



Traumatic Amputation And Prosthetics

Independent Study Course
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Independent Study Outline

Purpose This independent study course provides participants with information about patients experiencing traumatic amputation during military service, rehabilitation following amputation, long-term care of the amputee, prosthetic clinical and administrative issues and primary care related to veterans with traumatic amputations.

Objectives After completing this independent study, participants should be able to:

- recognize common problems associated with traumatic amputations;
- identify methods of rehabilitation used with amputee patients;
- explain long term care of amputee patients;
- discuss prosthetics clinical issues;
- discuss prosthetics administrative issues; and
- understand primary care needs of traumatic amputee patients.

Target Audience This independent study is designed for Department of Veterans Affairs' physicians, nurses and other primary health care providers. Other health care providers are encouraged to complete the study.

Program Content Materials

Chapters

1. Introduction
2. A Veteran's Perspective: A Soldier's Story
3. Traumatic Amputations During Military Service
4. Rehabilitation Following Amputation
5. Long-term Care of the Amputee
6. Prosthetics Clinical Issues
7. Prosthetics Administrative Issues
8. Primary Care Related to Veterans With Traumatic Amputations
9. Appendices



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1. INTRODUCTION

A veteran with a traumatic amputation presents a stark reminder of the tragedy of warfare. Battlefield trauma has necessitated amputations since even before the establishment of military medicine. While the advent of antibiotics, prompt trauma care, and vascular repairs have reduced the need for some amputations, even today, these continue to be a risk for American military personnel carrying out combat missions.

Almost 21,000 major amputations were documented in the Union Army during the Civil War. Over 4,000 amputations were performed on U.S. service personnel during World War I and almost 15,000 service members had major amputations during World War II. During the Korean War, over 1,000 Army personnel suffered traumatic amputations, while others lost body parts due to frostbite and other cold injuries. An estimated 6,000 amputations occurred during the Vietnam War and 15 were documented during the Gulf War. Even during peacetime, an estimated 20 members of the Army per year experience traumatic amputations. Clearly the VA has a special obligation to ensure that individuals with service-related traumatic amputations receive high-quality care at our facilities.

Patients with diabetes and vascular disease comprise the majority of amputee veterans and individuals at risk for amputation treated in the VA system. These patients are familiar to many VA health care providers and the VA recently has developed a CD-ROM based training program titled "Preservation-Amputation Care and Treatment" (PACT), which provides recommendations for primary care staff involved in their care.

Health care professionals may be less familiar with the treatment needs of individuals with traumatic amputations. For instance, such patients usually are younger at the time of amputation and are more likely to have upper extremity amputations than older amputee veterans with diabetes and vascular disease. Also, a larger percentage may be employed and participate in sports or other activities, requiring specially designed prosthetic devices.

This program is intended to provide information to primary health care providers and others so they can better care for veterans with traumatic amputations, including prevention and recognition of complications and prompt referral for specialty care when needed.

We also would like to encourage VA staff to complete other VHI educational modules and the PACT program. For additional information, please contact your facility's Educational Coordinator.



2. A VETERAN'S PERSPECTIVE

A Soldier's Story by Fred Downs

I was a 23-year-old Army Infantry Second Lieutenant in Vietnam when I stepped on a Bounding Mine we called a "Bouncing Betty." The mine was designed to bound out of the ground, when triggered, and explode at waist height. It was designed to kill the man who stepped on it. The mine had a killing radius of 30 meters.

I had just looked at the watch on my left wrist to determine if the combat patrol I was leading was on schedule. The Army issue watch read 0745 hours on January 11, 1968. The sun had been up for an hour and a half. My orders that morning were to lead a combat patrol into a war-ravaged deserted village in an area through which we had been fighting back and forth for over a week. The village was located next to a beautiful white sandy beach bordering the South China Sea in the central part of Vietnam. The bamboo and mud homes we called "Hootches" were burned, smoking hulks, or torn, shattered wrecks. One of our fighter-bombers had dropped a 1,000-pound bomb in the middle of the village a few days earlier, leaving a gigantic crater that became a refuge when we took incoming fire. The debris of battle lay everywhere.

The operational area, Quang Ngh Province in Central Vietnam near the DMZ, was under the control of the Viet Cong, and would prove to be one of five provinces in South Vietnam that would never be under the control of the Americans or South Vietnamese government. The Viet Cong was strongly supported by the people in the Province. Twenty years after the war, when I returned to Vietnam, I met the Province Leader who explained to me that he left home to become an officer in the North Vietnamese Army, but his brothers and cousins stayed in the Province to become Viet Cong Guerrilla fighters. He told me they were all committed to fighting to the death. His comments helped me understand why 20 years earlier, Quang Ngh Province was a very tough area for U.S. to occupy. The enemy was all around and they were determined never to be defeated.

In January 1968, our Battalion, in which I was the Platoon Leader of the 1st Platoon, Delta Company, the 1/14 Infantry, 3rd Brigade, 4th Infantry Division, was given the task of trying to regain control of a section of the Province and had been inserted into the area in a combat assault by helicopter "Slicks" and "Gun Ships" the previous week. The Battalion had taken numerous casualties since the assault. My platoon had had numerous firefights and encounters with the Viet Cong. We had fought through the area around the village the day before, killing a squad of Viet Cong, flushing them out of their tunnels with our "Tunnel Rats" if we could, or engaging them in brief firefights in the hedgerows and thick jungle growth. Other squads of Viet Cong engaged our units with gunfire and mortar attacks. Four of my men had



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been wounded by booby traps and mines. Three days earlier, I had been knocked to the ground when one of my men stepped in front of me to enter a hedgerow and triggered a land mine. I was blown off my feet and stunned, but was not otherwise injured. Two soldiers were wounded and had to be air evacuated out with a “Dust Off” helicopter.

Although shaken, I continued to lead the platoon. I had been “in-country” six months, and had already received four wounds during that time. They were considered minor or “flesh wounds” because they were not serious enough to take me out of the field. My platoon medic, an 18-year-old kid from Texas whom everyone called Doc, would patch me up and we would continue with the combat patrol. The first time I was wounded was at night during an artillery barrage; a spent piece of artillery shrapnel grazed my head and knocked me down. The second wound I received was when a North Vietnamese Army (NVA) soldier popped out of a hole in the jungle floor 30 feet in front of me and fired at my head. The bullet grazed the tip of my left ear. The third wound was from grenade shrapnel. One of my soldiers and I were in a furious close-in fight with three NVA soldiers when a hand grenade exploded, sending a piece of shrapnel into my upper left arm. The fourth wound, actually a series of multiple flesh wounds, occurred when my platoon was ambushed in the jungle. During the course of the ambush, I received rock shrapnel wounds in the face when an enemy machine gun fired into the rock next to my face. A few minutes later both of my hips were bruised when bullets slammed into the ammo pouches carried around my waist and bullets tore through my jungle fatigues. I was knocked to the ground when my boot heel was hit with a bullet. Later in the ambush, a machine gun bullet grazed my left hand.

I was so surprised each time I was wounded. I would feel a sharp pain and was astonished to see blood flowing from my body. “I’ve been hit!” I would think. “This can’t be happening to me!” I had seen many of our men killed and others who had been wounded to various degrees. Some had their limbs torn off or had huge gaping wounds in their chest or stomach. Head wounds were more frightening when the skull was opened up to expose the brain. Other men just had a gunshot hole or shrapnel wounds. I always thought bad things happen to other men, but never to me. I was lucky.

My luck ran out on January 11, 1968. My platoon was strung out in a long line as we entered the abandoned village. I carried my M-16 rifle in my right hand. I inhaled a drag off a cigarette and looked at the watch on my left wrist. 0745 hours.

I never heard the explosion. Instantly I was flying through the air, surrounded in total silence as black clouds of powder flew by me. I threw my arms out in front to catch myself and was horror stricken to see my left arm was gone above the elbow. “Oh God, Oh God!” my mind flashed. A jagged white bone stuck out of the stump. Shreds of bloody muscle, tendons and flesh whipped back from the stump. Sickened by the sight, I turned my head to see in terror



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that my right arm was also shredded to the bone. My horror was intensified as I saw the two brilliantly white forearm bones from my wrist to the elbow. They were lying in a bed of bloody flesh. My stomach heaved in revulsion.

Strangely enough, my mind struggled with the swirl of shocking events, but seemed to split into parallel operations so that it could continue to function normally. My thoughts continued as a combat officer, analyzing what was happening, I deduced I had stepped on a “Bouncing Betty” land mine and I wondered if this was the beginning of another ambush.

I landed on my feet and staggered forward a few steps before falling forward. I attempted to land on my left shoulder so my stump and arm would not be jammed into the earth. I rolled onto my back to hold my stump and arm out of the dirt. I did not realize the “Bouncing Betty,” which had exploded next to my left hip, had caused massive damage to my waist, buttocks, legs and feet. I lay there, bleeding profusely into the ground.

I was covered in blood and dirt. I stared in fascination at the white splintered bone jutting from my left stump. Gorge raised in my throat as depression and abject despair swept over me in waves. I tried to lift my right arm out of the dirt, but I couldn’t control movement. The arm flopped grotesquely; the muscles, tendons and nerves destroyed or too damaged to respond properly. More waves of depression swept through me.

I looked around, realizing how silent it was. Both my eardrums had been ripped by the blast. Sound began to return. I heard men screaming. How strange that I didn’t feel great pain, only a high intensity tingling. I was quiet, thinking about what was happening to me. Maybe I had had so many wounds my brain was overloaded with so many pain signals, like a circuit board with too many signals, that none of the signals were getting through.

I looked back towards my platoon. The Radio/Telephone Operator, who had been walking behind me, was sitting in a pool of blood, his uniform covered with blood. He was screaming. I heard another man screaming. Who is he, I wondered? There was activity all around me as some men rushed to the wounded and others took up defensive positions against attack.

One of the M-60 Machine Gunners ran up next to me and pulled out his knife. He cut away my web gear with the four hand grenades fastened to it. He asked what he could do for me. I told him to go over, pick up my arm, and bring it back to me. I told him and the other men gathered around me that I did not want to leave my arm in the village because I did not want the enemy to know they had severely wounded me.



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The Machine Gunner ran over to where my arm was laying and gingerly picked it up. He carried it back, laid it on my stomach, lifted my right arm out of the dirt and draped it across my severed arm. I thanked him. My platoon sergeant, squad leaders, and some of the men circled around where I lay to talk to me. The medic was busy patching up the other men. I was badly wounded and realized I would be the last one to be cared for by him. He had to first treat the men he thought would survive, and treat me last.

I was astonished when the thought occurred to me that I was dying. The medic ran to me and dropped to his knees, fumbling in his medic bag for a capsule of morphine, ripping off the cover and pushing the needle into my arm. He pushed the empty capsule's needle into the lapels of my fatigue shirt and bent the needle back to hold it securely so the medical staff back in the rear would know how many shots of morphine I had received. I asked him how bad I was wounded. He replied I was in pretty bad shape.

The "Dust-Off" helicopter, called in by my platoon sergeant, landed nearby and the rotor wash blew a cloud of sand and dirt over us. Two men ran to me, unfolded a stretcher, and laid it next to me. I was loaded onto the stretcher. As the men hurried towards the open doors of the "Dust-Off," the man carrying the head end of the stretcher began to vomit and he dropped the stretcher, jarring my whole body. Another man took over carrying. They hooked my litter into the bottom of a 3-tier rack in the helicopter. The pilot lifted off with three of the wounded in tiers and three lying on the floor of the helicopter.

There were six men wounded when I stepped on the "Bouncing Betty." The Radio-Telephone Operator, who was walking behind me, was shredded in the front of his body from the waist down. Another man was hit in the stomach with shrapnel; he was the other man who had been screaming. The point man was hit in the back of the knee, and two other men were hit in their bodies by shrapnel.

