Osteomyoplastic Reconstructive Technique for Primary and Secondary Amputations:

(Ertl Procedure)

Introduction

Lower extremity amputation is a surgical procedure that dates to pre-history and is one of the oldest surgical procedures described. Neolithic man is known to have survived traumatic, ritualistic, punitive, and therapeutic amputation. Plato and Hypocrites have described therapeutic amputation techniques.

The treatment of severe lower extremity trauma and peripheral vascular disease has made great advances in the modern surgical era. Revascularization, internal fixation of fractures, microvascular techniques, and free tissue procedures have improved and have favorably enhanced the patient's outcome. Failure of these techniques in the lower extremities may result in factors that can lead to amputation surgery. The reality being that all efforts were pursued to salvage and maintain the extremity with amputation being the only alternative to return the patient to his family and an active lifestyle. Amputation is then viewed as a failure by both the surgeon and the patient, who then pictures himself as incomplete, by societal standards. In many regions of the world these advanced surgical techniques are unavailable, or even too costly, and amputation remains the primary form of treatment.

When compared to the prosthetic industry, amputation techniques have changed little over the years and are usually performed by the most junior member of the

surgical team. In contrast, the prosthetists have made significant advances in accommodating the amputated extremity, at times attempting to improve on less than optimal surgical results. In spite of a well-performed amputation and a well-fitted prosthesis some patients have persistent symptoms of residual extremity pain, swelling, sense of instability and decreased length of prosthetic wear. These patients pose a challenging situation from a surgical reconstructive perspective. The effects of previous surgery, altered anatomy, muscle and bone atrophy, aerobic deconditioning and maintenance of residual limb length create additional difficulties when considering surgical reconstruction.

The osteomyoplastic lower extremity amputation procedure was described by Professor Janos v. Ertl, MD, in 1939. This encompassed the sum of his experiences from the post war eras, operating on an estimated 13,000 amputees.[7, 8] The principles of the surgical technique were not only limited to the amputation field but had their origins in the field of reconstructive surgery. The procedure arose from the observation that the periosteum had regenerative potential in bony injuries. Ertl first applied this principle to procedures utilizing osteo-periosteal grafts to the mandible and the skull during World War I.[7, 8] As this was a trench war, many soldiers survived with maiming injuries to their face and cranium. Ertl reconstructed these osseous defects with flexible, free osteo-periosteal grafts harvested from the tibia. As the potential for these grafts to regenerate an osseous structure was realized, the grafts were then applied to a wider use, including the spine, long bones, and amputations. Along with osseous reconstruction in amputations, particular attention was also applied to the handling of the soft tissues.

Neuromuscular isolation, high ligation of the nerves, myoplasty, and smooth skin closure provided the patient with a cylindrical residual extremity with end-bearing capabilities. Ertl believed that this returned the residual extremity to as normal an anatomic, physiologic, and biologic state as possible. Within the literature, this has been referred to as the Ertl procedure. This procedure is applied to both primary and secondary diaphyseal amputations of the femur, tibia, humerus, metatarsals and digits.

Our experience with this procedure has been positive and offers the surgeon an option when presented with difficult surgical primary and reconstructive amputee symptoms.

Description of Transtibial Procedure

Informed consent was obtained from all patients. In very short residual extremities, the possibility of knee disarticulation or above the knee amputation was also discussed. Attempts were made to maintain the knee and residual extremity in these patients.

The patient is positioned supine, a bump under the hip may be utilized to control rotation of the limb, and a tourniquet is applied. Use of a tourniquet in vascular patients was used on a discretionary basis. After prepping and draping of the extremity, the previous incisions are identified and utilized. There has been no difference in wound healing between anterior-posterior, oblique, or medial-lateral incisions. Following incision, dissection is carried down to the muscular layer. Frequently the residual extremity has no distal bony muscular coverage since the

musculature was either poorly secured or allowed to retract. Dissection is then carried more proximal with the anterior, lateral, and posterior compartments being identified and isolated. If a long posterior muscle flap was utilized for anterior coverage in the primary amputation, care should be taken to preserve the length of this posterior muscle compartment. During isolation of the muscle compartments, care should be taken to maintain fascial attachments to the musculature for later myoplastic reconstruction. Following isolation of the muscle compartments, the main neurovascular structures are identified, released from scar tissue and separated. This should include the tibial nerve, artery, and vein, the superficial and deep peroneal nerves, the peroneal nerve (both superficial and deep), artery and vein, the sural nerve, and the saphenous nerve and vein. Palpation of neuromas may aide in localizing neurovascular bundles as these have commonly been ligated in unison. Once separated, the identified nerve should be transected as high as possible and allowed to retract into the soft tissue bed. The artery and nerve are separated and ligated in a separate fashion.

