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Transfemoral Amputation

Biomechanics and Surgery

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The technique of transfemoral amputation has evolved during the last decade whereby muscle stabilization and biomechanical principles have gained new significance. Maintenance of the femoral shaft axis close to normal can be achieved by preservation of the adductor magnus and by myodesis of the muscle to the residual femur. By following established biomechanical principles, and satisfactory surgical techniques, patients undergoing transfemoral amputation are easier to fit with a prosthesis and more likely to remain able to ambulate. Reduction in stump problems can be achieved, and improvement in stump strength is seen.

Technologic advances have allowed significant changes in designs, components, and manufacture of transfemoral prostheses during the last decade. Patient demands for more active lifestyles have resulted in innovative techniques for socket shapes, and new technology for knee components and prosthetic feet. However, the surgical technique of transfemoral amputation had remained unchanged until the late 1980s.

Most standard texts describe a conventional transfemoral (above the knee) amputation where the surgical procedure uses symmetric fish mouth flaps or a slightly longer anterior skin flap.[1,2,9] Preservation of length and maintaining the femur in a central position in the soft tissue envelope were the main goals of surgery. Hamstring and hip adductor muscles were sacrificed, weakening their ability to extend and adduct the hip. In most cases, the muscles were anchored inadequately to the femur.

Flexion and abduction deformities were accepted as inevitable and the shorter the stump, the greater the tendency for deformity. The femur tended to fall into an abducted position, as compared with the nonamputated leg. Muscles were sectioned at the level to which the skin retracted, and the cut muscle beveled toward the anticipated level of bone section.

Myodesis consisted of anchoring the remaining muscle through drill holes near the cut end of the bone, and was undertaken with the muscle in a shortened position. Myoplasty was done by suturing the fascia of the sectioned agonistic and antagonistic muscles to each other. The ensuing problem of stabilizing the stump in the prosthetic socket had been recognized by prosthetists for several years.[15,18] Socket modifications and prosthetic alignment changes were used to attempt to improve gait by improving stability. Ischial containment sockets with a narrow mediolateral configuration were developed to hold the femur in a more adducted

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position. Control of the residual femur was thought to be possible by three-point external pressure.[15,18] By holding the femur in the socket, patient gait and activity were possibly improved.

In a study of 50 patients with a transfemoral amputation it was reported that socket shape did not influence the position of the residual femur, that surgical technique was an important factor, and that prosthesis alignment did not seem to influence the position of the residual femoral shaft either.[2] One of the major problems confronting the patient with a transfemoral amputation is the increased energy expenditure for walking, which is 65% above normal for level walking.[4,20] Loss of the knee joint leads to inefficient gait, and patients with little or no physical reserve may lose the ability to walk again. Contributing to this problem is the abduction of the femur.

BIOMECHANICS OF TRANSFEMORAL AMPUTATION

The normal anatomic and mechanical alignment of the lower limb have been well defined.[3,10,16] In two legged stance, the mechanical axis of the lower limb runs from the center of the femoral head through the center of the knee to the midpoint of the ankle, and measures 3° from the vertical. The femoral shaft axis measures 9° from the vertical (Fig 1), placing the normal anatomic alignment of the femur in adduction. This allows the hip stabilizers (gluteus medius and minimus) and abductors (gluteus medius and tensor fasciae latae) to function normally and reduce the lateral motion of the center of mass of the body, producing smoother and more energy efficient gait.[5]

Patients with a limb amputated above the knee with a conventional amputation show alteration of mechanical and anatomic alignment, because the residual femur no longer has its normal alignment with the tibia, leaving the femoral shaft axis in abduction as compared with the sound limb. This abduction of the fe-