Blood dripped on me from the two men in the stretchers above. The pilot turned to look at me. He studied me for a minute; I saw his lips move as he talked into the helmet's microphone. The medic who flew with the crew was sitting behind the pilot. He nodded and leaned down close to my head to yell above the cacophonous noise of the helicopter, "Ten minutes to Chi Lai. Can you make it?" I nodded my head yes. He lit a cigarette and stuck it in my mouth. He yelled, "Can I do anything for you?" I yelled back "Yeah, cut off my boot. My foot hurts like hell."

For some reason, the pain from a shrapnel wound in my foot was the only specific pain signal that was getting through to my brain. The medic cut off my boot to relieve the pain. I struggled to stay conscious because I knew that men who lost consciousness would die faster than men who did not. I was determined to make it back to the surgical unit in the rear, where I was



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confident the medical team would save my life. I would stay alert by paying close attention to everything around me.

The “Dust-Off” jolted as it landed hard on the pad. My litter was lifted out of the helicopter amidst much commotion of men talking and jostling me around. I was loaded into a square truck and after a short ride, my litter was carried into a room where men and women in white gowns and masks were standing. They were in groups around different operating tables. I guessed they were waiting for the six wounded men. I was transferred to an operating table and the circle of white closed in around me in a bustle of activity. I was surprised when two nurses, one on each side, started cutting off my remaining boot, sock, and clothes with scissors. I had never seen anyone’s clothes cut off.

I stared in sickening fascination as an orderly removed my wedding ring and watch from my severed arm and dropped the arm into a plastic bag. I thought the bloody, mangled arm looked awful, but the wrist and hand looked pretty good. I wondered if they would sew it back on.

There were two doctors standing on each side of my shoulders. They were talking to each other. The one on my left said, “Who the hell tied this God Damn tourniquet.” I watched in amazement as he used a scalpel to cut through the flesh on my stump down to a blood vessel, which he tied off. I thought, “*Jesus Christ! I didn’t even feel that. I must be in really bad shape.*”

There were people standing shoulder-to-shoulder all around the table. I looked at each one of the masked strangers, busy with their manipulations of my body. Cleaning, wiping, picking ragged clothing off me, probing with instruments, talking to each other and exclaiming when they found another wound.

A Red Cross lady stood at the foot of the table holding a clipboard and pencil. She kept asking me to tell her my name, rank and serial number. I kept repeating it. “My name is Frederick Downs, Jr., Second Lieutenant, 05337689.” I finally yelled, “What’s the matter with your God Damn ears?”, not realizing she was trying to keep me conscious as long as possible.

I remembered something that was important. My brother was on the USS America aircraft carrier and he needed to know I was wounded. “Tell my brother, Mike, I have been wounded. He is on the USS” I lost consciousness as my heart stopped.

Later, I would be known as the Lieutenant they brought back from the dead when they used closed heart massage and direct IV to get my heart going again. But all I knew when I became conscious after the surgery was the most unbelievable, excruciating pain imaginable over most of my body including left stump, right arm, left hip, both buttocks, back of both legs and left foot. God! All the nerves in my body were sending searing torrents of pain to my brain. The



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morphine was a weak barrier to that much pain. I was terrified that my arm was gone. Tears ran down my cheek. I gritted my teeth against the waves of pain. I was frantic. This could not be happening to me. This was a terrible thing that had happened. I was so depressed with the realization that I would be crippled the rest of my life. “Oh God,” I prayed for another chance to go back and take a different path from the land mine, but I knew it was impossible. My fate as a cripple was a final, irrevocable, inescapable future.

I cried for more painkiller, but the nurses explained I was only allowed so much. Otherwise, I would become addicted to the drug. I didn’t care. I needed to survive the pain now, or I wouldn’t live at all.

But I did live and I survived weeks and months of reconstructive surgery, misery and pain. The pain was excruciating and there was never a respite from it. I was air evaced from military hospital to military hospital in a continuous chain through Vietnam, the Philippines and Japan, and finally ended up at Fitzsimons Army Hospital near Denver, Colorado, a month after I was wounded. I hated the moves because they jostled my body adding to the pain, and twice I nearly died during the flights. After each move, the new clinical staff inflicted more pain on me as they debrided the wounds twice a day, and performed operation after operation in their attempts to save my right arm and legs. There were operations for skin grafts and operations for pedicle grafts. I developed a love/hate feeling towards all medical staff.

In addition to all the other pain, I suffered from Phantom pain. This was a strange sensation of my arm and hand, feeling as if it was still there. The pain was a sharp tingling, similar to the painful tingling one feels when they hit their crazy bone, only this did not go away. The pain was constant. My hand felt as if it were out on the end of my arm, like it always was. As the weeks and months progressed, the pain became bearable and oddly enough, my hand drew slowly back until it felt as if it were right at the end of my stump. I decided early on that the Phantom pain was caused by the severed nerve endings sending signals to the cells in the area around the severed nerve end. My mind still sent signals to my arm and hand, but when the signals reached the end of the severed nerves, those signals flashed around like a live electric wire that is knocked down in a storm and thrashes about, throwing sparks in all directions. I got used to it within half a year, but the Phantom pain still flares up occasionally.

The surgeons at the various military hospitals patched my body together so the right arm and both legs functioned again. At Fitzsimons Army Hospital, I was introduced to my first artificial arm. I hated everything about it. It was ugly, uncomfortable and difficult to operate. No one prepared me for it. I was led by a physical therapist one day over to the limb shop behind the main hospital and fitted for a socket. The team of doctors had prescribed an artificial limb for me, but no one had explained anything about it. I learned very little from the clinical staff about how to use my artificial arm or how to adapt to using it day to day. I learned most about



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the arm from fellow amputees. Fitzsimons had hundreds of amputees in 1968, and we helped each other adapt to our new, unfortunate circumstances.

When I first put the arm on, I was again depressed at how alien it felt and looked. The plastic and steel arm did not look natural or feel comfortable. However, I was determined to do everything I used to do. That meant I would force myself to learn to use the arm and I would not let myself be embarrassed to wear it in public.

I quickly adjusted to wearing the arm and have worn an above-elbow prosthetic arm for 33 years. I married a woman I met while at Fitzsimons and we have two daughters. I have a pilot's license, drive a car and do just about anything I did with two arms. A person's disability is based on their frame of mind. I decided from the beginning that I was not going to let losing a limb get me down. I was determined to enjoy my life, and I have had a good life with lots of friends and family.

Fourteen years after that fateful day when I was brought into the combat surgical unit in Vietnam, I met Dr. Dave Pilcher, the surgeon who asked "Who tied this God Damn tourniquet?".

He had asked me to lecture to his class of residents where he taught Trauma Surgery at the Medical School at the University of Vermont. The residents laughed when I related the incident, because he was famous for his outbursts when people tied a bad tourniquet. I thought how lucky I had been to have had Dr. Pilcher on duty the day I lost my arm. His skill and surgical techniques in the operating room saved my life and contributed to the salvage of my right arm and both my legs.

He was part of the larger team that saved my life. That team had included the field combat medic, the medivac helicopter crew and the medical staff at the 2nd Surg, and 85th Evac. Every single person was important to my survival.



3. TRAUMATIC AMPUTATIONS DURING MILITARY SERVICE (INCLUDING ISSUES OF SURGICAL REVISION AND LIMB SALVAGE)

by Paul J. Dougherty, Lieutenant Colonel, Medical Corps, United States Army

INTRODUCTION

One of the most graphic reminders of the destructiveness of war is the amputee. Every major conflict in the 20th century has seen large numbers of amputee veterans as the result of battle. During World War I, there were approximately 2,300 major amputee veterans who returned home from France (a major amputation is one which is proximal to the wrist or ankle).¹ During World War II, this figure reached approximately 18,000, including U.S. Navy and Marine Corps amputee veterans.² The Korean War saw approximately 1,500 amputee veterans as a result of battle casualties. It is unknown how many patients sustained amputations due to battle injuries from the Vietnam War. Estimates range as high as 6,000 for all services.³ Amputee veterans are a major clinical problem for not only the initial care of the patient, but also through the patient's rehabilitation and eventual prosthetic fitting and long term follow-up at the Department of Veterans' Affairs (VA) Medical Center.

Special features of military surgery include having initial surgery performed at an austere forward hospital, some more advanced than others, and transportation of the patient through various echelons of care until the patient arrives back in the United States.¹⁻⁸ This is a much different situation than taking care of a patient at a trauma center in the United States, which has virtually unlimited resources. Military surgery is unique in the sense that we are simultaneously trying to provide care as well as moving the patient back through the evacuation chain. This necessitates special care that is not often seen in civilian trauma centers.

Amputee centers were initiated by the U.S. Army in World War I and II in order to consolidate the care of surgeons, prosthetists, nurses and therapists and provide consistent care for patients.^{1,2} Only one U.S. Army hospital, Valley Forge Army General Hospital, maintained a separate amputee service during the Vietnam War.⁶ The U.S. Navy had two amputee centers in World War II and maintained an active amputee program through the Vietnam War (Naval Hospitals Oakland and Philadelphia). Experience of World War I, World War II, the Korean War and the Vietnam War has shown that patients benefit by being moved to a site of definitive care as soon as possible.



Epidemiology

Amputations sustained in battle are severe injuries. Battle casualties are divided into “wounded in action,” “killed in action,” and “died of wounds.” “Wounded in action” are those patients who reach hospitalization alive, “killed in action” are those patients who die before hospitalization, and those who “die of wounds” are patients who die after being admitted into a medical treatment facility. The mortality from a significant amputation remains high. In the Bougainville campaign during World War II, the mortality rate was approximately 30 percent for “killed in action” and “wounded in action” for patients who sustained an amputation.⁹ One study from the Vietnam War found that there was approximately 35 percent mortality with amputee veterans on the battlefield. From this same study, approximately half of those who died of extremity wounds on the battlefield did so because of a traumatic amputation.¹⁰

Final levels of amputations have changed over time. During World War I, the transfemoral amputee was the most common.¹ During World War II and afterwards, the transtibial amputee became the most common.² The transtibial amputee also was the most common level of final amputation during the Korean and Vietnam wars and remains the most common level of battle amputee from other areas of conflict seen today.^{6,11}

TABLE I
LEVELS OF AMPUTATION

Level of Amputation	WWI (1)		WWII (12)		RVN (6)	
	Number	%	Number	%	Number	%
Transhumeral	556	24.2	203	6.70	57 (all UE)	13.9
Forearm	215	9.3	243	6.80		
Hip			7	0.02		
Transfemoral	1,145	49.9	1,049	35.00	109	26.5
Transtibial	335	14.5	1,487	49.80	175	42.6
Multiple	44		199	7.00	69	16.8

World War I data excludes 95 knee disarticulations.



Explosive munitions were by far the greatest cause of wounds leading to amputation during the Vietnam War. Land mines/booby traps were the cause in 64% of the patients, followed by artillery/mortar/grenades/rockets in 18% of patients.

INDICATIONS FOR SURGERY

Amputations at forward hospitals are performed to save life and limb. The surgical indications for amputations have shifted with time. During World War I, 25.5 % of amputations were due to the direct effects of trauma and 74.5 % for infection.¹ During World War II in the Mediterranean theater, amputations were due to the effects of trauma in 75 % of cases, infection 9.5 % (a reverse of the previous rate) and vascular injuries in 14.5 %.⁴ Data on 484 patients received at Valley Forge Army General Hospital showed that indications for surgery were trauma in 89.5% of the cases, failed vascular repair for 8.4% and infection 1.9%. The wounds leading to amputation often are not discrete involving an isolated area. Explosive munitions often damage the entire limb, and there are often wounds to other anatomical regions, as well.

