Extensor Function After Medial Gastrocnemius Flap Reconstruction of the Proximal Tibia

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Received: 26 September 2012 / Accepted: 5 February 2013 / Published online: 20 February 2013
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Abstract

Background Reconstruction of the extensor mechanism after resection of the proximal tibia is challenging, and several methods are available. A medial gastrocnemius flap commonly is used, although it may be associated with an extensor lag. This problem also is encountered, although perhaps to a lesser extent, with other techniques for reconstruction of the extensor apparatus. It is not known how such lag develops with time and how it correlates with functional outcome.

Questions/purposes We therefore (1) assessed patellar height with time, (2) correlated patellar height with function using the Musculoskeletal Tumor Society (MSTS) score, and (3) correlated patellar height with range of motion (ROM) after medial gastrocnemius flap reconstruction.

Methods Sixteen patients underwent tumor endoprosthesis implantation and extensor apparatus reconstruction between 1997 and 2009 using a medial gastrocnemius flap after sarcoma resection of the proximal tibia. These patients

represented 100% of the population for whom we performed extensor mechanism reconstructions during that time. The minimum followup was 2 years (mean, 5 years; range, 2–11 years). Fourteen patients were alive at the time of this study. We used the Blackburne-Peel Index to follow patellar height radiographically with time. Functional outcomes were assessed retrospectively using the MSTS, and ROM was evaluated through active extensor lag and flexion.

Results Eleven patients had patella alta develop, whereby the maximal patellar height was reached after a mean of 2 years and then stabilized. More normal patellar height was associated with better functional scores, a smaller extensor lag, but less flexion; the mean extensor lag (and flexion) of patients with patella alta was 17° (and 94°) compared with only 4° (and 77°) without.

Conclusions In our patients patella alta evolved during the first 2 postoperative years. Patella alta is associated with extensor lag, greater flexion, and worse MSTS scores. Surgical fixation of the patellar tendon more distally to its anatomic position or strict postoperative bracing may be advisable.

Level of Evidence Level IV, clinical cohort study. See the Guidelines for Authors for a complete description of levels of evidence.

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Introduction

The proximal tibia is a rarely affected site of primary malignant bone tumors [13, 22, 32]. At this location, the patellar tendon often has to be resected together with the tumor [5, 24, 37]. Many patients with musculoskeletal tumors are young and active, and high cure rates have been reported as a result of the steadily increasing success of chemotherapy after its introduction in the late 1970s [15].

Therefore, maintaining a functional mobile joint, particularly after resection of the proximal tibia including the extensor mechanism, has become crucial [21, 35].

There are various surgical treatment options, none of which is clearly superior in terms of patient-physician satisfaction [17, 26]. Limb amputation, Borggreve or Van Nes rotationplasty, and arthrodesis have fallen out of favor as primary options, although these procedures still belong to the armamentarium of the orthopaedic oncologist for selected indications [23, 33, 34]. Limb salvage techniques involving wide en bloc resection of the tumor represent the mainstay of treatment, being associated with an increased quality of life [16, 34]. The most popular reconstruction methods reported for the proximal tibia include osteoarticular allografts, allograft-prosthetic composite reconstructions, preserving the anatomic position of the tibial tubercle, and tumor mega-endoprostheses mostly with a gastrocnemius flap for coverage [1, 3–5, 9, 11, 12, 14, 18–20, 23, 24, 30, 34, 35, 37–41].

