The purpose of this case report is to 1) briefly describe the traditional above-knee (AK) quadrilateral socket, 2) describe the contoured adducted trochanteric-controlled alignment method (CAT-CAM) socket, 3) describe the management of a patient with a temporary CAT-CAM prosthesis, and 4) explain how the CAT-CAM prosthesis approach has resolved a medically complex clinical problem. The 49-year-old patient in this case study received a left AK amputation in 1984 and was provided with a quadrilateral socket. She abandoned this prosthesis after 2 years because of her dissatisfaction with the device (ie, poor fit, awkwardness, excessive energy expenditure) and because of her compromised cardiac condition. The patient was fitted with a CAT-CAM prosthesis in 1988 and reported increased comfort, ease of donning and doffing, and increased gait efficiency with the CAT-CAM prosthesis as compared with the quadrilateral socket. The patient required 19 days of prosthetic training and was discharged independent in ambulation and transfers using two straight canes. We consider the CAT-CAM prosthesis an improvement over the quadrilateral socket for increasing ambulation independence in the individual with AK amputation and other medical complications. [Mitchell CA, Versluis TL. Management of an above-knee amputee with complex medical problems using the CAT-CAM prosthesis. Phys Ther. 1990;70:389–393]

Key Words: Ambulation aids, general; Amputations, prosthetics; Amputees; Orthotics/splints/casts, lower extremity. Prosthesis.

Traditional Above-Knee Quadrilateral Socket

In 1950, the University of California at Berkeley introduced a new AK socket called the "quadrilateral socket." It replaced the traditional "plug fit" socket by offering the amputee more comfort and a more efficient gait pattern. The quadrilateral socket has been the standard design for over 30 years. This socket, as suggested by its name, is four-sided with an increased mediolateral diameter and decreased anteroposterior diameter. The primary weight-bearing surface is the ischial tuberosity, which rests on a posterior wall brim, much like a person sitting in a chair. The socket has reliefs built into it to allow space for functioning muscles, and bulges are added to the socket design to press on soft tissue to distribute pressure.
over the neurovascular bundles. The posterior wall encloses the hamstring muscles medially, then slants posterolaterally from 7 to 10 degrees on its inner surface to allow room for the gluteus maximus muscle. Distally, the posterior wall is slanted anteriorly to maintain the residual limb in flexion and to stretch the hamstring and gluteal muscles for maximum extension power.

The quadrilateral socket's lateral wall is higher than the posterior wall, and its primary function is to stabilize the femoral shaft and to enclose the gluteus maximus, vastus lateralis, and tensor fasciae latae muscles. Distally, the lateral wall adducts the femur and thus stretches the hip abductors.

The medial wall's primary role is to stabilize the residual limb against the lateral wall by compressing the adductor muscles. The anterior wall of the socket is higher than the posterior wall and acts to press the residual limb posteriorly so that the ischial tuberosity is seated properly on the posterior wall brim. The anterior wall also has built-in reliefs to reduce pressure on the hip flexor musculature and bulges to compress the Scarpa's triangle (the area containing the neurovascular structure, bordered by the inguinal ligament and the adductor longus and sartorius muscles), which is capable of withstanding firm pressure.

Clinicians over the years have noticed common gait deviations in patients using the quadrilateral socket. According to Sabolich, as the gluteus medius muscle pulls the femur into abduction, the pelvis slides medially on the ischial seat and increases femoral abduction, which decreases the efficiency of the hip abductors. While the distal aspect of the residual limb is moving laterally, the proximal aspect is moving medially, striking the medial wall and causing the amputee discomfort and possible skin breakdown. Long agrees with Sabolich and attributes the quadrilateral socket design with causing excessive hip abduction. He states that the increased mediolateral dimension and decreased anteroposterior dimension allow the ischial tuberosity to move off of the posterior wall brim. The amputee develops the following gait deviations to reduce the pressure on the lateral distal femur and medial proximal soft tissue: Trendelenburg's symptom, lateral trunk lean, increased lateral displacement of the body's center of gravity, unequal stance time, decreased stride length of the unaffected limb, and increased oxygen consumption.

**CAT-CAM Prosthesis as an Alternative**

The temporary CAT-CAM prosthesis used at our facility has a removable lateral wall that accommodates weight fluctuations and decreases the shearing force produced with donning and doffing the device (Fig 1). Applied to the residual limb by a series of Velcro straps, this lateral wall also allows easier inspection of incisions in amputees postoperatively. We believe, based on the patient's subjective report, that use of lightweight materials in the fabrication (polyethylene plastic for the lateral wall and copolymer plastic for the socket) helps to reduce the patient's energy expenditure during ambulation. Flan dry et al, in their study of five amputees using first a quadrilateral socket and then a CAT-CAM prosthesis, support this belief with their finding of lower oxygen consumption during gait with the use of the CAT-CAM device.