LIMB SALVAGE ON THE BATTLEFIELD

Several authors have analyzed amputations performed late after a patient was transported from Vietnam. Bagg, cited by Burkhalter, found that 13 of two hundred tibia fractures received at the 106th General Hospital in Japan from Vietnam required an amputation: (10 below knee and three above knee).¹³

Schmitt and Armstrong found that open fractures with vascular injury was the cause for nearly half (48%) of the late amputations seen in his facility during the Vietnam War, followed by vascular injuries alone (25%), fractures only (17%), and soft tissue infection (10%).¹⁴

Recent interest has focused on being able to determine which extremities will require amputation and which will fare best with limb salvage. Bosse et al., has reported on results of 556 limbs with “high energy” trauma of 539 patients enrolled in the multi-center Lower Extremity Assessment Project, prospectively evaluating published lower extremity injury severity scores with regards to sensitivity and specificity in predicting amputations. There were 63 immediate amputations and 86 delayed amputations. Threshold scores were found to have low sensitivity but relatively high specificity and could not be recommended by the authors as criteria to amputate a limb. Thus far, there is no scale that can reliably predict the outcome of a severely traumatized limb.¹⁵



It is not clear if new techniques developed since the Vietnam War will improve limb survival and function for patients injured on the battlefield. Vascular repair has been used since the Korean War. The open fracture with vascular injury can be treated by fracture stabilization and then repair of the vascular injury. Use of an external fixator is indicated to provide access to check the vascular status of the limb.

Using local or free flaps for soft tissue coverage should **never** be attempted in a battlefield hospital. Flaps do poorly in the evacuation chain. Patients who will be evacuated out of theater should not have extensive surgery performed for soft tissue coverage before evacuation. Attempts at coverage should only be performed when a patient is in a stable environment and will not be moved.

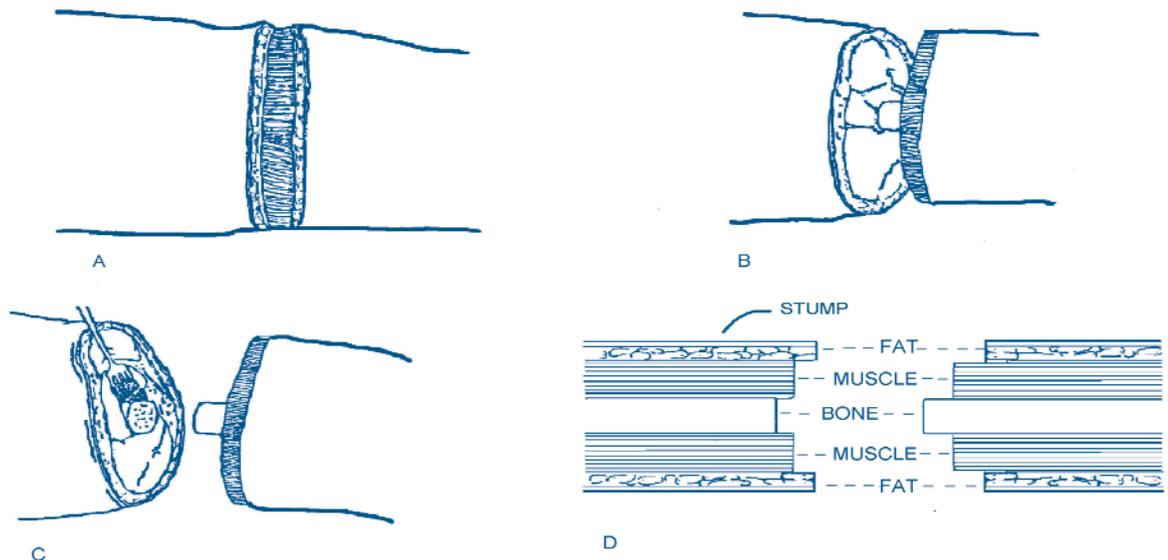


Figure 1

TECHNIQUE

The traditional technique for performing amputations on the battlefield has been the open circular technique (see Figure 1).¹⁻⁸ With a formal open circular technique, a circumferential incision is made at the lowest viable level of soft tissue through skin and subcutaneous fat. This level is allowed to retract and move proximally, and the muscle is incised. Named blood vessels are isolated and doubly ligated. Named nerves are isolated, stretched and have a single tie placed. The nerve is then divided and allowed to retract. The bone is then cut at the lowest level. A residual limb should have a concave appearance at the end of the formal open circular technique.



The usual patient who needs an urgent amputation already has a partial or complete traumatic amputation, which requires only completion of the amputation. The amputation is completed at the lowest viable level of soft tissue. No consideration is given to final length of the limb or prosthetic fitting at the initial surgical procedure. All foreign material that is readily accessible, as well as dirt and debris, should be removed and the wound lavaged. Patients who have the open circular technique require special post-operative care not commonly taught in civilian residencies. At the conclusion of the case, the patient should be placed in skin traction (See Figure 2). This is done to prevent retraction of the skin and bone protrusion. The open circular technique **must** be used in conjunction with skin traction post-operatively throughout the evacuation chain.



Figure 2

Skin traction is applied by putting a tincture of benzoin or similar adhesive over the distal six inches or so of the residual limb. A dressing is applied to the wound and the stockinet is pulled forward. The amount of traction put on is only to overcome the elastic recoil of skin (about two-four pounds for a transtibial amputee). This technique is not skeletal traction, as one would use for the reduction of fractures. Just before evacuation out of theater the patient should be placed in a transportation cast. A transportation cast also should have a Cramer ladder splint as an outrigger and the stockinet should be connected to this (See Figure 3). Recent discussion by ICRC and Red Cross doctors about construction of flaps and performing delayed primary closure at a second sitting have not given as reliable results as the open circular technique.^{11, 16}

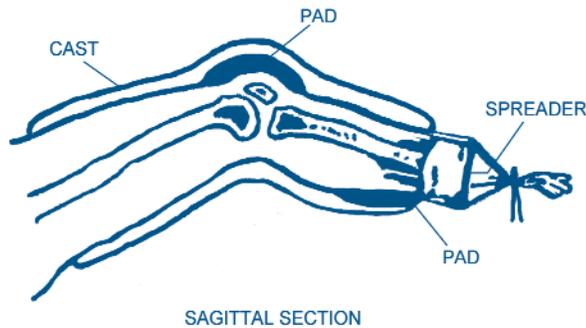


Figure 3

The unique features of military surgery on the battlefield necessitate the use of the “open circular” techniques to prevent infection. A survey by LaNoue during the Vietnam War outlined the safety of the open technique. Of 230 patients who had transtibial amputations and were evacuated back to the United States, showed that 59 % were left open and 41 % were closed in theater. Of those that were closed, 56 % failed due to gross infection, with some requiring urgent revision to a higher level. None of the limbs, which were left open,

had this complication. LaNoue also evaluated patients who had a first stage Syme’s amputation performed. A Syme’s amputation is when an ankle disarticulation is performed and a heel pad is left for covering the residual limb. He found that there was an 88% failure of the Symes’ that were performed in theater, all of which required amputation to the next higher level (transtibial). Definitive procedures such as the Symes’ should not be performed in theater. Rather, if there is an injury to the forefoot that may necessitate a Symes’ amputation at a later date, simple forefoot wound excision would be the best treatment. LaNoue attributed the poor outcome of patients in both these groups to the “trauma of transportation” through the air evacuation system. The considerations of civilian physicians are not necessarily the same as those of military surgeons. In civilian practice, provided circulation is normal, one would expect a 5% or so failure rate in using delayed primary closure of skin flaps, not over half the residual limb wounds as in LaNoue’s data. ⁶

Transportation casts should be applied to the patient in order to maintain skin traction throughout the evacuation chain. This also allows the patient to have limited ambulation. Skin traction to litters or beds while in the evacuation chain is difficult to maintain; therefore, a self-contained cast with an outrigger allows for this continuous traction to be maintained. Casts used with the major levels of amputation are as follows: for transtibial amputations, one should use a long leg cast with outrigger (See Figure 4); transfemoral amputations should have a low hip spica cast with an outrigger (See Figure 5). For upper extremity amputations, a transradial amputation should have a longarm cast and a transhumeral amputation needs a shoulder spica cast to maintain skin traction. ⁶⁻⁸



Figure 4



Figure 5

CARE AT A SITE OF DEFINITIVE CARE

Once a patient is received in the United States, the transportation cast should be removed at the amputation center and the wounds inspected. The patient is placed in skin traction in bed and as soon as possible, fitted with a plaster of Paris pylon for lower extremity amputee veterans, or for upper extremities, a provisional prosthesis that is made of casting material. After fitting with a pylon, lower extremity amputee veterans should be started on a program of early ambulation. Ambulation, even on an open residual limb, is beneficial to the patient. First, the patient redevelops a proprioceptive sense faster. Second, weight bearing on a hard plaster shell reduces the edema and swelling of the patient's residual limb and finally, the patients' mental status is improved by becoming upright as soon as possible.

When not in the pylon, the patient is maintained in skin traction. As more time is spent with the pylon, there is correspondingly less time spent in skin traction. As the edema and swelling subside, the plaster socket is changed.^{6, 17} Planning should be made by the amputee team for treatment of the residual limb and eventual permanent prosthetic fitting as soon as the patient is admitted to a site of definitive care. Once the limb has become stable, closure with flaps, skin grafts or simple local wound care and granulation can be performed. Most patients will require a second procedure for wound closure. Additionally, if the limb is not an optimal length, steps can be taken to provide for the best length as well as optimal closure of the residual limb. A rigid protocol for timing of closure and perhaps limb lengthening or shortening cannot be made until both the treatment team and patient have an understanding of the options available.



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4. REHABILITATION FOLLOWING AMPUTATION

by Katherine M. Flood, M.D. and Sheila Saliman, Ph.D.

REHABILITATION FOLLOWING AMPUTATION

The large numbers of military personnel who sustain limb amputations during armed conflicts have been the driving force in the development of prosthetic devices and rehabilitation techniques. During World War II, military planners quickly realized that the Veterans Administration hospital system was not prepared to care for the large number of war-injured amputees. As a result, the Army was made responsible for both early care and definitive rehabilitation of amputees. To provide the necessary services, the United States military established five “amputation centers” at ports of debarkation. The U.S. Army Surgeon General directed that all amputees be transferred “as soon as possible” to designated amputation centers. Since these centers were responsible for the amputee’s full rehabilitation, as well as early care, longer military hospital stays were required. By 1944, two additional centers were established to handle the workload.¹ The Army health care system has continued to assume the responsibility for the surgical and rehabilitative care of the soldier sustaining a limb amputation. For simplicity, the following discussion will be directed toward the soldier with limb amputation alone, though multiple injuries are more common and would affect all phases of the soldier’s care. In most cases, management techniques discussed will apply to both upper and lower limb amputations.

Losing a limb in a combat situation and the subsequent medical and surgical care is very different from a traumatic amputation in a civilian setting. The combat-injured amputee was initially treated in the austere medical environment of a field hospital and may have passed through several care venues before arriving at a place where definitive care began. The goal of immediate military medical care is to preserve life through maximal early intervention and safe evacuation. Due to gross contamination, a circular amputation is usually performed and the wound left open with skin traction applied. Therefore, not only had the soldier sustained the sudden, unpredicted loss of a limb, he had to deal with a gaping wound and a skin traction device while being moved from site to site. As recently as the Persian Gulf War, which resulted in 15 soldiers with limb amputation who were treated at Walter Reed Army Medical Center², it took approximately 19 days for casualties to arrive at medical centers in Europe and the United States.¹

The principles developed at the WWII Army Amputation Centers continue to serve as a model for amputee care today. These centers assemble an interdisciplinary team that consists of the patient, treating physicians, physical and occupational therapists, nursing staff, psychologists/psychiatrists, social workers, prosthetists, vocational counselors and other consultants, as



required. The leadership of the team may change throughout the hospital course, beginning with the surgeon and progressing to leadership by a physiatrist or other rehabilitation specialist. The goals of surgical care of the soldier with limb amputation are preservation of maximal residual limb length, adequate soft tissue coverage and proper handling of nerve endings. In many cases, wounds are allowed to heal by secondary intention. This may require long periods of time and result in a less than optimal residual limb. Rehabilitation must begin even before the wound is definitely closed or fully healed. During “preprosthetic rehabilitation,” efforts are directed toward pain control, emotional support, prevention of joint contractures, skin breakdown and general deconditioning.

