Knee function after operation for malignancy of the distal femur

Quadriceps muscle mass and knee extension strength in 21 patients with hinged endoprostheses

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We evaluated quadriceps muscle mass and knee extension strength in 21 patients after resection and endoprosthetic replacement of the distal femur for malignant bone tumor. In all cases, a modular cementless, hinged prosthesis had been used. The mean follow-up period was 4 (2–9) years. Muscle mass was measured ultrasonographically, and strength isokinetically with a Cybex 6000 dynamometer. All the data for the operated side are given as percentage of the non-operated side.

The average quadriceps mass was 48 (27–70) percent. The average peak torque was 31 (14–48) and 36 (18–55) percent at the speed of 30°/s and 90°/s, respectively. The reduction in extension strength became greater with increasing flexion. There was a moderate correlation between muscle mass and muscle strength. Most of the patients who had kept more than 40 percent of the quadriceps mass had more than 30 percent peak torque. Patients with excellent function (Enneking 1987) had more quadriceps muscle mass and higher strength than those that were merely good with the borderline at about 40 percent muscle mass.

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Capanna et al. (1991) reported on function after resection and replacement of the distal femur in relation to the degree of quadriceps excision. There are also reports on the strength of the quadriceps muscle after its partial excision because of soft-tissue tumors (Markhede and Stener 1981, Murray et al. 1983). We report quantitative measurements of residual muscle mass and their correlation with muscle strength after limb-saving operations.

Patients and methods

Patients

Between November 1982 and August 1990, 50 patients with primary malignant bone tumor had resection of the distal femur, reconstructed with a modular uncemented prosthesis (Kotz modular femoral-tibial reconstruction system: KMFTR) at the Department of Orthopedics, University of Vienna. At the time of the study, 9 patients had already died; 14 patients living far abroad could not participate in the study. 3 patients had complications or an additional operation (fistula formation, loosening of prosthesis and conversion to rotation plasty); 2 patients had a quadriceps that was too weak to perform the dynamometric test after total resection of the tendinous continuity of the extension apparatus; 1 patient was excluded because the contralateral limb had been amputated. The remaining 21 patients formed the study group.

In these 12 men and 9 women, a modular prosthesis was implanted after wide resection of the tumor (Kotz et al. 1986). The resection was extraarticular with patellectomy in 2 cases and intraarticular without patellectomy in 19. In all cases, the complete muscle belly of the rectus femoris and the tendinous continuity to the tibial tuberosity were maintained. The patella was resurfaced using a PCA prosthesis. Other parts of the quadriceps were resected according to the individual oncological situation. The hamstrings were maintained in all patients, except one who had a big tumor at the dorsal side and therefore underwent massive resection of the hamstrings.

Active and passive knee motion exercises were started 5 days after the operation. Partial weight bearing was allowed after 6 weeks, and full weight bearing after 12 weeks.

In 6 patients, an expandable type of prosthesis was used (Kotz et al. 1991). In 2 patients it was implanted at the primary operation, and in 4 at a later stage. 2 of these patients developed an infection, and the resection piece had to be changed after massive debridement. Healing occurred in these patients and they were without any sign of infection at the time of investigation. Out of 15 patients with the standard prosthesis, 5 had additional operations during the course of the follow-up, 2 to change the axis due to signs of wear, 1 to change the anchoring piece due to stem-loosening, and 2 for both reasons.

All 21 patients were without any sign of recurrence or metastasis at the time of investigation. The average age at the definite operation was 24 (9–68) years. The average follow-up period at the time of measurement was 4 (2–9) years. Out of 15 patients with the standard prosthesis, 10 without any reoperation had an average follow-up of 4 (1.5–7) years, while 5 patients with additional operations had 6 (2–9) years after the definitive operation and 6 (1.5–8) years after the reoperation. The average follow-up of the 6 patients with the expandable prosthesis was 4 (3–6) years after the definitive operation and 1.5 (0.5–3) years after the latest elongation procedure.

The function was rated according to Enneking (1987). The following parameters were analyzed and scored: motion, pain, stability, deformity, strength, functional activities and emotional acceptance. Function was considered excellent if 6 parameters were excellent and one less than excellent; good if 6 parameters were good and one fair or poor; fair if 6 parameters were fair or better and 1 poor; poor if 2 parameters were poor.

Measurement of quadriceps muscle mass

Muscle mass of the quadriceps femoris was evaluated sonographically using a high frequency (7.5 or 10 MHz) mechanical sector scanner (ATL, UM4; Advanced Technology Labs, Bothell, WA, U.S.A.) in the supine position with extended legs. Measurement of the quadriceps cross-sectional area, according to Young et al. (1980, 1984), was modified to estimate the mass of the entire muscle belly.

