.8 years) were significantly older than those in the Initial group (15.7 years; $p<0.01$). The mean follow-up period was 13.4 years (range=1.6-31 years). The histologies of patients' sarcomas are osteosarcomas (28 cases), synovial sarcoma (two cases), fibrosarcoma (one case), liposarcoma (one case) and undifferentiated pleomorphic sarcoma (one case). Tumor locations were as follows: at the distal femur (21 cases) and at the proximal tibia (12 cases). In the Salvage group, all 15 previous surgeries were TKA. Of the 15 previous TKAs, KRP was performed as salvage surgery due to difficult to control infection in 14 cases and implant failure in one case.

Intraoperative and postoperative results. The complete intraoperative and postoperative results are presented in Table II. The mean overall operative time for KRP was 506 min. However, operative time was significantly shorter in the Initial group (470 min) compared to the Salvage group (553 min; $p<0.05$). The mean overall blood loss during KRP was 1,448 ml, but this was significantly greater in the Salvage group (2,105 ml) than the Initial group (945 ml; $p<0.01$), requiring more blood transfusions. The prolonged surgery and massive bleeding in the Salvage group may be due to the time required to remove the prosthesis and the difficulty in controlling the

Table III. Postoperative lower limb functions, including MSTS score and ROM (°).

Variables	Overall (n=33)	Initial (n=18)	Salvage (n=15)	p-Value
Overall MSTS evaluation (n)				
Excellent	16	8	8	
Good	15	9	6	
Moderate	2	1	1	
Fair	0	0	0	
Overall MSTS score (points, mean)	24.4	24.3	24.5	0.83
Range of Motion (degree, mean)	76.6	75.8	77.6	0.7

MSTS: Musculoskeletal tumor society.

bleeding from the bone marrow. Postoperative complications included infection (five cases), nerve palsy (five cases), ischemia (three cases), and nonunion (three cases). All five cases of infection were in the Salvage group, which was significantly greater than the lack of cases of infection in the Initial group ($p<0.05$). However, all five infectious cases in the Salvage group had already experienced infections after their initial TKA operation, thus requiring salvage surgery for controlling the infection. There was no novel case of infection after salvage surgery, and no case of implant failure as a postoperative complication between groups. Reoperations after KRP were required due to neurovascular anastomosis (two cases), hip disarticulation (two cases), above knee amputation (one case), debridement for infection (one case), and bone implantation for nonunion (one case). In the case of debridement for infection in the Salvage group, the infection was completely under control, suggesting that KRP is useful for cases of difficult infection control. The two cases of hip disarticulation were due to blood flow disturbance. The above knee amputation in the Salvage group was a 31-year-old woman with a good course of salvage KRP, but the appearance of the KRP was unacceptable and led to amputation. Disease statuses were continuous disease-free (CDF; 17 cases), no evidence of disease (NED; eight cases) and died of disease (DOD; eight cases).

Postoperative lower limb functions and 5-year survival rate. The mean overall postoperative MSTS score was 24.4 (range=16-28). There was no significant difference in mean postoperative MSTS scores between the Initial and Salvage groups (Table III). The mean ROM of the knee was 76.6° (range=50-100°). There was no significant difference in postoperative ROM of the knee between the two groups. Figure 2A and B presents the Kaplan-Meier survival curves in patients who underwent the initial and salvage KRP, and

the overall survival of the whole cohort. The overall 5-year survival rate was 81.7%. Five-year survival was 66.7% in the Initial group, compared with a significantly better rate of 100% in the Salvage group ($p<0.01$). The poor survival rate in the Initial group is thought to be due to the proximity of the tumor to the vessel, and its large size, making limb preservation impossible as an initial operation.

Discussion

The mortality and morbidity of osteosarcoma and soft tissue sarcoma are high for AYAs. Since 1976, an expandable prosthesis has been adopted for skeletally immature patients with malignant tumor in the extremity, especially in the lower extremity (7). While the appearance of the affected limb preserved with prosthesis is good, the prosthesis has many potential serious postoperative complications, such as infection and durability. In a systematic review, Thornley *et al.* summarized that deep infection, which required removal of the initial prosthesis, occurred in 247 of 2,721 patients (9%) at a mean of 24 months after the operation (range=1-372 months) (8). Infection control is often difficult to achieve after revision surgery for debridement and implant replacement, and amputations are often necessary. Furthermore, joint replacements in children often fail within a few decades and require revision. Zhang *et al.* reported that the estimated overall five-year and eight-year implant survival rates were 77.7% and 54.5%, respectively, requiring salvage surgery (9).

KRP is a surgical method in which the ankle joint is repurposed to function as the knee joint by segmental resection of the knee joint, followed by a 180° rotation of the lower leg for osteosynthesis. KRP was first performed by Borggreve in 1927 (10), and was later described for general use by Van Nes and Kotz *et al.* (5). Although biological reconstructions such as KRP include unfavorable aesthetics and limb length discrepancy, they are highly functional and are often more useful for infection control than a prosthesis (3).