Once soft tissue dissection is completed, attention is turned to the osseous structures. The periosteum is incised from anterior to posterior on the fibula and tibia. Utilizing a 45-degree angled chisel, an osteo-periosteal flap is elevated medially and laterally, maintaining the proximal attachment. Small cortical fragments are left attached to the periosteum. Once the osteo-periosteal flaps are created, any exposed cortical bone that remains is resected to the same level, facilitating the suturing of the osteo-periosteal flaps. This requires no more than 1.5-2 cm of bone to be resected. The medial tibial flap is sutured to the lateral fibular flap and the

lateral tibial flap is sutured to the medial fibular flap, resulting in a tube-like structure. Occasionally it is necessary to split the fibula longitudinally creating medial and lateral periosteal-cortical flaps, which are used and secured in the same fashion as above. Care should be taken not to abduct the fibula too much as this will place stress on the proximal tibio-fibular joint.

In short or very short residual extremities, free osteoperiosteal grafts are harvested from the proximal tibia, contralateral extremity or iliac crest to maintain bony length. This may also be performed on any length of residual extremity. We have utilized free osteoperiosteal grafts in primary amputations harvested from the removed limb without difficulty and complete synostosis formation.

Some short transtibial extremities exhibit an abduction of the fibula (abducted fibula) secondary to the pull of the biceps femoris muscle. This may lead to a lateral pressure point and prosthetic difficulties. The fibula is reduced into an adducted position and a lag screw placed into the proximal tibio-fibular joint, stabilizing this dynamic deformity with or without an arthrodesis of this joint.

The mobilized musculature is then brought distally covering the osteo-periosteal bridge and a myoplasty is completed suturing the posterior musculature to the anterior and lateral musculature. However, the goal is to provide soft tissue coverage to the distal aspect of the residual extremity. Following the completion of the myoplasty, the skin is mobilized over the underlying myoplasty. Care is given to reapproximate the skin in a symmetric fashion leaving neither dog-ears nor crevices. Drains are placed for hematoma decompression. After sterile dressings are applied, the extremity is placed in a plaster splint in extension. The splint is

removed between 2 and 7 days. A temporary total contact end bearing prosthesis is begun in 5 to 8 weeks. Physical therapy is also instituted for education on transfers, desensitization of the residual extremity, aerobic conditioning, and upper body strengthening.

In primary amputations the same technique is utilized.

Primary amputations are approached in a similar fashion. Care being given to ensure sufficient skin to coverage for the greater muscle bulk.

<u>Results</u> - Transtibial

Between January 1980 and January 1995 three surgeons performed transtibial osteomyoplastic lower extremity amputation reconstructions in 164 patients. There were 7 bilateral amputees treated in stages. Twelve patients were deceased from unrelated causes and 9 patients were lost to follow-up. A total of 143 patients with 150 osteomyoplastic reconstructions, with a minimum of 2-year follow-up, were available for review. The average follow-up was 9 years with a range of 2-15 years. There were 109 males and 41 females with an average age at the time of reconstruction of 48.5 years. Age ranged from 12-88 years of age. There were 72 right and 78 left lower extremities involved. The initial causes of amputation were traumatic in 63.3% (95), peripheral vascular disease in 27.3% (41), infection in 7.3% (11) and tumor in 2% (3). The average time to surgical reconstruction after primary amputation was 9.5 years, with a range of 2 months to 47 years.

The overall results when using the 30 point scale for these patients revealed a 73.3% (n=110) excellent result, 18.7% (n=28) good result, 5.3% (n=8) fair result, and 2.7% (n=4) poor result. The 4 poor results were in dysvascular patients as there

was continued pain in spite of improvements in all other categories. When questioned with overall satisfaction, 97.3% of the patients felt their final result improved the residual extremity function and also improved their perceived quality of life.

<u>Description of procedure: Transfemoral</u>

The patient is informed of the surgical risks and complications. All attempts are made to maintain residual extremity length to spare the cost of increased energy expenditure. A diagrammatic transverse section at the appropriate transfemoral level is helpful during surgery. In secondary reconstuctive cases, the previous operative report should be reviewed and attention directed toward the treatment of the muscles and nerves, which may assist in the exposure and dissection.