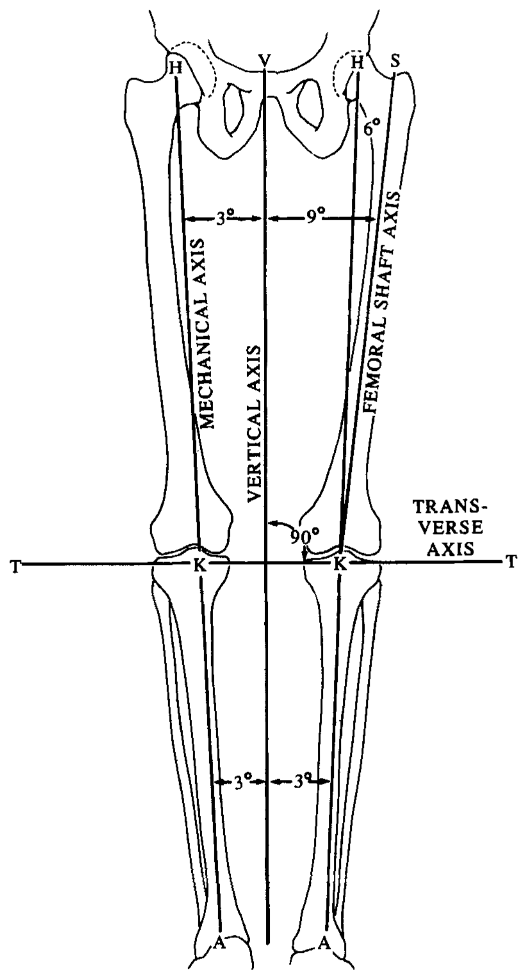

Fig 1. Axes of the lower extremity. (Reprinted with permission from Gottschalk F, Kourosh S, Stills M, McClellan B, Roberts J: Does socket configuration influence the position of the femur in above-knee amputation? J Prosthet Orthot 2:94–102, 1989.)

mur is a result of the unapposed abductor mechanism.

Amputation with an abducted femur leads to an increase in side lurch and higher energy consumption. Loss of normal adductor muscle insertion leads to a shortened effective moment arm (Fig 2). The resultant smaller mass of adductor muscle has to generate a larger force to hold the femur in its normal position and is unable to generate sufficient force

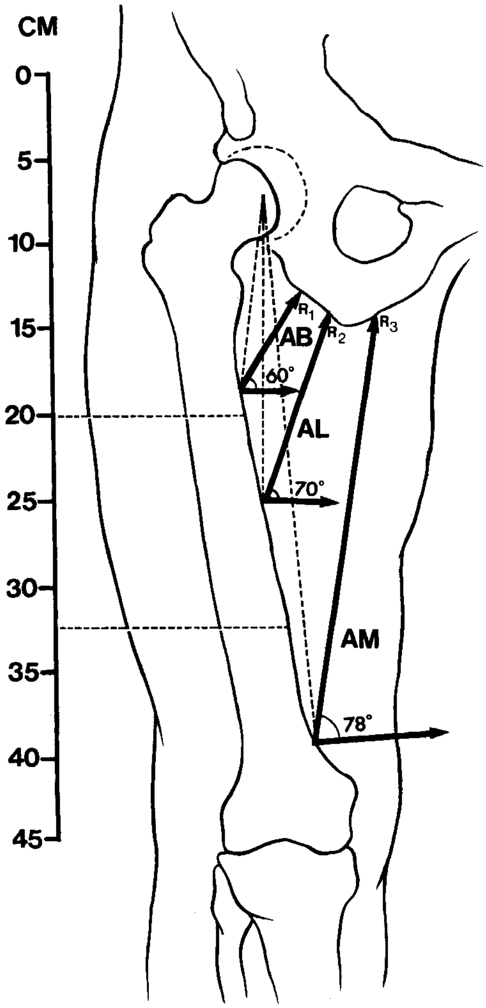

Fig 2. Diagram of moment arms of the three adductor muscles. (Reprinted with permission from Gottschalk F, Kourosh S, Stills M, McClellan B, Roberts J: Does socket configuration influence the position of the femur in above-knee amputation? J Prosthet Orthot 2:94–102, 1989.)

leading to an abducted position of the femur.[7]