Tumor mega-endoprostheses are an attractive option with good functional outcomes because they are versatile, allow immediate weightbearing, and may be more cost effective [12, 41]. However, since tendinous tissue does not grow naturally to metal, controversy remains regarding reconstruction techniques for the extensor mechanism [3, 5, 9, 14, 20, 24, 27, 37–41]. Several synthetic devices, such as nonabsorbable tapes, tubes, sutures, cerclage wires, and transplants, such as autograft and allograft from the sartorius or biceps tendons and gastrocnemius flaps have been used [3, 5, 7, 9, 14, 20, 24, 31, 37–41]. It has been reported that the patellar ligament stretches after reconstruction with a tumor prosthesis and medial gastrocnemius flap, whereas it remains stable when reconstructed with an allograft-prosthesis composite [3, 37, 39]. The patellar height may be measured with various indexes, including the Blackburne-Peel index [2, 6, 8, 10, 25, 28, 29, 36]. However, when stretching of the patellar ligament takes place, the incidence and impact of this finding on radiographs, clinical outcomes, and range of motion (ROM) remain controversial [1, 3–5, 9, 11, 12, 14, 19, 20, 23, 24, 30, 34, 35, 37–41].

We therefore (1) assessed patellar height with time, (2) correlated patellar height (Blackburne-Peel Index) with function using a standardized outcomes tool (Musculoskeletal Tumor Society score [MSTS]), and (3) correlated patellar height with ROM (extension and flexion) after medial gastrocnemius flap reconstruction.

Patients and Methods

In this retrospective study, 16 patients underwent resection of the proximal tibia or fibula between 1997 and 2009 with reconstruction using a tumor endoprosthesis and a medial

gastrocnemius flap. These patients represented 100% of the population for whom we performed extensor mechanism reconstructions during that time. There were five female and 11 male patients with a mean age at diagnosis of 23.5 years (range, 14–56 years). The diagnoses included osteosarcoma (12 patients), Ewing's sarcoma (two patients), and leiomyosarcoma (two patients). All but one patient received neoadjuvant and adjuvant chemotherapy.

The following surgical technique was used in all patients [18]. Using an anteromedial parapatellar approach, lateral and medial fasciocutaneous flaps were created. Medially, the pes anserinus and semimembranosus were released. Posteriorly, intervals between the gastrocnemius and soleus and the popliteus and posterior deep flexors were developed. At the distal end of the popliteus at the arcade of the soleus, the anterior tibial artery was ligated to mobilize the posterior neurovascular bundle. Laterally, the common peroneal nerve was protected. Arthrotomy was performed through release of the biceps femoris and lateral collateral ligament. The patellar and cruciate ligaments were released near the tibial insertion. Osteotomies of the fibula and tibia were performed. The intermuscular septum was released and the knee was intraarticularly resected. The tumor endoprosthesis was inserted. The remainder of the patellar tendon was directly fixed to the prosthesis without a mesh, but using a nonabsorbable suture with modified Mason-Allen stitches and Prusik knots, taking care to position the patella at the same height as its original insertion point, with reference to the joint line (Fig. 1). The medial gastrocnemius muscle was released distally and rotated anteriorly, while protecting the sural nerve and vasculature, and reattached to the retinacula and pes anserinus. Thus, the gastrocnemius flap covered the endoprosthesis and the patellar ligament. A suction drain was placed before skin closure and placement of a brace. Antibiotics were given until the beginning of chemotherapy (up to 2 weeks). The brace was worn for 4 to 6 weeks. Isometric exercises were started immediately, and partial weightbearing was allowed for 6 weeks. Passive and active knee mobilization was started under physiotherapeutic guidance and with the help of a continuous passive motion machine after 6 weeks, with progressive 30°-increments per 2 weeks.

The mean resection length was 13.1 cm (range, 11.5–16 cm), while wide margins were obtained in all patients. An uncemented MUTARS® (MUTARS® Proximal Tibia; implantcast GmbH, Buxtehude, Germany) prosthesis was used in all patients. A split skin graft was used in three patients. Patients were assessed at a minimum followup of 2 years (mean, 5 years; range, 2–11 years). Fourteen of the 16 patients had no evidence of disease. Two patients died of distant metastases. There were no local recurrences. Complications included aseptic loosening of the prosthesis (one), periprosthetic fracture with associated ligament

Fig. 1 An intraoperative picture shows fixation of the patellar tendon to the prosthesis using a modified Mason-Allen stitch to the remnant of the patellar tendon, and a Prusik stitch to the prosthesis. On top of this construct, the medial head of the gastrocnemius muscle is added to cover not only the patellar tendon but also the prosthesis to fuse with the induced membrane around the prosthesis and ultimately to power the extension. The level of the inferior pole of the patella is referenced to the joint line, as determined on preoperative imaging.