PREPROSTHETIC MANAGEMENT

Pain Control

In addition to analgesic medications (including narcotics), control of residual limb edema is extremely important in decreasing pain and promoting healing. The best control of edema is achieved with a rigid dressing, such as post-operative casting. In cases where wound closure is incomplete or frequent inspection is required, a rigid dressing may not be possible. In these cases, elastic bandage wrapping or layering of tubular elastic material may be used. Wrapping with an elastic bandage is a skill that must be taught to health care personnel and the amputee. There is grave potential for inappropriate application of the wrap, resulting in increased rather than decreased edema and pain. With the previously described interventions, elevation of the residual limb should be encouraged, though care must be taken with joint positioning not to produce contractures. Protection of the residual limb from trauma, desensitization of the residual limb by sensory stimulation and proper positioning of the residual limb also are important in pain control. Other physical therapy modalities might be considered in resistant pain, such as transcutaneous nerve stimulation. The existence of other previously unidentified injuries, such as herniated lumbar or cervical disks with nerve root compression or occult fractures should be considered and appropriately investigated. Input from the rehabilitation team members, such as physical and occupational therapists and nursing staff, can be quite valuable in characterizing the pain and arriving at a treatment plan.

Prevention of Secondary Complications

To prevent contractures, joints must be moved through the full range of motion either actively or passively three times, at least twice a day. Static positioning in non-functional positions must be avoided. For example, the resting position of the knee should be extension, not flexion. To prevent decubitus ulcer formation, attention must be directed toward positioning, the fit



and application of dressings or skin traction devices and the identification of patients at risk due to immobility, altered sensation (anesthetic skin areas) or decreased cognitive level. To prevent general deconditioning, the amputee must be out of bed as soon as possible and working toward independence in mobility and self-care activities as soon as medically and surgically stable. Even patients who cannot be out of bed should perform active range of motion exercises, resistive exercises using weights and other devices and isometric contractions of muscles in immobilized limbs.

Emotional Support

Individuals' responses to amputation encompass a range of emotions and thoughts, from transitory shock and loss, to relief at the cessation of pain or disease, to long-term grief and severe depression. The physician can play a central role in facilitating a patient's healthy adjustment to the loss of a limb. A physician who provides education, communicates a willingness to explore difficult issues such as sexuality and social stigma, and possesses an awareness of the indicators of severe emotional distress is in a position to impact significantly the patient's recovery, both mentally and emotionally, as well as physically.

The extent to which the patient is educated about amputation is an important factor in post-surgery adjustment and the success of rehabilitation. In civilian settings, and in cases where amputations are performed on veterans due to long-term complications from earlier combat injuries, there is usually time for patients to be educated before surgery. These patients benefit from hearing clear, concrete explanations of the actual surgical procedure, including a rationale for the level at which the amputation will be performed. Unless informed about the need for a residual limb to be short enough to comfortably accommodate a prosthesis, for example, the patient may assume that only the smallest possible amount of limb would be amputated. If there is uncertainty about the level of amputation because of issues such as an unknown extent of the spread of gangrene, the patient should be informed as to the extent of required surgical interventions and how the decision about where to amputate will be made. Certain religious traditions mandate that a person be buried with all body parts, so a physician should explain how the hospital normally disposes of the amputated limb, in case a patient wishes to make other arrangements.

In situations where amputations occurred during combat or emergently following a severe injury, of course, no pre-amputation education is possible. However, it appears that veterans whose limbs were amputated emergently achieve greater adjustment when education is provided to them early in their rehabilitation.³ In cases of surgical amputation, patients can be helped to construe the amputation as a necessary and ultimately positive process, which was life-saving, allowed for relief from pain or arrested a progressive infection. It is important to remind the patient that a normal, active lifestyle after amputation is a reasonable goal.



Reassurance that every effort was made to preserve the limb before the decision to amputate can be helpful in allowing the patient to accept the loss.

For individuals whose limbs were amputated traumatically in a combat situation, the critical focus of education is post-surgery care and recovery. Patients should be made aware of the process of healing from the surgery, including the use of compression dressings to shrink the residual limb, the role of physical therapy in training them to transfer and ambulate single-limbed, and the process of selecting, being casted for, and learning to use a prosthesis. Thorough knowledge about what to expect can allay fears, place a focus on rehabilitation and recovery of function, and encourage active participation in post-surgery care.

Physicians can provide important education to their patients, but in most cases, the physician will not have undergone amputation personally. It can be invaluable for a patient to speak with someone who has lost a limb for a first-hand account of what to expect from rehabilitation. This person can provide empathy and support, as well as reassurance that successful recovery is possible. The Army Amputation Centers had the advantage of many amputees at various stages of recovery, allowing for peer support and teaching. Physicians should be aware of resources in their institutions and communities for peer support.

Physicians who will be working with patients during the acute phase of rehabilitation can help facilitate successful recovery and return to normal functioning. Patients benefit from being encouraged to identify and articulate specific goals for their rehabilitation. Some patients may feel it is important to have a prosthesis that looks as natural as possible, while others may place more emphasis on sturdiness and durability. A patient may define successful rehabilitation as returning to work or a particular sporting activity, or may wish to perfect stair climbing to continue living in a non-accessible home. Working toward an individualized set of goals can enhance a patient's motivation, persistence and satisfaction with rehabilitation.

A physician can further facilitate successful rehabilitation by openly raising difficult and often embarrassing or upsetting topics that may be a reality after amputation. Once given permission to discuss their feelings, patients usually experience dramatic relief from talking about their fears of being socially stigmatized, feelings of unattractiveness and undesirability, and experiences of insensitivity or prejudice. A patient may have few people in his life who are willing to address these issues directly and with compassion, and a physician may need to offer no more than an empathic ear and reassurance that the patient's responses are normal and understandable.

Little data exist about the combat veteran's acute adjustment to amputation. This probably stems in part from the logistical difficulties of conducting research in the context of a war zone. The data that are available suggest that veterans' early responses to amputation are similar to those of civilians; they can be expected to feel the full range of normal emotions



such as loss, guilt, anger and dependency.⁴ Veterans who have pre-existing maladaptive responses to stress are at greater risk for complications in their initial adjustment to the amputation. Furst and Humphrey⁵ reported on the perceptions and attitudes of younger, trauma-associated amputees, spouses of the amputees and the public regarding the degree of disability associated with amputation. They noted a great degree of individuality in coping styles, but rare evidence of persistent suffering or psychological disability in the amputees. Amputees were inclined to attribute family support as crucial to adjustment to amputation, while family members stressed the amputees' own personality. Given a list of six common impairments (going blind, losing a leg, losing the preferred arm, becoming deaf, severe facial disfigurement and paralysis), amputees and their spouses rated their own amputation as the least severe handicap, while the general public group rated amputation second only to blindness. Amputees also tended to view themselves as slightly less "fortunate" after the amputation compared to before amputation, but even then, their ratings were above those of their spouses and the general public sample.

Several factors appear to facilitate positive coping with the feelings and life changes precipitated by the amputation. Individuals who are able to re-define a sense of self-worth to include intrinsic qualities rather than physical or material achievements appear to adapt better to the loss of a limb. It also is helpful to be able to identify aspects of positive personal change that have emerged from the amputation, such as a renewed sense of priorities or a greater awareness of the preciousness of being alive. A strong social support network, a sense of faith or spiritual belief, and a willingness to allow one to fully grieve and then move on also facilitate positive adjustment. An excellent resource for physicians to recommend to their patients is [Coping with limb loss: A guide to living with amputation for you and your family](#), by Ellen Winchell, Ph.D.⁶ Dr. Winchell is herself a person who experienced an amputation, and she provides a personal and professional perspective on adapting to the loss of a limb.

While many veterans develop a healthy response to amputation, there are some issues unique to combat amputees that can negatively affect psychological adjustment. A study of 114 Vietnam combat veterans found no significant differences between amputees and non-amputees on measures of PTSD, depression, hopelessness, psychiatric distress, guilt or societal adaptation. However, the study did find that a greater intensity of combat experiences predicted worsened psychological functioning in the form of PTSD, depression and psychological distress. The author of this study concludes, "The combat experience and the multiple events of which it is comprised are a more powerful determinant of psychological functioning and societal adaptation than the single event of being wounded."⁷ Additionally, veterans with an amputation alone have been found to live relatively normal lives at long term follow-up, while those who experienced an amputation along with another major medical complication developed psychological symptoms and the need for care.⁸ Thus, physicians working with individuals who lost limbs as a result of combat must be aware that their patients may indeed require



psychological treatment to facilitate adjustment to the amputation; however, the psychological distress may arise less as a consequence of the limb loss itself than as a result of the experience of combat and all of its concomitant stresses.⁹

PROSTHETIC FITTING AND TRAINING

Early prosthetic fitting, before the wound is completely healed, is common in the management of the traumatic amputee. For the upper limb amputee, it has been reported to increase the acceptance and use of the prosthetic device long term.¹⁰ Early fitting and mobilization of the lower limb amputee has the advantage of decreasing the risk of deconditioning, muscle atrophy and joint contracture. In addition, some clinicians believe that early fitting and use of a prosthetic device provides sensory feedback that may reduce the risk of phantom pain syndromes.

The early or temporary prosthesis may be applied in the operating room immediately following surgical closure. It generally consists of a plaster or fiber glass “socket” with a pylon and appropriate joints and terminal device applied and aligned by a prosthetist. Therapy staff will begin working on functional activities with the amputee as soon as the patient is medically stable.

During the training period, the amputee not only learns how to use the prosthesis, but also learns how to care for the residual limb and maintain the prosthetic device. The amputee should learn to recognize problems with the fit of the prosthesis and how to make adjustments to compensate for usual changes in limb volume. The amputee also must learn to recognize situations that require the immediate attention of the prosthetist or other members of the health care team. During the initial months following prosthetic fitting, it is anticipated that residual limb volume and shape will change as underutilized muscles atrophy and residual edema resolves. Weight gain or loss also may significantly alter the fit of the prosthesis, so this will require modification or recasting of the prosthetic socket. To prevent complications, it is necessary for the amputee to recognize when to seek prosthetic modification.

Vocational Rehabilitation

Rehabilitation is complete when the amputee has achieved all functional goals and resumed the expected societal role, including productive work. Return to military duty after amputation appears to be rare; about 2.3%. Reports of vocational outcome of soldiers with amputations are generally limited to just a few years after the amputation and military discharge. It was reported in 1946 that 78% of WWII amputees were employed or full-time students. A 1982 report indicated that the unemployment rate for soldiers sustaining limb amputation in the Vietnam conflict was twice that of non-injured Vietnam veterans. Amputees also earned



less money, held more blue-collar jobs and obtained fewer college degrees.¹ In contrast, a retrospective analysis of functional outcome in 18 civilian traumatic upper limb amputees, for whom data were available showed that only four who were previously employed were unemployed. Of those employed, only eight were in the same job.¹¹ The type or severity of the limb injury was not found to be closely related to sub-optimal vocational outcomes, but rather motivation, availability of vocational retraining and a low unemployment rate in the general population were important factors. This supports the need for early, intensive vocational rehabilitation intervention.¹

FUNCTIONAL STATUS FOLLOWING AMPUTATION

In general, the longer the residual limb and the more joints preserved, the more functional the prosthesis. While the acceptance and daily use of lower limb prosthetic devices is generally high, abandonment of upper limb prosthetic devices is common. This is due to the function of the lower limb being gross motor, and support that is well substituted for by the prosthesis, while upper limb function is primarily fine motor activity, which is not well served by a prosthetic device.