Decrease in muscle strength in patients with a transfemoral amputation is a result of several factors: reduction in muscle mass at amputation, inadequate mechanical fixation of muscles, and atrophy of the remaining musculature.[14,19] Sectioning of the muscles not only removes muscle bulk, but also may interfere with the nerve innervation to that muscle. Electromyographic studies of adductor magnus show that it is active at the beginning of stance phase, again at the end of stance, and into early swing phase.[8,11] Because of the muscle's dual innervation by the sciatic and obturator nerves, it is most likely that different parts of the muscle are active at different times during the gait cycle. In a cadaver study, it was reported that the adductor magnus had the most advantageous moment arm to hold the femur in a normal adducted position[7] (Fig 2). The directions of the components of force normal to the lines joining the points of attachment of the muscles also are shown.

The cadaver study showed that the adductor magnus is three to four times larger in physiologic cross sectional area and volume than the adductor longus and brevis combined. The unique anatomy of the adductor magnus with two nerve innervations and two separate functions (hip adduction and hip extension) allows the muscle to be a major stabilizer of the femur. A technique, therefore has been proposed to preserve muscle and restore normal femoral alignment.

Based on the contribution of each adductor moment, if the distal third of the femur is amputated and an inadequate myodesis of adductor magnus is done, then 70% of the adduction moment is lost. The intact adductor longus and brevis would provide the only mechanism for holding the femur in adduction.

The goal of surgery should be the creation of a dynamically balanced residual limb with good motor control and sensation. Preservation of the adductor magnus is possible and helps maintain the muscle balance between adductors and abductors. A muscle preserving technique whereby the distal insertions of the muscles are resected from the original bony attachment and reattached at a new level, maintaining muscle tension, is recommended. When myodesis is complete, the excess tissue can be excised or sutured to fascia.

Indications for Surgery

Vascular Disease

Probably the most common cause for transfemoral amputation is severe vascular and diabetic disease in the patient and poor potential of the patient to heal a lower level amputation. The majority of these patients have widespread systemic manifestations of the disease. On average, patients with purely vascular disease tend to have a higher frequency of transfemoral amputation.

Trauma

These patients tend to be of a younger age group. Severe soft tissue, vascular, neurologic, and bone injury are the reasons for amputation. Maximum length should be maintained and a good soft tissue envelope is essential. Fractures of the femur should be stabilized appropriately rather than amputating at a higher level. This may necessitate a two-stage procedure, because the initial wound is often left open.

Infection

Amputation for severe infection or chronic osteomyelitis should be done as a two-stage procedure with appropriate antibiotic treatment.

Tumors

The level of amputation is determined by the type and location of the tumor. A recent study has shown that patients who have had knee fusions for limb salvage do not function as well as patients who have had amputations.[17]

