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Patient-oriented Functional Results of Total Femoral Endoprosthetic Reconstruction Following Oncologic Resection

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Abstract

Background and Objectives—Functional outcomes following oncologic total femoral endoprosthetic reconstruction (TFR) are lacking. We compared patient-oriented functional results of TFRs to proximal femur and distal femur reconstructions (PFR and DFR). We also compared function and complications with regard to knee and hip componentry.

Methods—54 TFR patients were identified from 3 institutional prospective databases. 41 had fixed- and 13 had rotating-hinge knees, 37 hemiarthroplasty and 17 total hip arthroplasty componentry. Toronto Extremity Salvage Scores (TESS) for n=27 were compared between groups and to cohorts of PFR (n=31) and DFR (n=85) patients using the Mann-Whitney U test.

Results—Follow-up averaged 4 years. Mechanical complications included 5 hip dislocations and 1 femoral malrotation. Four dislocations were in fixed-hinge implants, all in those lacking abductor reattachment. TESS averaged 69.3±17.8, statistically decreased from DFR (p=0.002) and PFR patients (p=0.036). No significant differences were detected between patients in the fixed-hinge (n=18) and rotating-hinge (n=9) groups (p = 0.944), or total hip (n=8) and hemiarthroplasty (n=19) groups (p=0.633).

Conclusions—TFR is reserved for extreme cases of limb salvage, portending a poor prognosis overall. Function reflects additive impairments from PFR and DFR. TFR outcomes differ little with rotating- or fixed-hinge, total hip or hemiarthroplasty implants.

Keywords

total femur; endoprosthesis; sarcoma; limb-salvage

Introduction

Wide resection and endoprosthetic reconstruction of large segments of bone has become a well-accepted alternative to amputation for local management of musculoskeletal tumors when compromise of neither surgical margins nor ultimate functional outcome is expected. The most common bone requiring such resection and reconstruction is the femur. Indeed, the first limb salvage alternatives to amputation for primary bone sarcomas involved resection of the entire femur and reconstruction with a custom metallic endoprosthesis. Advances in imaging have since improved the predictable oncologic safety of partial femur resections. Furthermore, reconstructions of either the hip or the knee are assumed to provide ostensibly better functional results than reconstruction of the entire bone and both joints. Because of these factors, the relatively common indication for total femur resection and reconstruction during the late 1970s and early 1980s has become so narrowly defined that in the last two decades, it is rarely encountered even in large referral centers for sarcoma care. Nonetheless, there remain circumstances of especially extensive bone length involvement by a tumor or complications of primary reconstruction with a proximal or distal femur endoprosthesis that render total femur resection and reconstruction the only option for limb salvage.

Since the first reported endoprosthetic reconstruction of the entire femur by Buchman in 1965¹, the bulk of literature concerning total femur resection and reconstruction has come from small case series (7 or fewer patients) reported independently²⁻¹⁰, or embedded within reports of larger series of endoprosthetic reconstruction of other skeletal sites¹¹⁻¹⁴. Of the few larger series (11 to 21 patients), two reported results of the 1970s era custom prostheses and focused on the primary novelty of the limb salvage procedure itself^{15,16}, two are embedded in larger reports of endoprosthetic reconstruction^{17,18}, and three focus specifically on the technical challenges inherent to the undertaking of contemporary total femur resection and endoprosthetic reconstruction¹⁹⁻²¹. None of these prior studies has provided patient-oriented outcomes results.

Furthermore, in this era of modular endoprostheses, there has been no attention paid specifically to design characteristics helpful to reconstruction of the entire femur. Rather, independently designed proximal and distal femur endoprostheses are simply connected by a modular segment. Specifically, there has been a significant upswing in the popularity of rotating-hinge componentry for distal femur reconstructions. This popularity is pervasive enough that fixed-hinge implants are becoming less available. A rotating-hinge joint mechanism at the knee may have implications in the setting of a total femur reconstruction that are distinct from its implications in the setting of distal femur reconstruction alone, especially when concomitant, massive myomectomies are necessary. In contrast to a distal femur only implant, a total femur enables neither normal proximal femur rotational control by lacking normal muscular insertions for the adductors and flexors, nor knee rotational control by lacking normal muscular origins for the quadriceps other than the rectus femoris. Challenges with rotational instability at the knee and hip have been reported in the TFR setting¹⁹; the effect of rotating-hinge componentry on this instability has not been investigated.

Prior to the practically inevitable disappearance of fixed-hinge components from the modular endoprosthesis market, we felt it was important to determine if there were discernible differences between these fixed-hinge and rotating-hinge devices. Rotating-hinge and fixed-hinge devices in the knee have not specifically been compared with regard to function and stability for the hip and knee in patients following TFR. With this paucity of literature regarding contemporary modular implants in mind, we have undertaken a retrospective review of prospectively collected data from patients treated with total femur resection and endoprosthetic reconstruction. We hypothesized that instability would be

more problematic in patients with rotating hinge knee componentry. We also report the first patient-oriented functional outcomes for patients following TFR.