At the beginning of the examination, the proximal end of the rectus femoris muscle was identified sonographically and marked on the skin with a pen. From this point, further marks at a distance of 5 cm each were made on the skin down to the patella. A transverse scan through the rectus femoris was performed at each skin marker, and the areas of the rectus femoris were calculated. The other parts of the quadriceps femoris were examined in the same manner. Muscle volume was calculated by addition of the cross-sectional areas of each corresponding muscle in cm^2 and multiplication of the sum by 5 (5 cm was the distance between the single sections). Finally, the muscle mass on the operated side was given as percent of that of the non-operated side.

The quadriceps muscles of 4 healthy volunteers were measured in the same way. To check the reproducibility of measurement, this procedure was repeated 4 times in the same volunteers, and the coefficient of variation was calculated for each subject. The mean coefficient of variation in muscle mass for each healthy volunteer was 3.2 (1.3–5.3) percent.

Dynamometry

Isokinetic testing of the quadriceps and hamstrings across both knee joints was performed using a Cybex 6000 dynamometer (Lumex Inc., Ronkonkoma, NY, U.S.A.) with a short lever arm and a dual shin pad while the patients were seated (Davies 1985). The non-operated limb was tested first. The test consisted of the following steps: (1) an initial warm-up with 3 leg extensions and flexions at a slow speed (30°/s), (2) brief rest, (3) 3 maximal leg extensions and flexions at 30°/s, (4) a 30 s rest period, (5) a second warm-up with 3 repetitions at an intermediate speed (90°/s) and (6) 10 maximal leg extensions and flexions at 90°/s. After seat and machine readjustments, the patient repeated the procedure for the operated leg.

Peak torque for each of the slow and the intermediate speeds was defined as the highest value from all repetitions and from all points in the range of motion. Total work (area under the torque-angle curve) was gained from the best of 3 performances at slow speed and 10 repetitions at intermediate speed. Torque at each angle point was also obtained from the best performance. These values were used to calculate the percentage of the operated side in relation to the non-operated side.

Results

The average quadriceps mass on the operated side was 48 (27–70) percent of the contralateral side. This value reflects the combined effect of the local excision, perioperative atrophy and postoperative recovery. The average muscle mass of the rectus femoris alone was 81 (56–113) percent. This represents the effect of atrophy and recovery because the rectus femoris was not excised.

Table 1. Peak torque and total work of knee extensor on the operated side. Values are given in percent of the non-operated side

	Peak torque				Total work			
	Mean	*SD*	Min	Max	Mean	*SD*	Min	Max
All patients (n 21)								
30°/s	31	*11*	14	48	34	*13*	11	58
90°/s	36	*11*	18	55	35	*13*	12	58
Patients with intraarticular resection (n 19)								
30°/s	33	*10*	14	48	35	*12*	12	58
90°/s	37	*10*	19	55	37	*12*	16	58
Patients with extraarticular resection (n 2)								
30°/s	19	–	16	21	19	–	12	25
90°/s	23	–	18	28	20	–	12	27

The strength of the knee extensor muscle was reduced on the operated side and the reduction was greater in the more flexed position (Table 1, Figure 1). Knee flexion torque did not show a distinct angle-related change as was the case with the extension torque (Figure 2).

Correlation between quadriceps mass and knee extension strength

The quadriceps muscle mass was moderately correlated to the knee extension peak torque at the speed of 30°/s (*r* 0.61). The correlation was more pronounced at the speed of 90°/s (*r* 0.77). When the quadriceps mass exceeded 40 percent of that of the non-operated side, peak torque was more than 30 percent at the speed of 90°/s (Figure 3). This tendency was also seen in all patients except 4 at the speed of 30°/s.

Function

11 patients had excellent and 10 good function. There was no common reason for the lower score in the good group. The excellent patients had more quadriceps muscle mass and higher knee extension strength at both speeds than those who were good (Table 2); all excellent and only 4/10 good had a muscle mass over 40 percent. This value was related to the borderline between excellent and good function (chi-square test, $P < 0.01$).

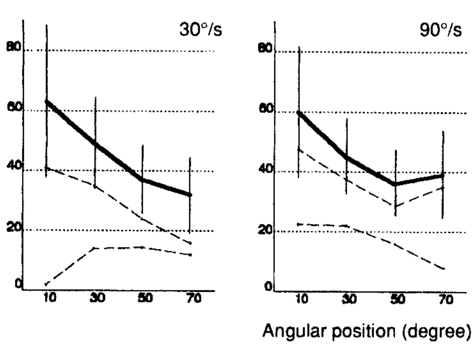

Figure 1. Knee extension strength on the operated side in relation to the non-operated side (percent) in different angular positions during extension at the speed of 30°/s and 90°/s (mean *SD*) of patients with intraarticular resection (n 19). The differences between the angular positions are significant ($P <$ 0.01, paired *t*-test), with the exception between 50° and 70°. Points connected with dotted lines represent 2 patients with extraarticular resection.