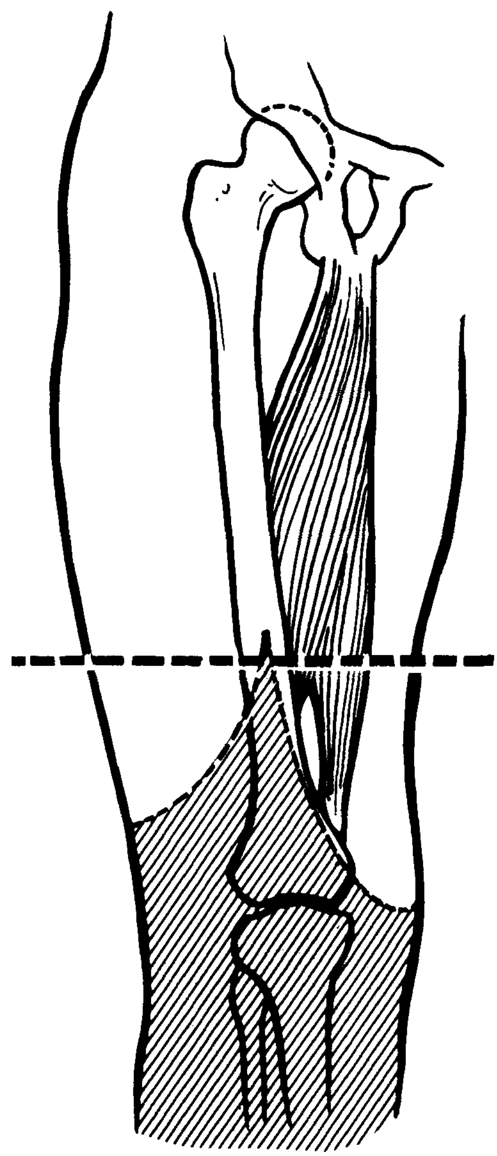

Fig 3. Diagram of skin flaps and bone resection. (Reprinted with permission from Gottschalk F: Transfemoral Amputation. In Bowker JH, Michael JW (eds). Atlas of Limb Prosthetics: Surgical Prosthetic and Rehabilitation Principles. Ed 2. St Louis, Mosby–Year Book 501–507, 1992.)

MATERIALS AND METHODS

Technique

Positioning of the patient on the operating table helps with the surgery. The buttock on the surgically treated side should be elevated on folded sheets or blankets to allow full hip extension and adduction during the procedure.

Skin flaps should be marked before the skin incision. A long medial flap in the sagittal plane is recommended (Fig 3). In trauma the most viable soft tissue is recommended as the flap. Muscles should not be sectioned until they have been identified. The quadriceps is detached just proximal to the patella, retaining some of its tendinous portion.

The vastus medialis is reflected off the intermuscular septum. The adductor magnus is detached from the adductor tubercle by sharp dissection and reflected medially to expose the femoral shaft. It may be necessary to detach an additional 2 to 3 cm of adductor magnus from the linea aspera. The vessels are identified and ligated at or proximal to Hunter's canal. The smaller muscles (gracilis, sartorius, semimembranosus, and semitendinosus) may be transected approximately 1 to 2 inches longer than the proposed bone cut to facilitate their inclusion and anchorage as part of a myoplasty.

The femur is exposed approximately 12 to 14 cm above the condylar level and is cut with a power saw using an oscillating blade transecting the bone approximately 12 cm above the joint line. The blade should be cooled with saline. Two or three small drill holes are made on the lateral cortex of the distal femur and additional holes are made anteriorly and posteriorly approximately 1 to 1.5 cm from the cut end.

The adductor magnus tendon then is sutured with nonabsorbable or long lasting absorbable suture material to the lateral aspect of the femur via the drill holes (Fig 4). Before securing the sutures, the femur is held in maximum adduction, while the adductor magnus is brought across the cut end of the femur, maintaining its tension. Additional anterior and posterior sutures are placed to prevent the muscle from sliding forward or backward over the end of the bone.

The quadriceps is drawn over the end of the bone anchored adductor magnus complex, and is sutured to the posterior femur via the posterior drill holes. The hip should be in extension when this is done to prevent creating a hip flexion contracture. The remaining posterior muscles are anchored to the posterior area of the adductor magnus. The investing fascia of the thigh is then sutured, with the fasciae latae being sutured to the medial fascia. Skin sutures or staples may be used. A stump dressing incorporating an elastic wrap is applied.

The use of myoplasty alone to anchor the muscles does not seem to restore normal muscle tension nor does it allow for adequate muscle control of the femur.

Thirty patients who had had a transfemoral amputation in the previous 5 years were evaluated. Their age, gender, and indications for surgery were documented. Postoperative radiographs with the patient standing in and out of the prosthesis were measured to assess femoral alignment of the amputation compared to the intact knee. Patient activity with the prosthesis also was assessed using an informal questionnaire.