Materials and Methods

With Institutional Review Board approval, the prospectively collected databases of patients from three tertiary sarcoma centers were searched retrospectively to identify all patients who underwent total femur endoprosthetic replacement. Surgical indications, including oncologic diagnosis as well as history of prior surgeries, were recorded, along with technical details of the surgical reconstruction, complications, follow-up, disease status, and patient-oriented functional outcomes when recorded in the form of the Toronto Extremity Salvage Scores (TESS) at latest follow-up. TESS results were only included in the analysis if obtained at least six months after the index surgery. TESS results were plotted against follow-up duration to illustrate the relationship with time.

For analysis, patients were grouped according to knee reconstruction componentry and proximal reconstruction parameters, as well as by primary versus revision surgery. These groups were compared according to technical complications using the chi-square test and functional outcomes using the Mann-Whitney U test for nonparametric measures.

For illustrative purposes, the functional outcome of the group of total femur endoprosthetic replacement patients was compared to that in groups of patients treated with proximal or distal partial femur endoprosthetic replacement. For this comparison, the prospectively collected sarcoma database from one of the participating institutions was reviewed to identify all patients who underwent proximal or distal femur resection and endoprosthetic reconstruction. Patients with TESS data available and minimum 6 months follow-up were included in the comparison groups. These comparisons were also performed using the Mann-Whitney U statistical test.

Results

Fifty-four patients were identified as having total femur endoprosthetic replacements from the prospectively collected databases (Table 1). Twenty-two of the index surgeries were secondary procedures addressing either mechanical failure of earlier constructs or local/regional recurrences. Thirty-two femoral resections were performed as the primary oncologic procedure. Twelve patients had metastatic carcinoma, 19 osteosarcoma, 10 non-osteogenic spindle cell sarcomas of bone, 5 chondrosarcomas, 4 Ewing sarcoma family tumors, 3 soft-tissue sarcomas secondarily involving the femur, and 1 Hodgkin's lymphoma. At the knee, 13 implants had rotating hinge componentry and 41 had fixed hinges.

Complications included 5 hip dislocations and one 180-degree total femoral rotation. Four of the hip dislocations occurred in the fixed-hinge group (4 of 41), while one hip dislocation and the other severe instability episode of total femoral rotation occurred in the rotating-hinge group (2 of 13; $p = 0.75$). Two of the dislocations were in patients with acetabular reconstruction (2 of 17, none constrained), three following bipolar reconstruction (3 of 27; $p = 0.533$). Two of the dislocations followed no capsular reconstruction (2 of 30) and three followed a mesh-enhanced capsular reconstruction (3 of 5; $p < 0.01$, biased by extremely small sample with mesh reconstruction). None of the dislocations had any abductor reattachment ($p = 0.043$). Wound healing complications and infections required 5 debridements and 2 amputations. In addition, two patients with metastatic carcinoma developed local relapse (2 of 12) after total femur resection and reconstruction. There was one other local recurrence following total femur resection, which resulted in hindquarter amputation.

The mean follow-up was 4 years (range 1 month to 21 years). Patients with less than 6 months follow-up were not included in functional outcome assessments, but were included in the series because such short follow-up was always associated with early demise from disease, rather than simply being lost to follow-up. At latest follow-up, twenty-eight patients remained alive, 20 with no evidence of disease and 8 with evidence of systemic disease. Twenty-six patients died from their disease. Among 27 patients for whom total femoral resection was a primary oncologic procedure in the setting of no identifiable distant disease at presentation, 13 were alive (10 without evidence of disease, 3 with metastases) and 14 had died of disease. Among the 12 patients with metastatic carcinoma, at latest follow-up, seven have died of disease and five remain alive, three with disease.

TESS averaged 69.3 ± 17.8 among the 27 total femur patients for whom it was available. These had no clear relationship with duration of follow-up (Figure 1). In comparison, 31 proximal femur replacement patients had an average TESS of 78.3 ± 16.4 (range 42.2 to 99.1) and 85 distal femur replacement patients had an average TESS of 80.5 ± 14.2 (39.7 to 100.0). The demographics of these comparison groups are noted in Table 2. The TFR TESS scores were significantly worse than those of either the proximal or distal femur patient groups by the Mann-Whitney U test ($p = 0.036$ and $p = 0.003$, respectively).