Upper Limb Loss

In the civilian population, upper limb amputations comprise less than 25% of limb amputations performed, with trauma as the leading cause.¹¹ In contrast, upper limb amputations are reported to have comprised 68% of Civil War amputations (not including digit and partial hand amputations).¹

While the terms “above and below elbow amputation” are still commonly heard, transition to the more descriptive, anatomically-based ISPO (International Society for Prosthetics and Orthotics) classification system is being encouraged. In this system, amputations are named based on anatomic and radiologic findings and classified as longitudinal, or transverse and complete or partial. Traumatic amputations are generally transverse and complete, with the exception of partial hand amputations. The partial hand amputations may include single or multiple digits, parts of digits or loss at any level between the digits and radio-ulnar-carpal joint. Amputations between the radio-ulnar-carpal joint and the ulnar-humeral joint (elbow) are transradial, and between the ulnar-humeral joint and the gleno-humeral joint are transhumeral amputations. These last two levels may be further described by the percentage of segment length loss compared to the intact side. Above the gleno-humeral joint, a forequarter amputation may be performed, which involves removal of the lateral portion of the clavicle and the scapula.



All unilateral upper limb amputees are taught one-handed techniques for activities of daily living (ADL) and other necessary activities. If the dominant limb has been amputated, early therapy is aimed at increasing fine motor skills in the remaining non-dominant extremity and switching dominance. If the non-dominant extremity has been amputated, the amputee will use the remaining dominant extremity for most activities, relying very little on the prosthesis.¹²

Single digit amputations, with the exception of the thumb, are not amenable to functional prosthetic devices. There are, however, very realistic appearing cosmetic devices available. When the thumb has been lost, the hand loses all prehensile function. Functional prosthetic devices consist of a post that attaches to the hand to allow opposition. Indeed, prosthetic restoration of multiple digit or partial hand amputation is aimed at providing opposition and grasp. These devices are generally custom designed, taking into account the amputee's intended activities and interests.¹

When rehabilitation is complete, a unilateral transradial or transhumeral amputee is expected to be independent in all ADL, most household activities, driving and work. Restrictions regarding handling of delicate, heavy or voluminous objects are dependent on level of amputation and prosthetic design. The typical transradial amputee should be able to lift 20-30 pounds. The typical transhumeral amputee should be able to lift 10-15 pounds. A bilateral transhumeral amputee is expected to be independent in ADL after assistance with donning the prostheses and being able to perform some household activities, drive with adaptive devices and perform some types of sedentary work. Bilateral transradial or transhumeral/transradial amputees will function at some level between the unilateral amputee and the bilateral transhumeral amputee. Bilateral amputees will be limited with respect to handling delicate objects or lifting objects greater than 15 pounds.¹² Side dominance will be assumed on the longer, more functional side for the bilateral upper limb amputee.

Lower Limb Loss

In the civilian population, vascular disease is by far the leading cause of lower limb amputation.¹³ The vascular amputee differs greatly from the combat-injured amputee with respect to age, general health and preamputation functional status. As in the civilian population, lower limb amputation is more common than upper limb amputation. Statistics from WWII indicate that 71% of amputations were lower limb and of those, 9% were bilateral.¹

In the ISPO classification system, amputations between the knee and the hip joint are transfemoral, and those between the tibio-talar joint and knee are transtibial. Amputation proximal to the hip joint is a hemipelvectomy. Amputations in the foot may be named in the same way as partial hand amputations, but there also are some specialized techniques of which to be



aware. Amputation at the metatarsal-tarsal joint is known as a Lisfranc amputation, and amputation at the mid tarsal level (anterior to the talus and calcaneus) is known as a Chopart amputation. Both of these levels present unique prosthetic problems. The Symes amputation completed electively at an amputation center is not uncommon in combat-injured amputees. The Symes amputation involves amputation through the talo-fibular-tibial joint with preservation and fixation of the heel pad to allow for end-bearing.

Energy cost of ambulation is dependent on the path the center of mass of the body follows. Ideally, the only motion would be in the intended direction – a straight line. The design and mechanics of the human body make this efficiency impossible, but in return, allow for adjustment to uneven surfaces, climbing, etc. Change in the normal function, motion or loss of any part of the lower limb will result in deviation of the center mass and increased energy requirements per unit distance traveled. The first adaptation the amputee will make will be to walk slower in order to normalize the energy consumption per kilogram per minute.¹⁴

Soldiers with amputations at the transmetatarsal level or more distal will benefit from shoe fillers, custom inserts and/or modifications to rigidize the sole of the shoe. Amputation at this level generally has minimal impact on mobility in the otherwise healthy soldier. Symes level amputees will require a prosthetic device very similar to the transtibial prosthesis. Reports regarding impact of a Syme's amputation on energy consumption are limited, but it appears to be similar to transtibial amputation.¹⁵ Ambulation with a transtibial prosthesis (for traumatic amputees) has been reported to increase the energy cost of ambulation between 7-33%.¹⁶ At the completion of rehabilitation, the transtibial or more distal amputee should be able to ambulate with the prosthesis on level ground, ramps and curbs without assistive devices, drive a motor vehicle with an automatic transmission (with minor modification for right lower extremity amputees), be independent in ADL and household activities, be able to stand or walk up to two hours, rise from the floor or kneeling independently, climb stairs with a reciprocal gait, return to most avocational interests (possibly with specialized prostheses or equipment) and return to most work.¹⁴

The loss of the knee joint has profound effects on the efficiency of ambulation and function of the lower limb amputee. Ambulation with a traumatically-acquired transfemoral prosthesis has been reported to decrease comfortable walking speed 30-40% and increase energy expenditure per kilogram per unit distance 30-50%.¹⁵ The unilateral combat-injured transfemoral amputee should be able to ambulate on level ground, ramps and curbs with no more assistance than a straight cane, though distance will likely be limited due to energy expenditure. Like the transtibial amputee, the transfemoral amputee will be independent in ADL and most household activities, independent in donning and doffing the prosthesis and maintaining components. The transfemoral amputee will tolerate up to two hours of standing or walking, rise from the floor independently, climb stairs with the intact limb and drive a motor vehicle with an



automatic transmission (right sided amputees require modification of the gas pedal). The transfemoral amputee will return to work, but may not be able to perform activities requiring heavy lifting or carrying of heavy objects, or that rely on good balance or mobility. The transfemoral amputee should return to most avocational activities, including sports activities, sometimes with appropriate modification of equipment, the prosthesis, or the way in which the activity is performed.¹⁵

Functionally, amputation at a level leaving five cm. of residual femur or less results in the loss of hip joint as well as foot, ankle and knee joint function. The loss of multiple joints will increase energy requirements of ambulation 100% or more. Young, otherwise healthy hip disarticulation or amputees who are more proximal may ambulate with only a single cane, but distance will be limited by energy requirements. Like other unilateral amputees, these soldiers will be independent in ADL and household activities that do not require prolonged standing or walking. The hip disarticulation amputee can drive under the same circumstances as other unilateral lower limb amputees. This soldier will be employed in sedentary work and participate in avocational activities with specialized equipment and prosthetic devices. Even young, otherwise healthy persons with amputation at this level may find wheeled mobility to be more efficient than walking. In this case, care should be taken to provide the patient with the most appropriate and functional wheelchair or motorized conveyance.

The impact of bilateral lower limb amputation on function and energy requirements of mobility are additive. Energy requirements for ambulation with bilateral transtibial prostheses are increased 60-100%.¹ Standing and ambulation time is limited to one hour or less. The bilateral transtibial amputee may return to sedentary work with some restrictions and to avocational activities with specialized equipment or modifications of the activity. The amputee may require specialized prosthetic devices (“shower” legs) for ADL. Restrictions increase with combined transfemoral/transtibial and bilateral transfemoral amputations. Persons with amputations at these levels may require modifications to their wheel chairs to assure stability and safety.

SUMMARY

The combat-injured amputee will have received immediate and rehabilitative care at military health care facilities. An interdisciplinary team of surgical, medical and rehabilitation health care professionals provided this care. The emphasis of this care will have been control of pain, emotional support, prevention of secondary complications, early prosthetic fitting and training and reintegration into the civilian sector, including vocational activities. The functional and social outcome is dependent on the level of amputation and the presence, severity and permanence of associated injuries, but will be profoundly influenced by psychosocial factors, as well.



5. LONG-TERM CARE OF THE AMPUTEE

by Katherine M. Flood, M.D. and Shelia Saliman, Ph.D.

COMPLICATIONS EXPERIENCED BY PERSONS WITH LIMB AMPUTATION

The majority of combat-injured amputees seen at VHA facilities will be “graduates” of military rehabilitation programs. Often, these veterans will have an established relationship with a prosthetist and will take any problems related to the artificial limb to the prosthetist. If this relationship has been disrupted for some reason, or the prosthetist has been unable to resolve the issue, then the veteran may seek the assistance of the primary care provider.

A 1983 survey of veterans who had sustained traumatic lower limb amputations identified problems with mechanical skin irritation, often associated with unaccommodated changes in the residual limb shape or volume, wear of inserts and liners or initial faulty construction of the prosthetic socket, as their primary amputation-related problem. In fact, more than 50% of respondents complained of “socket” problems. In addition, complaints of residual limb pain with prosthetic wearing, at rest or with use, or without the prosthesis, occurred in more than 50% of amputees. Complaints of back, groin and intact limb pain also were common. On evaluation of the prosthesis, problems were found with socket fit, prosthetic suspension and alignment and function of components (knee joints and feet).¹⁷

LONG-TERM PSYCHOSOCIAL ADJUSTMENT

Long-term emotional adjustment in veterans who experienced amputations because of combat appears generally comparable to the adjustment of civilians, and to the post-war adjustment of veterans who did not experience amputations.^{18, 19, 20} Successful rehabilitation and a return to independent functioning is a realistic goal.²¹ As an individual heals from the surgery, learns to use a prosthesis and begins to resume activities of daily living, adaptation to altered life circumstances is influenced by several factors, including pre-amputation psychological adjustment, prior experience with loss or trauma, typical coping styles, and interpersonal factors such as experiences of stigma and victimization.²² As with civilians, prior psychological functioning plays a strong role in their feelings and with the impact that the amputation has had on their lives may develop significantly lowered self-esteem, a negatively altered body-image, a crippling sense of vulnerability, substance abuse, clinical depression or suicidal thoughts. Physicians who observe these indicators of psychological distress can provide referrals for the patient to a peer support group or mental health professional.



In addition to the wide range of initial emotional reactions, patients face a stunning array of challenges to everyday living, including the need to re-learn taken-for-granted physical activities, increased fatigue, changes in recreational activities, economic burdens of medical costs and loss of work and reaction of friends and family members.

DISORDERS OF SKIN

Excessive Moisture

Skin functions to dissipate heat by the mechanism of perspiration. The increased energy needs of ambulation with a lower limb prosthesis results in increased heat production and the need to perspire. At the same time, the residual limb is covered with relatively impermeable materials. Blockage of eccrine glands by excessive sweating may result in superficial small blisters while deeper rupture results in a “prickly heat” rash. Still deeper rupture may result in the formation of papulas. Increased wetness of the residual limb in the socket may result in skin maceration and increased risk of infection and decreased tolerance for pressure or shear. The skin of most long term prosthetic wearers adapts to the lack of air circulation and heat of the socket. Recurrence of this problem may be related to changes in prosthetic materials, design or use of the prosthesis, changes in medical condition or changes in pharmacologic regimen. If the problem cannot be resolved by the prosthetist, the use of magnesium containing antiperspirants, iontophoresis with copper sulfate or formalin, or the use of cornstarch or unscented talc on the residual limb may be helpful.²³

Mechanical Stress

Maceration occurs because of rubbing over pressure points combined with moisture from perspiration.²⁴ The amputee should be questioned as to whether there has been significant weight loss, gain or edema of the residual or intact limb that might affect the socket fit. Information regarding other events, such as new or more intense activity, should be sought. Information regarding actions taken by the amputee or the prosthetist to correct the problem should be elicited, as well. Excessive moisture may be managed as described above. Friction may be reduced by the use of a nylon sheath next to the skin under the prosthetic socks or use of a transparent dressing, such as Tegaderm or Opsite. If occlusive dressings are used to allow prosthetic wear, care must be taken to allow the areas regular exposure to air. Bulky or thick wound dressing should be avoided, since this will only increase pressure on the area inside the socket. If the break in skin integrity is severe or progresses to ulceration, prosthetic wearing should be suspended until the lesion has healed.