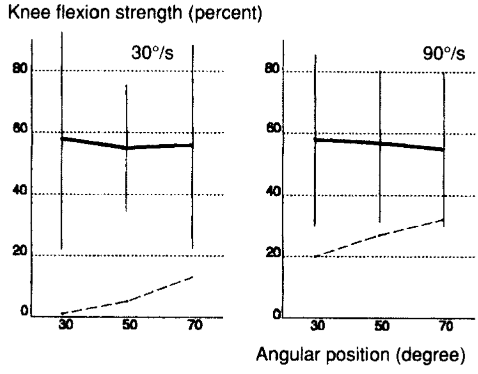

Figure 2. Knee flexion strength on the operated side in relation to the non-operated side (percent) in different angular positions of the knee during flexion at the speed of 30°/s and 90°/s (mean *SD*) of patients with intact hamstrings (n 20). The differences between any angle points are not significant (paired *t*-test). Points connected with dotted lines represent 1 patient with extensive resection of hamstrings.

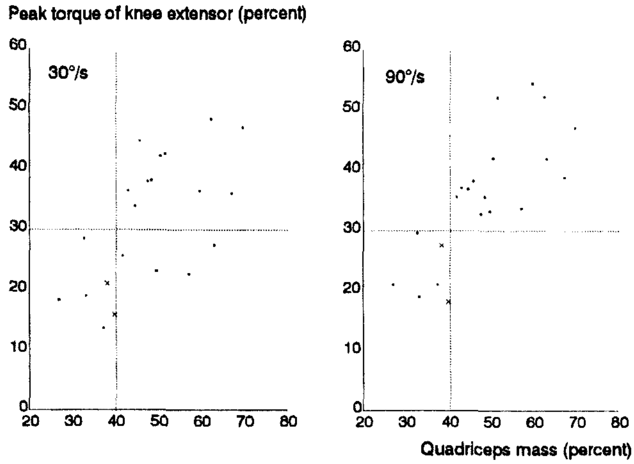

Figure 3. Correlation between quadriceps muscle mass and peak torque of knee extension on the operated side at the speed of A – 30°/s (r 0.61, $P <$ 0.01 for all patients and r 0.57, $P <$ 0.01 for patients with intraarticular resection) and B – 90°/s (r 0.77, $P <$ 0.001 for all patients and r 0.76, $P <$ 0.001 for patients with intraarticular resection). Data are presented in relation to the non-operated side (percent). Points represent patients with intraarticular resection while crosses represent those with extraarticular resection.

Table 2. Comparison between patients with excellent results (n 11) and those with good results (n 10). Values are given in percent of the non-operated side (mean *SD*)

	Muscle mass	Peak torque	
		30°/s	90°/s
Excellent	54 *8*	37 *7*	42 *8*
Good	42 *12*	25 *10*	29 *9*
P-value [a]	< 0.05	< 0.01	< 0.01

[a] Student's *t*-test

Discussion

Our observation that the reduction in extension strength was more pronounced in the more flexed position of the knee joint agrees with findings after partial resection of the quadriceps because of soft-tissue tumors (Markhede and Stener 1981, Murray et al. 1983). The pronounced reduction of strength in flexion, i.e., at angles at which normally the greatest torque is produced, probably reflects an intrinsic characteristic of the injured tissue. However, in our study it could also be attributed to the shape of the prosthesis. Because of the fixed axis and the construction of a condylar surface of the prosthesis, the lever arm of the force acting on a patella could be shorter in the flexed position.

In contrast to the extension strength, the reduction in flexion strength remained constant in various angular positions. As long as the patients are furnished with the hinged prosthesis, it is not very important to have a physiologically well-balanced hamstrings-to-quadriceps ratio throughout the whole range of motion. However, a sufficient balance in the remaining musculature, with a reserve strength in both directions, would protect the prosthesis and could help to avoid an alarming increase in the prosthesis load on every occasion in daily life (van Krieken et al. 1985). Therefore, the muscle strength in flexed position should be evaluated carefully and, if necessary, intensive and careful rehabilitation should be done.

Patients after extraarticular resection had even less strength of the knee extensor. This is in accordance with a previous report documenting the compromised function of the knee extensor after patellectomy (Watkins et al. 1983). In our patients, however, the strength after extraarticular resection was not extremely low considering their muscle mass at the same time (Figure 3). Perhaps, with a hinged, constrained and intrinsically stable prosthesis, the extensor apparatus could still transmit the muscle power fairly well even without a patella.

Correlation between quadriceps mass and knee extension strength, both in relation to the non-operated side, was moderate. This is not surprising because there exist other factors affecting strength, especially on the operated side, for example, changes in muscle fiber orientation and length-tension properties, which are not influenced by mass only. Still, it is undoubted that maximum retention of the muscle mass would pave the way to more strength and better function. According to our results, if oncologically permissible, 40 percent is considered to be a minimum desirable aim for muscle retention to achieve an excellent functional result. Still, our study also showed that with intact tendinous continuity and a stable prosthesis without complications, good function can be expected even after extensive excision of the muscle.

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