The TESS results were not significantly different between the 18 fixed-hinge and 9 rotating-hinge patients who had TESS data. The respective means were 68.3 ± 19.9 and 71.0 ± 14.2 ($p = 0.994$). TESS did not differ between 8 acetabular reconstructions and 19 hemiarthroplasties, 71.5 ± 16.5 and 67.7 ± 17.9 , respectively ($p = 0.633$). There were also no significant differences between the 13 primary TFRs and the 14 revision TFRs in TESS outcomes. The respective means were 67.4 ± 20.9 and 71.4 ± 15.7 ($p = 0.734$).

Discussion

We report that mean patient-oriented functional scores were significantly lower among total femur endoprosthetic reconstruction (TFR; TESS 69) patients than among comparison patients who had undergone reconstruction of only the proximal (PFR; TESS 78) or distal femur (DFR; TESS 81). In fact, the drop in the mean TFR TESS score compared to the normal population was almost equal to the decrease in TESS for the proximal and distal femur reconstruction groups combined. Beyond the statistical significance of this detriment to function compared to partial femur replacements, such a 10 point difference on the TESS is also considered clinically meaningful for patient satisfaction and function²².

The functional results in our series cannot be considered independent from the oncologic results, which can have powerful effects on both psychological and systemic functional status. Although reasonable local control was achieved, with only three local recurrences following 54 TFRs—two in patients with metastatic carcinoma—there was a high rate of systemic relapse. Among the sarcoma patients with initial absence of distant metastases, 13 of 27 remained alive at latest follow-up, within the expected prognostic range for large and high grade bone sarcomas, but nonetheless representing poor overall health status²³. Even in this localized disease subgroup, a number of patients were treated with TFR due to pathologic fracture or intra-osseous skip metastases, both of which have been associated with a poor prognosis for osteosarcoma specifically²⁴⁻²⁶. While our oncologic results match well the previously reported survival and disease status at follow-up after TFR in other series^{19,20,27}, it is important to consider that TESS-measured patient-oriented results cannot distinguish completely between the effects of the surgical reconstruction and the overall health of the patient. For example, a patient moribund with metastatic disease may be wheelchair bound from dyspnea rather than from endoprosthetic failure. In contrast to

physician-metered, limb-focused functional results, some of the detriment in function compared to partial femur cohorts may be partly derived from general disease morbidity.

The patient-oriented functional results of TFR would be placed in better perspective by comparison to alternative options. Although not strictly limb-salvage patients, TESS results have previously been reported for sarcoma patients following amputations²⁸. The five trans-femoral amputation patients in that prior series had a mean TESS of 63.7 ± 9.1 , worse than our TFR patients, but not to a degree that bears strong clinical meaning. The most appropriate ablative surgery comparator group for TFR patients would be hip disarticulation patients, for whom no TESS results have been reported in that series or any of which we are aware. Functional morbidity from amputation is considered to worsen as the level moves proximally, and did so between trans-tibial and trans-femoral patients in the report by a raw difference of nearly 12 points. Nonetheless, estimating a TESS in the mid- to low-50s for hip disarticulation is a very rough estimate at best. Because hip disarticulation patients rarely are fit with functional walking prosthetics, in contrast to both trans-femoral and trans-tibial amputees, the incremental TESS detriment may be much larger. In the absence of hard data for hip disarticulation patients, however, we comfortably extrapolate that even the morbid functional status of TFR patients marks an improvement over the ablative alternative.

Neither the knee componentry nor the proximal femur componentry or soft-tissue reconstruction significantly affected the patient-oriented outcome scores. While this study has limited power due to the small subgroup sizes, no trends were detected either. With regard to stability, one patient in the rotating-hinge group never walked successfully due to an inability to control rotation of the femur. However, the data from the overall group did not suggest that rotating-hinge patients had more difficulty with stability. In fact, 4 of the 5 hip dislocations occurred in the fixed-hinge knee componentry group. All 5 TFR hip dislocations occurred in patients without abductor reattachment. While this is not a surprising result, it is a result from which little may be changed in our practice. Whenever a tumor resection permitted the maintenance of the trochanter or abductor tendons, they were secured to the prosthesis, but this circumstance was not universally available. While data in another study of PFR patients has recommended enhanced capsular reconstruction²⁹, especially when trochanter reattachment is not oncologically feasible, such reconstructions failed to prevent dislocation in three TFR patients in our series.

One of the arguments for rotating-hinge knee componentry in DFRs has been reduced rates of aseptic loosening compared to former fixed hinge cohorts³⁰. Such a difference has not been noted when non-cemented stems have been used³¹. Despite long follow-up of a few of the patients in this TFR series, aseptic loosening was a cause for revision in none of them. It may be that post-TFR patients are less active than their partial femur replacement counterparts. Although somewhat controversial, activity levels have been suspected to negatively predict implant survival rates in other arthroplasty settings³²⁻³⁴.