Fig. 2A–B (A) Patella alta is shown in a tumor endoprosthesis. (B) To obtain the Blackburne-Peel Index (BPI), a horizontal line has to be drawn on the tibial plateau. Then a tangent (2) is constructed and drawn from the distal part of the patella to the previously mentioned horizontal line. This tangent is divided by the length (1) of the articular surface of the patella. Normal Blackburne-Peel values range between 0.5 to 1. Patella alta is defined as values greater than 1.

lengthening (one), infection (one), and compartment syndrome (one). There was no flap necrosis.

Radiologic outcome was assessed on standard AP and lateral radiographs of the knee using the Blackburne-Peel Index [6] for preoperative and all postoperative lateral radiographs to define the patellar height with time (Fig. 2) [37]. The Blackburne-Peel Index describes the relationship of the patella to the trochlea by relating the length of the articular surface of the patella to the distance of the inferior patella to the tibial plateau. Increased values are defined as one or greater [36]. Clinical outcomes were assessed using the MSTS score [16]. Scores of 23 or greater were considered excellent, 15 to 22 were good, 8 to 14 were fair, and less than 8 were poor [3]. We were able to obtain current MSTS scores from 12 of the 16 patients because

Fig. 3 The mean preoperative Blackburne-Peel Index (BPI) was 0.92 compared with 1.34 postoperatively.

two patients had died and two had moved. ROM was evaluated through active extensor lag and flexion.

Results

Normal patellar height was found in all patients preoperatively. However patella alta was present in 11 (69%) of the 16 patients postoperatively. The mean preoperative BPI was 0.92 compared with 1.34 postoperatively, which equals an increase of 0.42 (31%) (Fig. 3). The maximum patellar height was reached after a mean of 24 months. When comparing the mean Blackburne-Peel Index within the first 2 postoperative years with the one after 2 postoperative years in all of the eight patients followed up for almost 5 years, the main change, ie, patellar increase, occurred within the first 2 postoperative years, only to be stable afterward (Fig. 4). Therefore, the patella had the tendency to be stabilized at its elevated level approximately 2 years postoperatively.

Decreased mean postoperative Blackburne-Peel Index values, reflecting more normal (lower) patellar height, were associated with better functional scores (Fig. 5). A mean postoperative Blackburne-Peel Index increase of 0.26 was found with excellent scores compared with 0.54 with good scores. Increasing patellar height led to more dependency on walking supports. The mean preoperative to postoperative increase in Blackburne-Peel Index in nine (75%) patients who were independent of assistive devices was 0.38 compared with 0.72 in three (25%) patients who depended on assistive devices. Patella alta was present in all five (100%) patients with pain scores of 2 or 3, whereas normal patellar height was found in three of seven (43%) patients with pain scores of 4 or 5. Overall, the mean MSTS score was 22 points (range, 14–28 points) for patients who were assessed. Excellent scores were achieved in four (33%) and good in eight (67%) patients.

Fig. 4 Maximal patellar height, measured by the Blackburne-Peel Index (BPI), was reached after a mean of 24 months. In the eight patients followed up to almost 5 years, the patella had the tendency to be stabilized at its raised level at approximately 2 years.

Fig. 5 Patients with an excellent MSTS score (≥ 23) showed an extensor lag of 8°, flexion of 78°, and mean Blackburne-Peel Index increase of 0.26. Patients with a good MSTS score (15–22) had an increased extensor lag of 14°, greater flexion of 96°, and a higher mean postoperative increase in Blackburne-Peel Index.

The mean scores for each task were 4 for support, 3.8 for gait, 3.7 for walking ability, 3.7 for pain, 3.6 for emotional acceptance, and 2.9 for function.