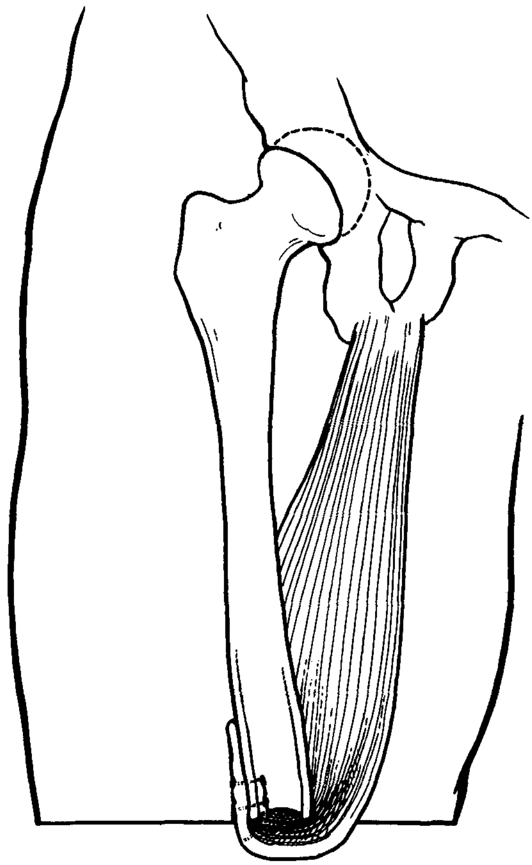

Fig 4. Diagram to show attachment of adductor magnus to lateral femur. (Reprinted with permission from Gottschalk F: Transfemoral Amputation. In Bowker JH, Michael JW (eds). Atlas of Limb Prosthetics. Surgical, Prosthetic and Rehabilitation Principles. Ed 2. St Louis, Mosby–Year Book 501–507, 1992.)

RESULTS

During the last 5 years, 30 patients have had a muscle preserving amputation. Five have been lost to followup. Twenty patients have been followed up during the last 2 years (Table 1). Ages range from 26 to 73 years.

Two patients had knee fusions converted to transfemoral amputations. Both had suffered fracture through allograft bone and were unable to bear weight. One patient had severe ankylosis of the knee after several failed knee replacements. Six patients had amputations for vascular problems, two for chronic infection, and the remainder for trauma.

All 20 patients have become prosthetic users (Table 2). Complications were seen in two patients. One had acute postoperative infection develop and another had a late infection. The older prosthetic users use a cane for walking. No stump breakdowns have occurred to date. Two patients have discomfort at the end of the stump when using their prostheses, but are fully active. No adductor rolls were seen in any of the patients.

Postoperative radiographs in and out of the sockets show maintenance of the femoral alignment on the amputated side. The femoral shaft axis on the amputated side varied from 2° to 9° varus. Strength testing of these patients compared with that of patients with a conventional transfemoral amputation shows improved strength and stump control as measured on a modified isokinetic tester. Gait analysis of some of the patients shows a decreased lurch. The energy cost of walking for patients with an adductor preserving myodesis still is being investigated.

DISCUSSION

It has long been recognized that patients with transfemoral amputations have a higher level of energy expenditure for normal walking because of loss of the knee joint. A contributing factor to the gait disturbance in patients with a transfemoral amputation is the mechanical disadvantage of an abducted position of the residual femur, which forces the patient to walk with increased energy expenditure despite satisfactory fitting with a prosthesis. Many patients who are compliant prosthetic users have pain and discomfort develop at the distal lateral end of the femur, in the socket, as a direct result of the abducted position.

The adductor roll that frequently is seen in patients with a transfemoral amputation is another cause of the patient walking with the leg abducted. The muscle preserving adductor myodesis seems to prevent the formation of an adductor roll, and allows for a more comfortable fitting socket. By applying the biomechanics of the adductor muscles of the thigh and improving the surgical technique to hold the femur in adduction, a patient who may have been a marginal prosthetic user could become a definitive prosthetic user. As reported by James[14] and confirmed by Thiele et al,[19] patients with a conventional transfemoral amputation had decreased muscle strength because of a reduced muscle mass, inadequate fixation of the remaining muscles, and muscle atrophy. By doing the amputation with a muscle preserving technique and myodesis fixation, muscle length and tension are maintained, producing enough muscle power to overcome the shorter horizontal moment arm for adductor magnus. In addition, the femur is held in its anatomic axis, which allows the abductor mechanism to function normally.