The CAT-CAM prosthesis encloses the thigh by forming a wedging or "locking" effect that prevents the socket from moving on the residual limb. Sabolich states this locking effect is accomplished by holding the femur in abduction with a three-point pressure system.

Sabolich also describes the differences between the CAT-CAM prosthesis and the quadrilateral socket. To summarize, the anteroposterior dimension of the CAT-CAM prosthesis is increased while the mediolateral dimension is decreased, causing an anterolateral shift in the adductor longus tendon that results in decreased pressure on the tendon and the Scarpa's triangle. The socket design has been changed to allow the ischial tuberosity to sit inside the socket, and it is seated on an angled surface to bear only partial vertical loading. In addition, the design undercut the greater trochanter where a fossa is placed, allowing the ischial tuberosity and descending ramus to rest. During gait, the femur is held in addition, eliminating the lateral trunk lean noted in amputees using the quadrilateral socket.

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Velcro USA Inc, PO Box 5218, 406 Brown Ave, Manchester, NH 03108.
Flandry et al., in their study of five amputees using the CAT-CAM prosthesis, supported Sabolich's claims and found decreased hip abduction during gait and standing, bringing the body's base of support closer to midline. They also found a decreased Trendelenburg symptom, decreased lateral trunk lean, increased stride length, and cadence, and decreased oxygen consumption. Subjectively, the amputees felt more comfortable with the CAT-CAM prosthesis and reported increased balance and stability. When offered the option of returning to their quadrilateral sockets, four of the five subjects rejected this offer. 

Sabolich also states that the CAT-CAM prosthesis is the preferred prosthetic device of amputees with a short femur in their residual limb and of individuals with bilateral AK amputations, especially for perineal and sitting comfort. Other quadrilateral socket problems resolved with the CAT-CAM prosthesis are decreased range of motion at the hip joint, compromised peripheral vascular and cardiovascular systems (decreased energy expenditure), and poor muscle tone.

A previous study conducted at our facility identified criteria contributing to successful long-term prosthetic use in patients with an amputation secondary to vascular disease. The results showed that AK amputees fitted with quadrilateral sockets had a low success rate for long-term prosthesis use. Additional medical problems were a significant criterion in those patients who discontinued wearing their prosthesis. In the last two years, our facility has fitted several AK amputees with the CAT-CAM prosthesis. Above-knee amputees who were predicted to be marginal candidates for successful prosthetic fitting because of their complicated medical conditions have done quite well. These patients seem to train more quickly and have fewer complaints than patients fitted with the traditional quadrilateral AK socket.

Clinical Approach with the CAT-CAM Prosthesis

Patient Medical History

The patient in this case study was a 69-year-old woman who suffered a mild left cerebrovascular accident in 1980 with a residual effect of complete right homonymous hemianopsia. In 1981, a mitral valve replacement was performed. In 1984, a revision of the mitral valve replacement was performed with postoperative complications resulting in right peroneal nerve paralysis secondary to long-term compression and left AK amputation secondary to bilateral inguinal emboli. The patient then received prosthetic training with a quadrilateral socket and was ambulatory with two straight canes until 1986. The patient was wheelchair bound because of an ill-fitting prosthesis and deteriorated cardiac status from 1986 until receiving a heart transplant on May 31, 1988.

Initial Assessment

The patient was referred to physical therapy for evaluation and prosthetic training and was initially seen June 1, 1988. Manual muscle testing revealed Fair (3/5) muscle strength in bilateral lower extremities with the exception of the right tibialis anterior muscle, which tested Trace (1/5), and the right gluteus medius muscle, which tested Fair minus (3-5). These weaknesses were residual deficits of bilateral inguinal emboli. Resisted movements to the patient's upper extremities were contraindicated because of her recent heart transplant. Neurological examination showed sensation intact to light touch, pinprick, proprioception, and two-point discrimination. Deep tendon reflexes were also intact. Active ROM was within normal limits at all joints. Supine-to-sitting and sit-to-stand transfers were independent; however, bed-to-chair transfers required minimal assistance of one person.

At the beginning of treatment, the patient ambulated 2 m with a quadrilateral prosthesis, two straight canes, and minimal assistance of one person. In addition, the patient required a plastic ankle-foot orthosis to prevent foot drop secondary to peroneal nerve paralysis on the right side. The patient ambulated using excessive bilateral hip flexion and left lower extremity abduction. Endurance was poor with fatigue present after ambulating 2 m, demonstrated by the patient becoming short of breath and having subjective complaints of being "tired." The prosthesis was determined to be ill-fitting by both the patient and the therapist. The socket was considered unacceptable by the therapist because of socket "pistoning," medial tissue not being contained in the prosthesis, and improper seating of the ischial tuberosity on the posterior wall. The patient was dissatisfied with the fit and comfort of application of the prosthesis. On visual examination, the residual limb appeared reddened at pressure points located at the site of the adductor longus tendon and posteriorly near the ischial tuberosity, and general muscle atrophy was noted in the quadriceps femoris, hamstring, and gluteal muscles. The patient also had edema throughout her face, trunk, and extremities, thought to be secondary to corticosteroid use. Precautions for the patient included not being allowed to ambulate without a prosthesis or to lift over 10 lb with her upper extremities for 3 months following the heart transplant.