The mean active extensor lag and flexion were 13° (range, 0°–45°) and 90° (range, 60°–120°), respectively. Five (31%) of the 16 patients achieved full active extension without extensor lag, five (31%) patients had a lag of 20° or greater, five (31%) patients had a lag between 10° and 19°, and one (6%) patient had a lag between 1° and 9°. Ten (63%) of the 16 patients achieved flexion of 90° or greater. The patellar height associated with the ROM. In patients

Fig. 6 Five patients with an extensor lag of 20° or greater had a mean postoperative increase in Blackburne-Peel Index (BPI) of 0.63. Eleven patients with an extensor lag less than 20° had a postoperative increase of only 0.32.

with normal patellar height, the mean active extensor lag (and flexion) were less pronounced, 4° (and 77°), compared with 17° (and 94°) in patients with patella alta. A mean

postoperative Blackburne-Peel Index (and preoperative to postoperative increase in Blackburne-Peel Index) of only 1.23 (and 0.32) was found in patients with an extensor lag less than 20° compared with 1.58 (and 0.63) in patients with an extensor lag of 20° or greater (Fig. 6). A mean postoperative Blackburne-Peel Index (and preoperative to postoperative increase in Blackburne-Peel Index) of only 1.10 (and 0.19) was found in patients with flexion less than 90° compared with 1.48 (and 0.55) in patients with flexion of 90° or greater.

Discussion

Extensor mechanism reconstruction after proximal tibia resection is challenging and using the medial head of the gastrocnemius muscle is one option [1, 9, 14, 17, 38] (Fig. 1). In our study, we had three major findings: (1) an increase in patellar height (patella alta), reflecting patellar tendon lengthening, evolved within the first 2 postoperative years and remained stable thereafter; (2) increased patellar height was associated with worse MSTS functional scores; and (3) increased patellar height was correlated with more severe active extensor lag and greater flexion of the knee.

This study has some limitations. Because tumors of the proximal tibia are relatively rare, our study group was relatively small [13, 22, 32]. Thus, we were unable to include a control group in which another surgical technique could have been used [12, 40, 41]. For the purpose of clarity, we chose to report our results using the Blackburne-Peel Index [6] (Fig. 2) as our measurement tool for patellar height over other known indexes, such as the Caton-Deschamps [8], Miura [29], or Insall-Salvati [25]. We also evaluated the Caton-Deschamps and Miura indexes, which yielded similar results to the Blackburne-Peel Index, but when using the Caton-Deschamps index for example, it is difficult to find the anterosuperior aspect of the tibia preoperatively [10]. We were unable to determine whether the increasing extensor lag during the first 2 postoperative years occurred during the early postoperative rehabilitation phase or later.

Our study indicates that increased patellar height (patella alta) occurred within the first 2 years after surgery and remained stable afterward (Figs. 2 and 4). Shimose et al. [37], in a case-series of seven patients, also observed that the patellar tendon stretched during the first few months postoperatively by about the same amount as found in our series. In contrast to our results, the extensor lag improved continuously in that series. In addition, this patellar height finding is in contrast to that of normal knee arthroplasties, where patellar tendon length has been reported to decrease [28]. This might be because tendons do not grow on the metal naturally and anchorage might loosen as long as scar formation has not finished [3, 5, 9, 14, 20, 24, 37–41].

In line with previous studies, the use of tumor mega-endoprostheses and medial gastrocnemius flaps for reconstruction of the proximal tibia and extensor mechanism provides good functional results as assessed by the MSTS score [16, 27, 34, 38]. In a study by Tan et al. [38], 42 patients underwent prosthetic reconstruction of the proximal tibia which resulted in a mean MSTS score of 25. To our knowledge, our study is the first to identify that increased patellar height (patella alta) was associated with lower MSTS functional scores (Fig. 5). This discovery might be explained biomechanically. An increase in patellar height requires a stronger force to achieve full extension, because the patella acts as a lever arm to increase the force of the quadriceps [2, 21]. Thus, when patella alta is present, the generated force is not sufficient enough and weaker knee extension results owing to a malfunctioning extension apparatus. Ultimately, substantial gait and functional impairment may arise, which was supported by the results from Kendall et al. [27] and our study.