Previous texts on the technique of transfemoral amputation make no mention of the adductor muscles and their importance in controlling the position of the femur.[1,2,4,9] Conventional transfemoral amputation creates a femur lying in abduction with a large medial soft tissue mass (Fig 5). This deviation from the normal mechanical axis of the limb results from loss of muscle bulk, loss of muscle insertion, and position of the thigh at the time of wound closure.[6]

A comprehensive magnetic resonance imaging study of patients with unilateral am-

TABLE 1. Causes of Amputations

Causes of Amputation	Number of Patients
Trauma	9
Dysvascular	5
Infection	2
Tumor	3
Failed Knee Replacement	1

Fig 5. Standing xerograph of transfemoral amputation showing abducted femur and distal medial soft tissue mass, with patient wearing prosthesis.

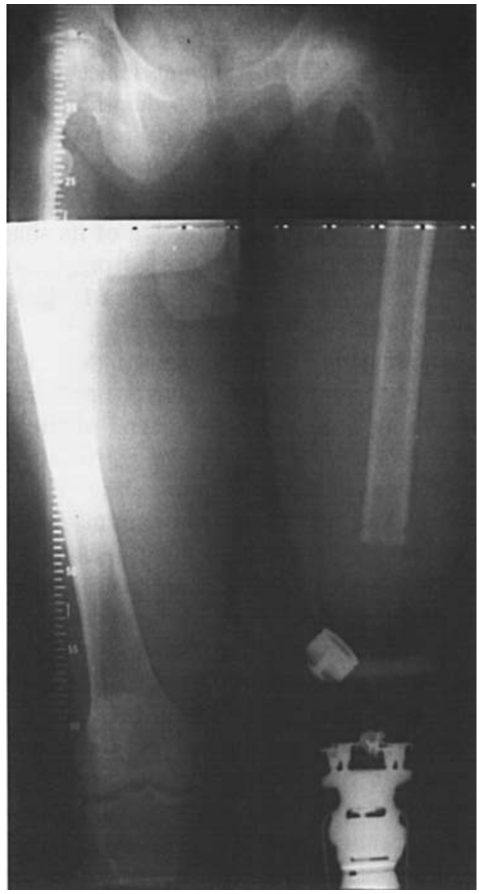

Fig 6. Standing radiograph of transfemoral amputation with adductor myodesis and normal femoral alignment, with patient wearing prosthesis.

putation has shown that the stump is affected by several factors.[12] The length of the stump has a significant bearing on the remaining muscles that showed marked atrophy when not anchored distally. Muscles that had been sectioned showed 40% to 60% atrophy, whereas intact muscles on the amputated side were atrophied from 0% to 30%. The amount of atrophy of the intact muscles was related to stump length. The electromyographic activity of these muscles showed that reattached muscles remained func-

TABLE 2. Prosthetic Users

Demographics	Mean Age of Patients Using a Prosthesis (years)
17 Male	
3 Female	
Age range 26–73 years	
Mean age 49 years	
Dysvascular amputation	56
Traumatic amputation	45 (27–72)
Tumors	27

tional in locomotion in patients with an amputation in the distal half of the femur.[13]

Keeping the adductor magnus intact and adequately reanchoring it to the residual femur will maintain the needed balance between the hip abductors and adductors. It is not possible to hold the residual femur adducted with a prosthetic socket, irrespective of its shape or design, as has been reported previously, because the femur cannot be displaced in its soft tissue envelope.[5]

In a distal third femur amputation the tendon of the adductor magnus should be preserved and swung around the distal end of the femur and anchored by drill holes to the lateral femur, with the femur maximally adducted. This preserves maximum muscle force and provides a mechanical advantage for the adductors and abductors of the thigh. In a middle third amputation, instead of transecting adductor magnus, it should be detached from bone and swung around the distal end of the adducted femur.

Those patients who had a transfemoral amputation as described above, will have normal or near normal anatomic alignment of the femur ranging from 2° to 9° adduction (Fig 6). This preservation of the mechanics and muscle function of the amputated limb should allow patients to improve their ability to walk.

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