In the current study, all 15 salvage surgeries were performed after TKA as initial surgery. Of these 15 surgeries, 14 were performed due to difficulty in controlling infection in the initial surgery. No postoperative infection was observed in cases where KRP was performed as the initial surgery. Although 5 of 15 cases of salvage KRP had infection, all five cases of infection were due to the original infection in the initial TKA surgery. No novel infections after salvage surgery occurred. Furthermore, since debridement surgery, not amputation, was more effective in managing infection after salvage surgery, we believe that KRP surgery is useful for salvage surgery after difficult to control infection post-TKA. However, since operative time and blood loss are significantly greater with KRP as a salvage surgery than during KRP as the initial surgery, infections caused by salvage surgery must also be taken into account. Furthermore, KRP in the current study showed no implant

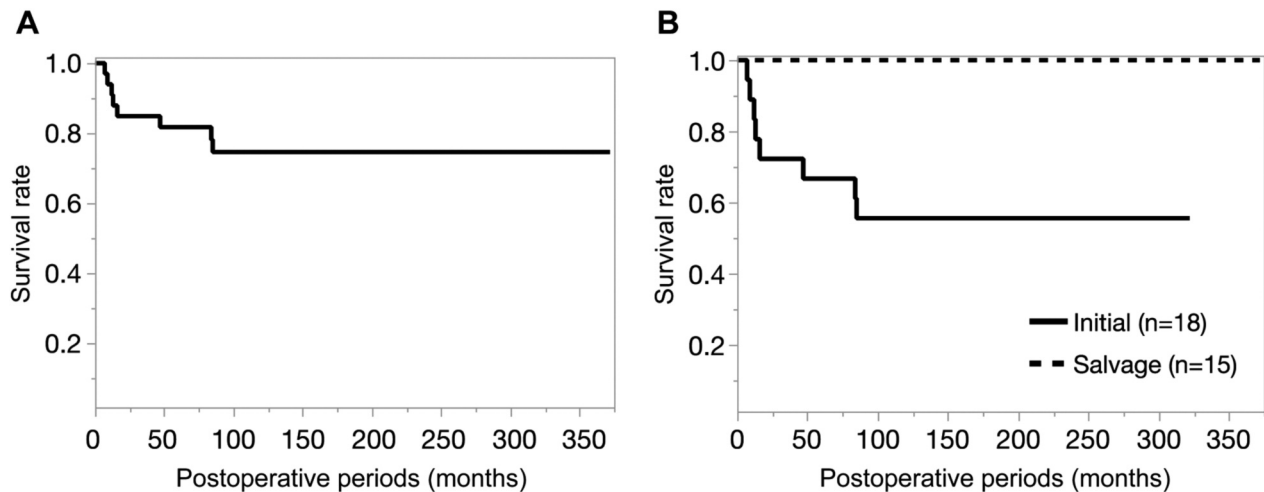


Figure 2. Kaplan-Meier survival analysis. (A) Kaplan-Meier analysis demonstrated that the overall 5-year survival rate was 81.7%. (B) Five-year survival rates were 66.7% in the Initial group and 100% in the Salvage group, respectively ($p=0.005$).

failure, with only one case of bone grafting (3%) due to bone union failure, suggesting that KRP was durable.

Kawai *et al.* reported an MSTS score of 24 points for TKA due to sarcoma, and KRP in the current study was also comparable to TKA, with a mean MSTS score of 24.4 points (11). The mean knee ROM was 76° post KRP, which is enough to allow for functional walking. Furthermore, the mean score of emotional acceptance among patients included in this study was approximately 4 (out of 5), indicating that patients' overall acceptance of KRP was relatively good. The 5-year overall survival rate was 81.7%, which compares favorably with 77.7% in TKA (9). Table IV presents the long-term follow-up of more than 5 years in the previous reports of KRP for sarcoma around the knee. While the mean follow-up period of the current study was 13.4 years, deemed a long-term report, the MSTS score was similar to previous reports (12-21). Guntmar *et al.* reported that long-term results indicate that KRP provides a high quality of life with a good functional outcome for activities of daily life and even sports (22).

Despite these favorable results, the AYA generation is an impressionable generation. In the present study, 21% of all cases were female, indicating KRP may be less popular in females due to its poor appearance. A 31-year-old female patient in this study, despite a good postoperative course of salvage KRP, disliked the appearance of the limb, leading to an additional amputation. While the KRP is functional, the acceptance of this procedure within the AYA generation indicates the procedure needs to be chosen carefully due to its unaesthetic appearance.

In conclusion, KRP is considered to be a comparable procedure to prosthesis in terms of functional prognosis. Furthermore, salvage KRP post-TKA was resistant to infection and performed as well as KRP as initial surgery. Whenever

Table IV. Main series reporting long-term outcomes of KRP for sarcoma around knee.

Study	Follow-up* (years)	No. of patients	MSTS scores*
Forni <i>et al.</i> (12)	17 (4)	20	N/A
Maria <i>et al.</i> (13)	15 (3-22)	25	25 (20-26)
Gebert <i>et al.</i> (14)	14 (10-25)	21	N/A
Rodl <i>et al.</i> (15)	12 (10-18)	22	N/A
Hillmann <i>et al.</i> (16)	10 (3-19)	14	24 (4)
Hopyan <i>et al.</i> (17)	9 (5-14)	5	20 (18-22)
Hanlon and Krajbich (18)	8 (4-11)	21	N/A
Fuchs <i>et al.</i> (19)	8 (4-16)	7	25 (22-27)
Veenstra <i>et al.</i> (20)	6 (1-11)	33	N/A
Gottsauner-Wolf <i>et al.</i> (21)	5 (3)	60	N/A
The current study	13.4 (9.6)	33	24.4 (2.72)

N/A: Not available; *Mean (SD or range).

possible, we believe that limb-sparing surgery should be performed as an initial procedure, however, from these results, it is indicated that KRP is an effective option for salvage surgery due to infection or implant failure of the initial surgery.

Conflicts of Interest

The Authors have no conflicts of interest directly relevant to the content of this article.

Authors' Contributions

H.K, T.Y, and T.I designed and performed experiments, analyzed data and wrote the article; H.K, Y.H, T.T, M.I, F.T, S.O gave technical support and conceptual advice.

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