Ulcerations result from excessive mechanical forces or pressure. Risk factors include ischemia, edema, adherent scars, impaired sensation and systemic disorders, such as diabetes.³ The amputee should be questioned as to whether there has been significant weight loss or gain, edema of the residual or intact limb that might impact the socket fit or the development of new medical disorders. Prosthetic socks and liners should be examined for wear or compression that may alter fit of the socket. The occurrence of ulceration requires suspension of prosthetic wearing and use. Treatment of the ulceration includes removal of devitalized tissue, cleansing and providing an optimal environment for healing. Skin areas adherent to bone should be mobilized by gentle massage. Ulceration over bone spurs is best treated with accommodation in the prosthetic socket. Surgical revision of the periosteum is reserved for when non-surgical interventions have failed. Prosthetic wear should not be resumed until the ulceration is healed and socket fit and prosthetic alignment have been evaluated and corrected by the prosthetist.

Blisters are the result of the combination of friction and pressure and may result from either a socket that is either too loose or too tight.³ Again, the amputee should be questioned as to whether there has been significant weight loss or gain or edema of the residual or intact limb that might impact the socket fit. Prosthetic socks and liners should be examined for wear or compression that may alter fit of the socket. Generally, the occurrence of a blister requires a break in prosthetic wear. Intact blisters should be protected and left to heal. Open blisters should be treated like ulcerations with cleansing and a protective dressing until healed.

Sebaceous glands are seldom problematic since the increased pressure within the gland due to blockage arrests the production of sebum. *Epidermoid cysts* may form in the adductor region of the thigh at the upper edge of the transfemoral prosthesis. If the cyst becomes infected, it is painful and will prevent wearing of the prosthesis. The infecting organism is usually staphylococci. Prevention is by meticulous skin hygiene and treatment is the usual treatment for superficial staph infections. *Apocrine glands* are important only in the groin and axilla. The brim of the transfemoral prosthesis may irritate the groin. Chronic irritation in the groin crease may result in hidradenitis suppurativa that is marked by foul discharge from painful cysts.²

Allergic reactions of skin are common in the amputee. Allergens may be components of the socket, liner or prosthetic socks. Information regarding changes in the prosthesis or socks, cleansing agents or lotions being used on the skin or changes in laundry detergent should be sought. The interaction of perspiration with the socket materials may result in chemical breakdown and production of irritating substances. Due to the moisture and heat within the socket, *fungal infections* of the skin are not uncommon. These should be treated with topical powders during prosthetic wearing and lotions, when the prosthesis is not worn.²



Ingrown or infected hair follicles often result from pistoning in the prosthetic socket. They are most simply treated by plucking the offending hair. If the infection is severe, incision and drainage and/or antibiotic treatment may be required. Recurrent problems may require chemical or electrolytic epilation.²

While the above skin problems are generally related to excessive pressure, *verruccose hyperplasia* is the result of lack of distal contact. If there is lack of firm containment of the distal residual limb in the socket, chronic edema will form distally. The skin will undergo changes that are very similar to stasis dermatitis. With time, the skin will assume a warty condition and be prone to breakdown and bacterial and fungal infection. The treatment is to restore distal contact in the socket.³

PAIN

Patients also require information about pain and phantom limb experiences following amputation. Most patients have *phantom limb sensations*, in which the person has a distinct sense that the limb is intact, to the extent that he may attempt to stand or walk on the missing limb. The sense of presence, itching or tingling from the amputated limb is not necessarily upsetting or particularly uncomfortable. This phenomenon is most marked in the immediate post-amputation period and gradually diminishes with time, but may persist in some form throughout life. The phantom limb may undergo a process known as telescoping. With time, the sensation is confined to the terminal digits of the phantom, which seem to be attached to the end of the residual limb.²⁵

In contrast, *phantom limb pain* can be quite intrusive. Phantom pain is reportedly present in 75% of amputees at some time, but appears to be a persistent, chronic problem in only about 5%.⁴ This pain varies in its intensity, duration and specific quality, ranging from mild feelings of electrical shock or tingling, to debilitating sensations of shooting, throbbing or burning. Patients can be reassured that phantom limb pain abates over time in most cases. However, there is evidence that significantly more veterans than civilians experience long-term phantom limb pain, and veterans' pain is less amenable to treatment.²⁶ The pathophysiology of phantom limb pain is unknown and theories involving peripheral, spinal cord, supraspinal and neuromatrix loci have been proposed.³ It also has been proposed that the reason for treatment failure may be that phantom pain is not a single disorder with a single locus and etiology, but may have many underlying pathophysiological processes and represent a collection of disorders. Each of these disorders may require a unique treatment approach.²⁷ Sherman, et al.,⁶ reported that only 1% of veteran amputees who were treated for phantom pain indicated that the treatments were effective. On the other hand, treating practitioners surveyed believed their management was effective. Surveys of care providers have identified as many as 50 different



treatment methods for phantom pain syndrome.³ These findings would seem to bear out the opinion of Anton Chekhov, “When a lot of remedies are suggested for a disease, that means it cannot be cured.”

The complexity of the problem being understood, the first step in managing phantom pain is to differentiate it from phantom sensation and other forms of residual limb pain or referred pain syndromes.³ A careful history regarding the onset and characteristics of the pain, exacerbating and remitting factors may help identify intrinsic residual limb factors or causes extrinsic to the residual limb. *Ischemia* may present as intermittent claudication – pain recurring at a set ambulation distance. Examination of the residual limb may show pallor or soft tissue breakdown. Evaluation may include arterial Doppler studies, TcPO₂ or xenon 133 vascular studies. Treatment is focused on skin healing, protection and optimizing arterial flow by prosthetic socket modification. Development of *ectopic bone spurs* may result in localized pain that may increase with prosthetic use. Diagnosis is made by correlating the locus of pain with x-ray findings. The first line of treatment is modification of the prosthetic socket to relieve pressure over the spur. Surgical resection is usually the last option. *Excess fibular length* may result in pain with weight bearing. Examination may show soft tissue breakdown at the end of the fibula and a prominent fibular end. X-rays will confirm the diagnosis. Management includes socket modifications and possibly, surgical revision. *Inadequate tibial beveling* may result in excessive pressure and pain at the tibial end. Examination may reveal a prominent tibial end, bursa formation and/or skin breakdown over the tibial end. Like other bony problems, the first line of treatment is socket modification, followed by surgical intervention. *A hypermobile fibula* may result from traumatic disruption of the tibial-fibular interosseous membrane resulting in pressure on the peroneal, tibial or sural nerve remnants. Treatment involves surgical fusion of the tibial-fibular joint.³

A *neuroma* occurs whenever a nerve is cut, but not all neuromas are symptomatic. Neuroma pain is described as sharp, shooting pain brought on or worsened by prosthetic wear, weight bearing or mechanical pressure. Examination may reveal a Tinel’s sign over the site of the neuroma and reproduction of symptoms with palpation of the neuroma. A neuroma may become symptomatic spontaneously, when it becomes entrapped in scar tissue, or when exposed to pressure due to soft tissue atrophy or changes in socket fit or prosthetic alignment. Neuromas may be visualized on MRI but, since they are expected, MRI findings must be correlated with symptoms and physical findings. The best treatment of neuroma pain is prevention by proper handling of nerve endings at the time of surgery. Once a neuroma becomes symptomatic, initial management consists of socket modification. Transcutaneous nerve stimulation (TNS) may be useful in symptom control. Pharmacologic agents used in the treatment of other neuropathic pain syndromes, such as anticonvulsants, low dose tricyclic antidepressants and non-narcotic analgesics may be tried. Use of opioids for chronic pain syndromes is



controversial. If injection of the neuroma with short-acting local anesthetic relieves the symptoms, CT-guided neurolysis with phenol or other substance may be tried. If conservative measures fail, surgical resection of the neuroma may have benefit.³ A surgeon with experience in handling nerve tissue should be consulted.

Amputees may suffer from medical conditions such as degenerative joint disease of the residual limb joints that cause pain, especially with weight bearing. Residual limb pain may be referred from other areas. Symptoms of radiculopathy, spinal stenosis, facet syndrome, piriformis syndrome and myofascial pain syndrome should be elicited and investigated.³

Once the diagnosis of phantom pain syndrome has been confirmed by ruling out other etiology, attempts at treatment may include medical/pharmacologic, surgical, psychologic or use of physical modalities. For most amputees, a number of interventions have been found to be effective in phantom pain relief. Pharmacological treatment may start with analgesics such as NSAIDs. These may be effective in phantom pain worsened by weather changes. As in other pain syndromes, anticonvulsants and low dose tricyclic antidepressants may be helpful. Neuroleptics, such as butyrophenone, phenothiazines and benzamides have been used to alter central mechanisms of pain. Sympathetic beta-blockers may act centrally by serotonergic mechanism and be effective for burning or throbbing pain. Mexiletine, a sodium channel blocker, has been utilized, as well, with some success, as has intravenous calcitonin.³ The role of opioid agents in the management of chronic pain is controversial. In the past, it has been discouraged due to fears of addiction and dependence, but recommendations that are more recent may require reconsideration of the treatment role of narcotics.

Surgical procedures for the management of phantom limb pain include dorsal root entry zone (DREZ) lesioning and implantation of electrical dorsal column and deep brain stimulators. Long-term outcomes from these procedures have been less than optimal and ablative procedures are not recommended for the treatment of this syndrome.³

In addition to the traditional approach of pain relievers or short-term use of anti-depressant medications, varieties of ancillary approaches are useful in addressing phantom limb pain. These include relaxation techniques and acupuncture; adjusting the prosthetic fit, desensitizing the limb, applying heat or massage, including ultrasound; electronic stimulation, such as TENS units and pulse magnetic resonators; and referral to a pain clinic.²⁸ Individuals who lost limbs because of combat may require long-term assistance with identifying effective methods to control phantom limb pain. Biofeedback may be useful for cramping types of pain associated with increased muscle tension. Hypnosis also has been used, but without definitive evidence of benefit. Phantom pain is not believed to be a psychologic disorder, so psychotherapy has a place only in the treatment of pre-existing psychologic disorders³ and in assisting the veteran to develop effective coping methods to mitigate the “suffering” aspect of pain experience.



Physical modalities such as range of motion exercises, massage, heat or cold modalities, acupuncture, TNS, vibration, percussion and desensitization techniques have been reported to provide short-term relief. They may be useful as an adjunct to other treatments and to control episodic exacerbation of pain.³

Sherman, et al.,⁵ point out that many of the reports claiming success in the treatment of phantom limb pain conducted time-limited follow-up. Due to this, while the treatment may produce initial, short-term relief, pain may recur and be even more resistant to treatment long term. Reports of successful treatment must be carefully evaluated, with respect to the length of follow-up.

AGING WITH LIMB AMPUTATION

Amputees are not exempt from the development disorders associated with aging, which may impair physical function. However, amputees are less able to adapt to these new impairments, so what may be a minor problem in an otherwise intact person has profound impact on the function of the amputee. Burger, et al.,²⁹ reported that one-third of persons who were young at the time of traumatic lower limb amputation faced limitations of mobility later in life.