Postoperative extension is critically important for the success of the reconstruction. In our study, patella alta was correlated with an increased mean active extensor lag and greater flexion of the knee (Fig. 6). Only five (31%) of the 16 patients had full extension and the overall average extensor lag was 13°. This clearly is inferior compared with extension after allograft reconstruction, where full extension may be more reliably achieved [3, 4, 11–13, 16, 19, 30, 41]. Based on the few reports [3, 4, 19] evaluating the extensor function specifically, patellar tendon reconstruction with allogenic tissue from a proximal tibia allograft sutured to the recipient's remnant patellar tendon restores active knee extension most reliably and provides a stable knee. In a study by Ayerza et al. [3], 24 of 34 (71%) patients with osteoarticular allografts achieved full extension without an extensor lag, whereas the remaining 10 (29%) patients had an average extensor lag of 6.5°. Gilbert et al. [19] evaluated 12 patients with allograft-prosthetic composite reconstructions, and did not find an extensor lag in nine of 12 (75%) patients, while the remaining three (25%) patients had an extensor lag between 5° and 15°. Biau et al. [4] studied 26 patients with allograft-prosthetic components and found a mean extensor lag of 7.7°. However, comparing our results with those from other series [5, 22, 38] using medial gastrocnemius flap reconstructions, we observed a slightly better outcome in our patients. Bickels et al. [5], for example, reviewed 55 patients during a 20-year period and found full extension to an extension lag of 20° in 44 (78%) patients, an extensor lag of 20° to 30° in 10 (19%) patients, and one greater than 40° in one (3%) patient. Unfortunately, full extension was not defined by a lag of 0°, which does not allow further comparison with other reports. The mean extensor lag of 50 patients studied by Grimer et al. [22] was 30°. When using

a medial gastrocnemius flap, there is debate regarding whether to augment the attachment with some kind of synthetic material [3, 5, 7, 9, 14, 20, 24, 31, 37–41]. As described, tight fixation during surgery is considered important, and the goal is scarring of the induced membrane around the prosthesis with the remnant patellar tendon and the gastrocnemius flap.

Enhancement with a synthetic tube might favor better extension as the extension lag was only 7.5° in 16 patients reported by Gosheger et al. [20]. We were not able to associate the amount of resection length with functional outcome because the range of resection length did not vary much in this small series of patients. Correlation of the patellar height, functional scores, extension lag, and flexion may be explained by ligament lengthening or because the patella was fixed more proximally of its anatomic insertion point. In accordance with the findings of Shimose et al. [37], we advocate providing strong continuity of the gastrocnemius flap by overtensioning the patellar remnant ligament, which usually is present, and bringing the patella distal to its anatomic position, which ultimately may decrease the extensor lag. It is important to reliably fix the tendon to the prosthesis and overlaying the gastrocnemius such that these two structures will become one structure together with the induced membrane around the prosthesis (Fig. 1) [1, 9, 18, 38, 40]. We believe that postoperative rehabilitation with immobilization in full extension for 6 weeks is critical and early mobilization might compromise stability of the patellar ligament. Our results showed an association of a more severe extension lag with greater flexion which may be indicative of patellar tendon lengthening owing to forced early flexion. It may be advisable to extend isometric muscle strengthening and delay active flexion exercises until passive flexion has reached 90°.

Our study showed that radiographically detectable patella alta, which seems to evolve during the first 2 postoperative years, is correlated with increased patellar tendon length, more pronounced extensor lag, greater flexion, and worse MSTS functional scores. Full extension may be achieved more reliably by anchoring the (augmented) patellar tendon and medial gastrocnemius flap more distally or by using strict postoperative bracing. Future studies should be directed at patellar height, extensor function, and functional outcomes for different surgery techniques, rehabilitation protocols, and radiographic detection of the development of patellar lengthening with time.

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