The extremity is prepared in standard fashion. A tourniquet may not always be feasible and a sterile tourniquet may be used. A bump is placed under the hip of the involved extremity to assist with rotational control. The previous incisions are identified and utilized.

Dissection is carried to the muscular layer. The muscles are often retracted and atrophic necessitating proximal dissection and muscle identification. The adductors, abductors, quadriceps, and hamstrings are isolated in their respective groups. The fascial envelope or more often scar tissue attachments are maintained for subsequent myoplasty. The neurovascular structures are identified, released from scar and separately isolated. It is important to separate the nerve from the artery as the neurovascular structures have often been ligated together. This aviods

pulsatile irritation of the nerve. The sciatic nerve may be identified by palpation of its neuroma, which may reach sizes up to 4 cm. The nerve trunk is mobilized by blunt dissection, distracted and transected at a higher level, allowing retraction into soft tissue surroundings. If a tourniquet has been used, it may be released to evaluate bleeding. The vascular structures are often friable and need to be handled carefully to avoid proximal retraction. The artery and associated veins are separately ligated to avoid arterio-venous connections.

Attention is directed towards the distal residual femur. All exostosis are removed and the periosteum incised anterior to posterior. Utilizing a 45 degree angled chisel, medial and lateral osteoperiosteal flaps are elevated maintaining their proximal attachments. Elevation of the flaps is aided by rotating the chisel 180 degrees lifting and maintaining the osteoperiosteal attachments. The femur is transected at the level of the osteoperiosteal flaps, with minimal femur necessitating removal. The medial and lateral flaps are sutured together and circumferential periosteal sutures are placed occluding the end of the open medullary canal. An alternative method is to prepare a longer medial or lateral based osteoperiosteal flap, securing it to the opposing and circumferential periosteum, achieving medullary coverage.

The myoplasty is performed by suturing the antagonistic muscle groups to each other and anchoring them into the periosteum, covering the osteoplasty. The adductors are sutured first to the abductor group or anchored to the lateral femoral periosteum. The abductors are imbricated over the adductor attachment and additionally secured to the periosteum anterior and posterior.. The flexors are

sutured to the extensor group and the underlying adductor/abductor groups, centralizing the distal femur in a muscular envelope.

The skin is fashioned to the underlying myoplasty in a symmetric fashion avoiding dog-ears and invaginations of the incision. A smooth contour is the goal allowing for a better limb prosthetic limb interface. Penrose drains are placed prior to completion of the closure.

Postoperatively the residual extremity is placed in an ace wrap hip spica or a bulky plaster splint, depending on length. Sutures are removed at 2 to 3 weeks depending on wound healing. Temporary total contact end bearing prosthetic fitting is coordinated with the patient's prosthetist, between 5 and 8 weeks postoperative. Physical therapy is initiated for transfers, desensitization, range of motion, aerobic conditioning and upper body strengthening.

Primary amputations are approached in a similar fashion. Care being given to ensure sufficient skin to coverage for the greater muscle bulk.

<u>Results</u> - Transfemoral

Between January 1980 and January 1995 three surgeons performed transfemoral osteomyoplastic lower extremity amputation reconstructions in 93 patients. There were two bilateral amputees. Thirteen patients were deceased from unrelated causes and 6 patients were lost to follow-up. A total 72 patients with74 transfemoral osteomyoplastic amputation reconstructions with a minimum 2 year follow-up were available for review. The average post operative follow-up was 9.8 years with a range from 2 to 15 years. There were 40 males and 32 females with an average age

at operation of 57.4 years. Age ranged from 29 to 79 years. There were 37 right and 37 left lower extremities involved.

The initial cause of amputation were traumatic in 60% (43), peripheral vascular disease in 30% (22), infection 4% (3) and tumor 6% (4). The average time to surgical reconstruction after primary amputation was 13.3 years, with a range of 10 months to 40 years.

The final overall results using the 30 point rating system demonstrated 70%(n=52) excellent, 20%(n=15) good, 4%(n=3) fair and 6%(n=4) poor. The 4 poor results occurred in 3 patients, one bilateral amputee, with peripheral vascular disease as there was continued pain in spite of improvements in other categories. When questioned with overall satisfaction 95.8% of these patients felt their final result improved the residual extremity function and also improved their percieved quality of life.

<u>Description of procedure: Transmetatarsal</u>

Use of a tourniquet in vascular patients is used on a discretionary basis. The extremity is prepared in standard fashion. The skin incision is made as distal as feasible and dorsal and plantar flaps created. The flexor and extensor muscle groups are elevated as one musculo-fascial flap.