Musculoskeletal Impairments

It is reasonable to predict that there would be an increased incidence of degenerative joint disease in the remaining joints of the residual limb, the intact limb and possibly the spine due to over use and altered body mechanics and stress on musculoskeletal structures. A study of British war veterans with major lower limb amputations showed a 61% incidence of hip osteoarthritis (OA) on the amputated side and a 23% rate on the intact side, compared to an 11% rate in the population. There was a three-fold increase in hip OA for transfemoral amputees compared to transtibial amputees.³⁰ A significant decrease in bone mass density (BMD) of the femoral neck of the amputated side compared to the intact side also was reported. As with OA, decreased BMD was more prominent in transfemoral amputees compared to transtibial amputees. In a study of Canadian war amputees, a significantly increased incidence of OA of the intact side knee was reported. Gait analysis showed larger forces across the intact side knee joint, as well.³¹

The strain of ambulation with a lower limb prosthetic device is not limited to the lower extremity joints. Fifty-two percent of amputees who were at least six months post amputation reported persistent, bothersome back pain. Fifty-three percent of the amputations had resulted from trauma, including war injuries. During the three months preceding the survey, 22%



reported that back pain had severely interfered with activities of daily living (ADL), 23% that recreational, social and family activities had been severely disrupted and 28% that work, including school and housework, had been severely limited. No relationship of back pain to level of amputation was identified. The majority of amputees reported the intensity of back pain as mild, but one-third reported severe pain. Seventy-two percent characterized the pain as intermittent and 22% as constant, but with variation in intensity, and 4% as constant with little variation in intensity.³² Clearly, back pain is common in lower extremity amputees, and in a significant number of these individuals, disabling.

Similar complications have been reported in upper limb amputees. Jones and Davidson³³ surveyed upper limb amputees regarding prosthetic use, intact limb problems and employment. Of 46 responses, 50% of amputees reported pain in the intact limb. There did not appear to be a relationship between employment and pain, or wearing a prosthesis and pain. Diagnoses related to the pain included epicondylitis, shoulder impingement, tenosynovitis, osteoarthritis, reflex sympathetic dystrophy-like syndrome, carpal tunnel syndrome and trigger finger.

Musculoskeletal complaints in amputees should be evaluated and treated in the same manner as such complaints in non-amputees. Usually, the first line of treatment is NSAID, joint protection and rest and physical therapy treatment (modalities and specific exercise programs). It must be kept in mind, though, that the functional impact of even minor impairment of the intact limb may be profound. The upper limb amputee with shoulder impingement no longer may be able to comb his/her hair or don a shirt. The lower limb amputee with OA of the intact limb knee no longer may be able to climb the stairs, get out of bed and go to the bathroom, or to complete necessary household activities. Therefore, while pursuing treatment to alleviate the musculoskeletal problem, the new, functional disabilities must be addressed by training in new techniques to accomplish common tasks or provision of adaptive equipment. The physical and/or occupational therapist can be of great service in this area.

Cardiovascular Disease and Other Systemic Disease

Hrubec and Ryder³⁴ described a statistically significant relationship between combat-related limb amputation and cardiovascular disorders, though the reason for this association was not clear. They postulated a possible association between amputation leading to sedentary life style and cardiovascular disease. Whatever the reason for the association, the onset of heart disease and its attendant exercise tolerance limitations may have profound impact on the function of the lower limb amputee. There have been many studies reporting the impact of amputation on the energy cost of ambulation.^{35, 36, 37, 38} All studies have shown significant increases in energy cost per body weight per unit distance for persons with lower limb amputation due to trauma or vascular disease. The increase in energy cost is greater for vascular amputees. Cardiovascular disease that results in decreased exercise tolerance may make ambulation non-functional. The same is true for pulmonary dysfunction that limits aerobic capacity.



Amputees who are experiencing decline in aerobic capacity may present with complaints about the weight of the prosthesis. If the prosthesis is of older design or materials, it may be possible to decrease prosthetic weight enough to decrease the energy cost of walking. The amputee must be warned, however, that it will take time and possibly training to adapt to the new prosthesis and caution should be used in making multiple prosthetic changes simultaneously. Consideration also should be given to assistive devices, such as manual or motorized wheel chairs.

The onset of functional decline can be even more difficult for the amputee than for the previously healthy individual. The amputee may need support and time to accept the new impairment and proceed with adaptation.

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6. PROSTHETICS CLINICAL ISSUES

by John Milani

CAUSES AND LEVELS OF AMPUTATION

Amputations are performed because of severe trauma to limbs, congenital anomalies and disease processes, such as peripheral vascular disease (PVD) or cancer. Amputation is categorized into those of the lower limb and those of the upper limb. Lower limb amputation includes: (1) transtibial (below knee); (2) knee disarticulation, (3) transfemoral (above knee), (4) hip disarticulation, (5) trans-pelvic (hemipelvectomy); and (6) partial foot. Partial foot amputation encompasses: transmetatarsal amputation; Lisfranc, in which all tarsal bones remain; Chopart, in which the talus and calcaneus remain; and Syme, or ankle disarticulation. Upper limb amputation includes: 1) partial hand, which takes in digit amputation; (2) wrist disarticulation; (3) transradial (below elbow); (4) elbow disarticulation; (5) transhumeral (above elbow); (6) shoulder disarticulation; and (7) forequarter amputation, in which the clavicle and scapula also are removed.

Functional Levels – Lower Limb

In general, functional levels are dependent upon several factors, among them the overall physical condition of the amputee. This includes the level of amputation, other orthopaedic conditions, cardiovascular conditions, respiratory conditions, vascular problems (particularly PVD), visual problems, CVA, and neuromuscular conditions all play a role in determining the level of functionality the amputee will have following surgery. In addition, the patient's emotional and mental state have an impact, particularly the amputee's understanding of his situation and cognitive ability. Other factors that directly affect the level of function include the patient's activity level, degree of motivation, vocation, age and the presence, or lack thereof, of a support system made up of family and friends.

To determine an amputee's ability to function with a prosthesis, the amputee is evaluated in clinic and a functional level is derived. There are five functional levels (K0-K4) that are used to establish a functional level for the amputee. These levels go from the least function to the greatest function. At the K0 functional level, the amputee does not have the ability or potential to ambulate or transfer safely without assistance and a prosthesis does not enhance their quality of life or mobility. At the K4 functional level, the amputee has the ability or potential for prosthetic ambulation that exceeds the basic ambulation skills, exhibiting high impact, stress or energy levels, typical of the demands of active adults, or athlete.⁶ The traumatic war amputee would be expected to function at the highest levels, K3 and K4.



Prescription Formulation

The Prosthetic Clinic Team evaluates the patient and then formulates a prosthetic prescription based on functional level, patient's age, date of amputation, condition of the residual limb, amputation level, activity level, vocation, sports participation, weight, motivation, cosmetic concerns and any other physical or cognitive conditions. Additionally, the Clinic Team must determine whether the patient understands and has the ability to don/doff the prosthesis and the ability to care for and maintain the prosthesis.

Lower Limb Prosthetic Socket Designs

In general, lower limb prostheses are fitted to provide weight bearing, balance, ambulation, function and cosmesis.

Partial foot amputations have several levels that include the transmetatarsal, Lisfranc (all tarsal bones remain), Pirogoff, Boyd and Chopart (calcaneus and tarsus are present). There are limited components available for these levels of amputations. Prostheses for a transmetatarsal amputation may require only shoe modifications such as a toe filler, long steel spring and rocker bar. Additionally a high top shoe can provide additional support. At the Chopart level, an ankle-foot-orthosis can be used with toe filler and shoe modifications.

A Syme amputation (ankle disarticulation) with full weight bearing capacity distally at the heel pad offers a very good functional level that also is comfortable. Traumatic amputees can benefit from the full weight-bearing feature and long lever arm for function. Additionally, this design offers anatomical suspension by intimate contours just proximal to the malleoli. The Syme prosthesis can be constructed with an opening (window) usually placed medially to allow donning and doffing of the prosthesis. Another method of fabrication is to make the Syme prosthesis without a window. The prosthesis is fabricated with a soft insert with wedges that incorporate the bulbous end. This creates a cylindrical shape to the insert. The insert then is donned onto the residuum, and the residuum with insert then is inserted into the socket. The prosthesis easily self-suspends, due to the intimate fit and addition of materials in the undercut areas. The major disadvantage of the Syme prosthesis is the bulbous end, which detracts from the cosmesis. This can be minimized by surgically shaving down the malleoli at the time of surgery. Another concern at one time was the limited number of prosthetic feet that could be used. Today there is a large variety of prosthetic feet that include energy storing capacity.

The transtibial level of amputation has traditionally been the most common level of amputation performed due to trauma and disease such as diabetes (PVD) or other circulatory diseases. The three most popular designs of prosthetic sockets include the patellar tendon bearing (PTB), total surface bearing (TSB) and plug fit.



Since the late 1950's, the PTB has been the design of choice for most traumatic transtibial amputees. The socket design of the PTB provides for selective weight bearing, usually at the medial tibial flare and at the patellar tendon. Other areas of the residual limb that can take weight and pressure that can be tolerated for support are at the antero-medial and antero-lateral areas of the socket and at the posterior musculature of the calf. The PTB design also provides distal socket contact, which prevents edema and improves proprioception. This socket design also provides relief (built in pockets) for bony prominences, tendons or sensitive tissue to sit in, so as not to overload these tissues with excessive pressure.

The TSB socket design was developed in the mid 1980's and provides for complete contact of the prosthetic socket to the residual limb with no built-in pockets for relief of bones and other sensitive tissue. By allowing total surface contact, all tissue of the residual limb is in contact with the prosthetic socket, thus reducing the loading on the medial tibial flare and patellar tendon. When using this type of design it is usually necessary to use a roll-on type of liner made of silicone, mineral gel or similar material. The thickness of these liners is usually three, six or nine millimeters. This design is fast becoming the socket design of choice for traumatic amputees.

The plug fit prosthesis was very popular from WWI to mid 1950's, but is seldom used today. This socket design provided weight bearing at the patellar tendon and was used in conjunction with a thigh lacer for suspension. Additionally by tightening the thigh lacer additional weight bearing was achieved on the thigh. The prosthesis was usually fabricated of wood and the distal end of the prosthesis usually was left open with no contact.

The knee disarticulation level is similar to the Syme level in that the residual limb is long, can usually bear full weight on the end and is fairly comfortable. A door or window is generally needed as with the Syme to allow the bulbous end to get past the narrower area of the limb just proximal to the femoral condyles. The major disadvantages of this design is the cosmesis and limited prosthetic knees that can be used to keep the knee center at the same height as the sound limb.



Figure 1

The three types of design utilized for transfemoral level prostheses are the quadrilateral (quad), ischial containment and plug fit. The quad design provides a socket that is rectangular in shape with a large medio-lateral and narrow antero-posterior opening. (Figure 1)

The quad socket is designed so that the ischial tuberosity sits on the top of the posterior wall of the prosthesis and parallels the gluteal fold. To keep the ischial tuberosity in place, the anterior wall of the prosthesis is approximately 1" to 2 1/2" higher than the posterior wall



(depending on length of the residual limb). The anterior wall exerts a posteriorly directed force, which keeps the ischial tuberosity from slipping forward into the socket. The height of the medial wall is the same as that of the posterior wall. The function of the medial wall is to contain the medial thigh tissue. Sometimes it is necessary to dip this wall slightly near the pubic ramus to avoid pressure on the pubis. The lateral wall is approximately 2" to 3" higher than the medial wall and usually is at or slightly distal to the greater trochanter. The lateral wall of the socket stabilizes the femur from abducting in stance phase. Additionally, reliefs (channels) are placed proximally in the socket to avoid excessive pressure on the adductor longus, quadriceps, rectus femoris and hamstring tendons. Distally, the socket provides total contact to prevent edema and has a relief at the distal lateral wall to prevent excessive pressure on the distal lateral femur.

There are several designs that fit into the ischial containment classification. The most popular include the Normal Shape Normal Alignment (NSNA), the Contoured Adducted Trochanteric-Controlled Alignment Method (CAT-CAM) and the Icelandic Scandinavian New York (ISNY). (Figure 2)



Figure 2

These designs along with others, provide for larger anterior-posterior openings and narrower medial-lateral openings. The rationale for this flip-flop from the Quad socket is that the anterior-posterior muscles are the ones that are used more extensively during ambulation, standing and stairway ascend/descend. The Ischial Containment designs also differ in that their proximal trim lines are considerably higher than traditional Quad sockets for containment of the ischial tuberosity and greater trochanter. This provides for greater stabilization and control of the femur than the Quad socket and increases the surface area of support for weight bearing. The lateral wall extends proximally to the iliac crest to encase the greater trochanter inside the socket. The posterior wall slopes up laterally from the posterior-medial corner, encapsulating the ischial tuberosity. The distal socket provides contact to prevent edema.⁴

This design due to the greater containment of the residual limb and control is very suitable for use by the traumatic amputee who is very active or athletic.