We contacted a prosthetist to fit the patient with a new prosthesis. The decision was made to fabricate a temporary CAT-CAM prosthesis for the patient.

Treatment

The primary goal of treatment was for the patient to ambulate 67 m independently using a CAT-CAM prosthesis.
with two straight canes on all surfaces. Other goals included independence in basic transfers, in performing a home exercise program, and in donning and doffing the prosthesis.

Once the prosthesis had been fabricated and final alterations in fitting completed, the patient and therapist worked on increasing independence in donning and doffing of the prosthesis and ambulation. Initial ambulation with the temporary prosthesis revealed gait deviations of right Trendelenburg's symptom, rapid knee extension during the swing phase of gait on the left side, and pistoning of the residual limb within the socket.

A home exercise program was prescribed to increase the patient's muscle strength, and she was instructed in proper positioning of the residual limb to prevent contractures. The home exercise program consisted of bilateral lower extremity-hip flexion, extension, and abduction and right knee extension. Upper extremity exercises consisted of shoulder flexion and abduction and elbow flexion and extension. The exercises were to be performed twice daily for 10 repetitions initially. The patient was progressed from performing active ROM on the lower extremities to resistive exercise, and the number of repetitions was increased to 20. The patient was instructed to lie prone for 20 minutes daily to prevent hip flexion contractures. In addition, the patient was instructed to use a perceived exertion scale (ie, shortness of breath, sweating), rather than monitoring her heart rate and blood pressure, as is common in cardiac patients without heart transplant, because the transplanted denervated heart does not respond with typical parasympathetic and sympathetic changes to exercise. The patient was treated a total of 19 times, four times as an inpatient and 15 times as an outpatient.

**Results of Treatment**

On June 28, 1988, a reassessment demonstrated an increase of muscle strength in the bilateral lower extremities to Normal (5/5) with the exception of Trace (1/5) results in the right tibialis anterior muscle and Good minus (4−/5) results in the right glutaeus medius muscle.

The patient initially ambulated with the left temporary prosthesis and the right AFO within the parallel bars (Fig 2), progressed to a wheeled walker (Fig 3), and finally ambulated with two straight canes (Fig 4). She used the canes on all surfaces including ascending and descending stairs. In the course of treatment, cadence was increased and gait deviations

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**Fig 2.** Patient ambulating in parallel bars.

**Fig 3.** Patient ambulating with front-wheeled walker.

**Fig 4.** Patient ambulating with two straight canes.
were diminished. On the final day of treatment (July 14, 1988), the patient ambulated 250 m independently with two straight canes, rode a stationary bicycle for 10 minutes without resistance, and was able to don and doff the prosthesis independently. The patient reported increased comfort, ease of donning and doffing, and increased gait efficiency with the CAT-CAM prosthesis as compared with the quadrilateral socket.

A follow-up telephone call at six months posttreatment revealed the patient still ambulating with a temporary prosthesis and two straight canes for an unlimited distance. The patient reported that she was riding a stationary bike up to 15 miles a day and continuing with her home exercise program. When asked about future plans for a definitive prosthesis, the patient reported that weight fluctuations prohibited a permanent prosthesis at this time.

**Discussion and Conclusions**

The intent of this case report was to present a patient with an AK amputation and complex medical problems who was successfully treated with a CAT-CAM temporary prosthesis. We believe the temporary CAT-CAM prosthesis allowed her to bear weight sooner than a conventional prosthesis because of the flexible, yet stable, socket. The socket is flexible in its ability to accommodate changing residual limb volume and is stable in its ability to hold the residual limb. We believe the temporary CAT-CAM prosthesis with adjustable socket is the prosthetic device of choice for AK amputees with problematic weight fluctuations secondary to complex medical problems.

Our patient was a good candidate for this prosthesis because of her weight fluctuations secondary to immunosuppressant corticosteroid use and because of her limitations with cardiac endurance. We believe the temporary CAT-CAM prosthesis allowed our patient to achieve a high level of independence and mobility in a minimal amount of time because of its structural characteristics allowing for flexibility and stability. Training protocols for other prostheses would have been halted or delayed because of the patient's weight fluctuations. Our patient was a challenge to rehabilitate because of her complex medical history, and further follow-up may be required to assess the long-term benefits of obtaining a definitive prosthesis. Additional research is needed to assess the design of the CAT-CAM prosthesis used in our facility to substantiate our conclusions based on one individual.

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**References**


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1 mile = 1.6 km.