The vessels are isolated and ligated and the digital nerves separated, distracted and ligated at a more proximal level.

Osteoperiosteal flaps are elevated from the first and fifth metatarsals as described above. The metatarsals are equally transected at the level of the osteoperiosteal

elevation. The osteoperiosteal flaps are sutured end to end and to each metatarsal, covering (closing) the exposed diaphysis. The flexor and extensor groups are sutured to each other through the fascial attachments, forming the myoplasty.

If used, the tourniquet is released and bleeding controlled. The skin is contoured to the underlying myoplasty, achieving a smooth transition. Penrose drains are placed for hematoma decompression. Sterile dressings and a well padded posterior splint are applied.

The splint is removed between 2 and 7 days. Physical therapy is also instituted for education on transfers, desensitization of the residual extremity, aerobic conditioning, and upper body strengthening. Full weight bearing is initiated between 4 and 6 weeks or pending wound healing.

<u>Transhumeral</u>

Sterile upper extremity preparation is completed in standard fashion. A sterile tourniquet may be used on a discretionary basis. Previous incisions are utilized and anterior-posterior or medial-lateral flaps elevated. The muscles are separated into anterior and posterior groups. Depending on the amputation level, the median, ulnar, radial nerve and their extensions are isolated, distracted and proximally ligated. The brachial artery is separated from its veins and separately ligated. Similar to the transfemoral amputation, osteoperiosteal flaps are created and sutured over the exposed medullary canal. If used, the tourniquet is released and bleeding controlled. The myoplasty is fashioned by suturing the flexor and extensor myofascial groups together and into the underlying periosteum. The skin is

contoured to the myoplasty in similar fashion as above. A bulky soft tissue dressing is applied. Prosthetic management is begun between 4 and 6 weeks post-operative.

Discussion

Conventional amputations can create multiple difficulties within the amputee. Loon [17,18] described two categories that amputee patients can fall into. The first are those directly related to the amputation and include pain, circulatory disturbance, local osteopenia, and muscle atrophy. The second category consists of those problems related when an attempt is made to restore function by the attachment of prosthesis to the residual extremity. From clinical observations involving amputees and Loon's descriptions, the extremity then becomes a passive, inactive participant in function and the constellation of symptoms is referred to here as the inactive residual extremity syndrome.

Numerous physiologic effects of conventional amputation contribute to the inactive residual extremity syndrome and have been elucidated in both animal and human studies. Conventional amputation procedures leave the intramedullary canal open. Non-traumatized bone exhibits an intramedullary pressure gradient of approximately 65 mmHg.[1] The increased venous pressure is necessary to maintain a centrifugal venous drainage in a rigid tubular bone. This medullary pressure appears to be important in extremity venous drainage[19] and in osteocyte nutrition.[23] When the medullary canal is left open, the normal venous pressure is lost and has been measured as 0 mmHg, there is a slowing of dye material on contrast venogram,

and dilated, tortuous intramedullary sinuses are also observed.[17, 18] With closure of the canal with osteo- periosteal flaps, these conditions reverse themselves as shown on post-operative venograms and in the transtibial amputee additionally stabilizes the fibula, creating a broader surface area to load and accept a prosthesis.[10,11,12,13,15,17,18] Maturation of the bony bridge can allow complete end weight bearing of the residual extremity.

Muscle and soft tissue blood flow is essential for primary healing and future function. Many amputations are performed with out restoring the length-tension relationship of the musculature. Subsequently, the muscle can undergo atrophy, fatty degeneration occurs, circulation slows, venous stasis arises as the muscles do not aide in pumping venous blood, and the result can be chronic edema. Shortly following amputation, there occurs a hypervascularity and tortuousity of the vessels.[16] However, this hypervascularity decreases within 1-2 weeks following the amputation. The soft tissue then becomes hypovascular but the tortuous vessels remain.[10,11,12,13] These similar angiographic findings were seen in patients with vessel occlusion and peripheral vascular disease, indicating pathologic circulation.[4,5,6,16] Arterio-venous malformations can also be seen at the distal portion of the stump creating a shunt in the extremity.