Two other series of TFRs merit consideration in light of our findings, one utilizing reconstruction by an entirely different method and another reporting TFR in an entirely different patient circumstance. An alternative to endoprosthetic reconstruction is allograft-prosthetic composite (APC) reconstruction of the entire femur. One large series of TFR patients that included 10 APC reconstructions was reported previously²⁷. No patient-oriented outcomes were collected or reported. The investigators noted no differences between the endoprosthetic and APC groups in terms of physician-measured function, other than a slightly reduced Trendelenburg in the APC patients. The potential for soft-tissue reattachment to the allograft seems to have had clinically discernible, if not functionally apparent effects. They noted none of the typical allograft complications of infection or

fracture, but only four of the APC patients survived to study end; all others deceased less than four years from surgery, potentially masking long-term complication rates.

Our series must also be compared with the recently reported series of 100 patients undergoing TFR for non-oncologic diagnoses³⁵. These procedures were primarily complex revision arthroplasties, but they nonetheless represent by far the largest series of TFRs with functional results available. Not unexpectedly, those patients fared well in comparison to ours and those reported in other oncologic TFR series. Extensive myomectomies for negative margins would not be required in arthroplasty revision situations as they are for resection of large femur tumors. Further, there is more frequently residual bone stock available to facilitate a solid abductor reattachment and often even some capsular tissues remaining at the hip to aid joint stability in these non-oncologic patients.

Awareness of that series' data prompted the subgroup analysis in our series comparing the subset of patients undergoing primary TFR to the subset of patients who underwent TFR as a revision procedure following prior oncologic PFR or DFR. While three of the index TFR surgeries were revisions of prior DFRs due to regional recurrences, most secondary TFRs were performed to manage mechanical complications following DFR or PFR. For these revisions due to mechanical issues, additional massive myomectomies were not repeated and therefore not likely to further affect hip and knee function. No statistical differences between the two subgroups were identified.

Conclusions

While total femoral endoprosthetic reconstruction offers improved function over that projected for hip disarticulation, this procedure is performed in a very high-risk patient population, and the patient-oriented functional results combine the detriments of both proximal and distal femur endoprosthetic reconstructions. Abductor reattachment is desirable, when oncologically feasible, to prevent hip instability. While both types of knee joint mechanisms appear to function well, and our group data show no gross differences, one anecdotally poor outcome still prompts our opinion that consideration should be given to use of a fixed hinge knee reconstruction in patients for whom massive myomectomies and poorer overall conditioning make knee stability a primary concern with regard to short-term mobility.

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Figure 1. Toronto Extremity Salvage Score versus duration follow-up after total femur endoprosthetic reconstruction. In this group including patients 6 months after surgery and beyond, the distribution of scores changes little with longer follow-up.

Table 1

Characteristics of patients that received total femoral resection and endoprosthetic replacement.

Parameter	Mean ± Standard Deviation or Ratio
Age	40.6 ± 19.9
Gender (male:female)	25:29
Diagnosis	
Primary sarcoma	40
Metastatic sarcoma	1
Metastatic Carcinoma	12
Lymphoma	1
Primary Surgery:Revision Surgery	40:14 (5 from prior local or regional recurrence)
Knee hinge componentry (fixed:rotating)	41:13
Hip acetabular componentry	
Bipolar	27
Unipolar	10
Cemented acetabular shell *	15
Porous in-growth acetabular shell	2
Hip capsular repair	
Enhanced with mesh	5
Suture only	19
None	30
Abductor reattachment	
Bone of trochanter	15
Tendon only	8
None	31

* One of these used a constrained liner.

Table 2

Demographics of Toronto Extremity Salvage Score (TESS) comparison groups, having undergone total femur replacement (TFR), proximal femur replacement (PFR), or distal femur replacement (DFR).

Parameter	TFR	PFR	DFR
Number	27	31	85
Age	32.7 ± 18.4	43.2 ± 17.0	31.6 ± 15.3
Gender (M:F)	11:16	22:9	44:41
Diagnosis			
Benign aggressive	0	2	4
Primary sarcoma	2	2	2
Recurrent sarcoma	23	26	79
Carcinoma met	2	1	0
Mean follow-up time (months)	89	96	93
Proximal Reconstruction			
Hip componentry			
Acetabular shell	8	13	--
Bipolar	17	15	--
Unipolar	2	3	--
Capsular repair			
None	15	6	--
Suture	9	7	--
Mesh	3	18	--
Abductor reattachment			
None	13	20	--
Tendon	3	7	--
Bone	11	4	--
Distal Reconstruction			
Fixed hinge	18	--	72
Rotating hinge	9	--	13
Dislocations	2	4	--
Revisions	4	6	19
Infections	4	3	7
Amputations	2	1	7