Myoplasty in the transtibial level reapproximates the flexors to the extensors over the bony bridge . For transfemoral amputations the adductors are attached to the abductors and the flexors to the extensors, centralizing the residual femur and securing the muscles to bone via the periosteum. This restores muscle tension and provides soft tissue covering over the distal osseous structures. Angiographic studies

after myoplasty have shown an improvement in circulation on arterial supply and venous drainage.[10] Vasculature changes that are seen with inactivity and immobilization are also reversed with myoplasty.[13] Medhat has also shown that terminal circulation in vascular patients is improved with myoplasty.[20] In relation to function of the residual extremity, a more rhythmic and phasic activity is seen on EMG studies as opposed to an irregular pattern without myoplasty.[3]

With the resultant physiologic changes within the residual extremity, edema can result which can alter the size and shape of the residual extremity.[17,18] This is believed to result from the relative inactivity of the extremity when myoplasty is not performed. With the resultant volume changes, the patient has difficulty fitting into the prosthetic socket, limiting ambulation, and can result in chronic skin changes. Continuing the cascade of changes, inactivity and the inability to load the bone will lead to atrophy of the muscle and local osteopenia/osteoperosis, poor venous return, loss of the pumping action of muscle and fatty degeneration. Size and shape of the residual extremity are maintained with osteomyoplastic reconstruction.

Pain is the most frequent and often the most disabling symptom for the amputee and often is the most common reason for seeking medical intervention. The genesis of pain may be phantom sensations, circulatory disturbances, local skin changes, exostosis, bone necrosis, and neuroma formation. Combining medullar closure, high neuroma resection, myoplasty, and meticulous skin closure, pain has been seen to decrease in the majority of patients treated. Four patients within our study group continued to experience pain. These were all in dysvascular patients. Although experiencing and improvement in all other categories that were rated,

including length of prosthetic wear, these patients most likely exhibited symptoms that were most likely continued vascular claudication.

Stability of the residual extremity is difficult to objectively measure. The clinician is usually reliant on the patient and their ability to function while the prosthesis is in place. The functional gains experienced by these patients were related to the decrease of pain and their ability to remain stable with in their socket following reconstruction. As their function improved, patients appeared to become more confident in push off, increasing their overall walking distance. Although four vascular patients did not improve on their pain scale, they did show improvement in their ambulatory potential. We postulate that that pain may be from persistent vascular claudication.

The efforts of the osteomyoplastic procedure are directed at creating a functional and active residual extremity based on reestablishing a physiologic environment. The resultant residual extremity will afford the amputee with a stronger and more durable limb with improved stability and proprioception. We have utilized free osteo-periosteal grafts to form our bone bridge in short residual limbs in order to maintain length and achieve the desired results. In longer residual limbs, minimal length is removed, in contrast to what has been described.[2,21,22] In addition, the overlying myoplasty will contribute to the total length of the extremity. The surgeon should not hesitate to sacrifice length when an increase in function can be achieved.[17] This technique has successfully been applied to both primary and secondary amputations.

The difficulty with assessing these patients' final result is that the final outcome involves variables that may affect the results, for example, socket design, prosthetic componentry and the use of different prosthetists with varying experience.

The osteomyoplastic lower extremity amputation reconstruction is technically challenging with a somewhat greater operative time than conventional techniques. It may be used for traumatic and vascular amputations with high success and high patient satisfaction. This procedure offers the surgical community with a dynamic procedure for both primary and secondary reconstructions in lower limb amputation surgery.

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Table-1

Pain	Points
a) no pain	5
b) slight pain/no compromise	
with activities	4
c) mild pain with normal	3
activity	2
d) pain with standing in	1
prosthesis	
e) pain w/out prosthesis	
Function	
a) unlimited walking ability	5
b) 6-12 blocks	4
c) 2-5 blocks	3
d) 1-2 blocks	2
e) indoors only or wheelchair	
assistance	1
Stability	
a) no weakness/no limitations	5
b) difficulty with uneven	4
terrain	3
c) difficulty with	2
stairs/inclines	1
d) extremity weakness	
e) thigh lacer/walking aids	
Swelling	
a) none/minimal/no socket	
compromise	5
b) with walking 6-12 blocks	4
c) with walking 2-5 blocks	3
d) with walking 1-2 blocks	2
e) with indoor walking	1
Hours of prosthetic wear	
a) 14-18 hours	5
b) 10-13 hours	4
c) 6-9 hours	3
d) 3-5 hours	2
e) 1-2 hours	1
Radiographs	
a) full synostosis	5
b) up to 75%	4
c) up to 50%	3
d) up to 25%	2
e) no synostosis	1
Total	30
Grading system	Excellent: 25-30 Good: 20-24 Fair: 15-19 Poor: <15