The plug fit design provides for a conical shape in which the residual limb slips into the socket and then is supported along the proximal brim (hanging up effect). This design was popular from post-WWI to the mid-1950's, but is seldom ever prescribed today. To use this design and provide suspension and control, it was necessary to use a pelvic hip joint, band, and belt. The



sockets were usually made of wood and were open-ended distally without socket contact. This design did not differentiate between pressure-tolerant or pressure-sensitive tissue. Additionally, the prosthesis had a tendency to piston (up and down telescoping action during swing phase).

The hip disarticulation and transpelvic levels of amputation usually require specialized socket designs due to the loss of most bony, weight-bearing structure. In the case of the hip disarticulation, the ischial tuberosity is intact and weight can be taken on this bony element. In the case of the transpelvic amputee, there are no bony structures to allow for weight bearing. The socket is designed to fully contain the soft tissues to allow hydrostatic support of the body weight. Sockets of this design may extend proximally to the torso (lower rib margin).

Lower Limb – Suspension Systems

Prosthetic designs for lower limbs include differential pressure suspension systems, anatomical suspension systems, strap suspension (PTB), thigh corset with mechanical hinges, Silesian Belt and pelvic joint with belt.

Transtibial (Below Knee)

At the transtibial level, differential pressure suspension systems use an atmospheric pressure (vacuum) or suction to maintain the prosthesis onto the residuum. These designs tend to provide the amputee with enhanced function, greatest range of motion, added sense of security, greater control of prosthesis and no piston action when fitted properly. Of all suspension modes, these designs tend to be the most desirable because of the enhanced retention of the prosthesis to the residua created by the atmospheric pressure (vacuum).⁵



Figure 3

One design incorporates an overall snug fit with a valve placed distally into the prosthetic socket. The skin is in direct contact with the socket interface. To don the prosthesis, a skin lotion is used to push the residua into the socket. The air is then expelled through the distal valve causing a vacuum to occur. In order to use this type of suspension, the residua have to be stable with no fluctuations in volume and generally need to be free of scars that could prevent vacuum from being achieved.⁵

Other atmospheric systems include the use of elastomer sleeves made of silicone, urethane or mineral gel. (Figure 3) These sleeves are rolled onto the residua and have a distal pin attachment (plunger) that anchors distally into the socket securing (locking) the prosthesis



in place. These systems allow for moderate volume changes by placing socks of varying plies on the outside of the sleeve to achieve a snug fit and for residua's that may have some scarring or grafts.⁵ Variants to these methods include the "hypobaric" design, which has a valve distally in the socket to expel air and a silicone rubber band (gasket) molded into standard textile stump socks at the proximal socket. This gasket is positioned so that it is at a level slightly distal to the proximal posterior socket edge, which creates a seal and maintains vacuum or suction. This silicone band is molded into prosthetic sheaths and stump socks of varying plies to accommodate volume changes. To enhance the seal, a skin lotion is used for a wet fit.⁵

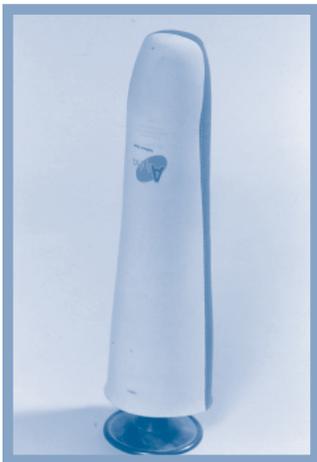


Figure 4

Another design allows a mineral gel sleeve to be rolled onto the residual limb, with a fabric backing and no distal pin. (*Figure 4*) Once the sleeve has been placed onto the residua, the residua is placed into the socket, where a distal valve expels the air. With all the air expelled, a second sleeve is placed over the inner mineral gel sleeve and outer socket, sealing any air from entering the socket, thus creating a suction or vacuum. This design can accommodate some volume changes by use of a thicker sleeve. The sleeves usually come in thicknesses of 3mm, 6mm and 9mm. Additionally, the socket can be padded with leather to re-establish the fit and vacuum required for suspension.

The simplest design of achieving suction suspension could be to use a rubberized sleeve over the outer socket surface and onto the mid-thigh, thus preventing air from entering into the socket. This design allows for stump socks and/or soft insert to be used.

Anatomical suspension designs are the second most desirable option for suspension of the prosthesis. Suspension is achieved by careful contouring of the proximal socket walls over and proximal to the femoral epicondyles to lock the condyles in place. This method of suspension is known as supracondylar (SC) and can be very effective in suspending the prosthesis and in providing enhanced mediolateral stability in individuals with a shorter residual limb. A variant to this design allows for molding of the socket anteriorly above the patella for added suspension and to control hyperextension in the shorter residual limb. This design is known as supracondylar/supra-patella (SC/SP) or (PTS). The advantages of these designs are increased ML stability with the SC and increased AP stability with the SP feature. Disadvantages include localized pressure over condyles and restriction of full flexion.⁵

When it is not feasible to use differential pressure or anatomical modes of suspension, a strap can be used to suspend the prosthesis. A popular strap, called a PTB cuff, is attached to the medial and lateral walls of the prosthesis at their posterior-proximal juncture and is then



angled proximally over the patella. The lower border of the cuff touches the superior border of the patella to achieve suspension. In addition to the cuff, a waist belt with extension assist can be attached to the proximal border of the cuff to increase suspension and to assist the individual in extending the prosthesis. This design can accommodate changes in volume and is relatively simple to adjust. Disadvantages include slight pistoning and belt irritation.⁵

The thigh corset with mechanical hinges was the design of choice up until the late 1950's or early 1960's and still has its place when the residual limb and or knee are severely damaged. Advantages in using the thigh lacer with joints include the reduction of weight bearing on the residual limb and can greatly increase the ML stability. Disadvantages include pistoning, added weight and bulk, difficulties in donning and excessive wear and tear on clothing.

Transfemoral (Above Knee)

The same differential pressure systems are used for the transfemoral level as in the transtibial level. The goal is to evacuate air from the prosthesis and to keep air from re-entering the prosthesis. This is accomplished by direct skin contact of the residual limb with the inner interface of the socket with a pull-sock method or wet method application. Once the residual limb is positioned in the socket, a distal valve is used to keep air from entering the prosthesis.⁵

As in the transtibial method, a roll-on sleeve made of silicone, urethane or mineral gel can be used. Attached to the distal end of the sleeve is a pin, which attaches to a locking mechanism located in the distal end of the socket.⁵

The knee disarticulation presents the problem of a bulbous end that cannot be readily fitted with a differential pressure system. It is, therefore, necessary to fabricate an insert with condylar wedges to allow the bulbous end of the residual limb to pass through the narrow opening. An option to this anatomical suspension method would be to place an anterior door into the distal socket to allow the residual limb to be donned, with the door positioned over the opening and held secure with Velcro straps.

The Silesian Belt is a belt that can be used in a quadrilateral socket with partial suction to help suspend the prosthesis. This belt can be used in conjunction with a TES belt, which is a neoprene rubber sleeve that fits over the outside of the socket and which goes around the individual's waist and is secured with Velcro closure. The Silesian Belt also can control prosthesis rotation, especially when the residual limb is flabby. Additionally, this belt can be used to accommodate volume changes of the residual limb.



To provide suspension and maximum ML stability to the individual with a short, weak or flabby residual femoral limb, a metal or plastic pelvic joint with band and leather belt can be used. The pelvic joint usually is attached to a quad socket or plug fit socket at the proximal lateral wall so that the center of the joint is approximately 1/2" anterior and 1/2" proximal to the greater trochanter. This positioning is used to approximate the anatomical hip joint. This suspension system also can provide some rotational stability of the prosthesis. Disadvantages would include pistoning, added weight and bulk, wear and tear on clothing and more time to don and doff.

LOWER LIMB PROSTHETIC COMPONENTS



Figure 5

Socket Liners

Socket liners (*Figure 5*) are used to cushion and protect fragile limbs and to accommodate volume changes. They can be used to suspend prostheses by rolling them onto a residual limb to provide suction suspension or they can have wedges built into them to provide supracondylar suspension. They can be made of silicone, urethane, and mineral gel, rubbers and expanded polyethylene foam. Liners fit inside prosthetic sockets.⁵

Ankle/Foot Components

The following ankle/foot components are described by function and design. Not all name brands are included.

Solid Ankle Cushion Heel (SACH) feet were developed in the 1950's and remain the simplest designs, the least expensive, relatively lightweight and most reliable foot components that are clinically accepted. Up until the mid-1980's, the SACH design had been the foot of choice. There are no moving parts, which makes this design very durable and ideal for children and for individuals whose ambulation is limited to walking. Many manufacturer designs also include sculptured toes and heel rise to allow women the ability to wear high-heel shoes. The SACH foot designs allow compression of the foam heel at heel-strike to simulate planterflexion. A wooden internal keel provides stability in mid-stance and allows for a relatively easy rollover in late stance.⁵

Single-Axis feet pre-date the American Civil War and still are used today on a limited basis. The main advantage is that the foot will allow for a quick foot-flat, which increases knee stability in an above-knee prosthetic wearer or in a below-knee prosthetic wearer who uses a



thigh corset with knee joints in early stance. This feature is important in the individual who has knee instability. Disadvantages include weight, maintenance, abrupt dorsiflexion stop, noise and cost.⁵

The multiaxial foot adds inversion-eversion and transverse rotation capabilities to the function of the single-axis foot and is often recommended to accommodate uneven terrain. Its weight and maintenance requirements are similar to that of the single-axis foot. Hikers, fisherman, golfers and others who find it necessary to walk on uneven terrain can use the multiaxial foot with much success.⁵

Stationary Ankle Flexible Endoskeletal (SAFE) feet became available in the 1980's. This design had an elastic keel, which enabled a smoother and easier rollover, which was more preferable than the rigid keel of the SACH foot. Some disadvantages include limited push-off, increased cost and added weight.⁵

Dynamic Response (formerly Energy Storing) feet have a plastic spring keel that provide a dynamic responsiveness during stance. There are numerous dynamic response feet available, such as the Carbon Copy, Seattle, Flex-foot, Springlite, etc. The more aggressive ambulator can use these designs, including runners and those participating in recreational or competitive sports who can load the forefoot for these activities. Disadvantages include increased fabrication time and increased cost for some designs.

Hybrid Design feet are available that combine multiaxial ankle mechanism with dynamic response, such as the College Park foot/ankle and the Phoenix foot. These designs can be used for recreational and competitive sports, as well as for uneven terrain. Disadvantages would include maintenance and cost.

Knee Components

As with the ankle/foot components, knee components are listed by function and design, rather than by manufacturer.

Single-Axis knees offer the simplest function and are the least expensive and most reliable for individuals who will be walking at a single speed. These knees have one center of rotation and act like a simple hinge. They are specially suited for use in remote areas where durability is a major concern. The knee also can be used for young children because of durability and cost. An adjustable friction control is usually incorporated to allow for swing dampening to limit heel rise and terminal impact. The amputee must use voluntary muscle control to keep the knee stable during ambulation.⁵



Stance Control (Formerly called Safety Knee) knees provide enhanced stance stability to that of the single axis knee by incorporating a weight-activated brake, which adds friction to the knee axis and prevents it from bending under weight bearing. This knee also has one axis of rotation. This knee is useful to train new amputees and those who have instability problems. Disadvantages include delayed swing phase, unloading fully to flex and sit and lack of use in bilateral situations. The knee cannot be flexed under weight-bearing conditions and this makes descending stairways step over step impossible. Additionally, over time the brake wears and loses its effectiveness.⁵

Polycentric knees have multiple centers of rotation. Many polycentric knees are designed to offer enhanced knee stability early in stance phase, combined with the ability to flex under weight bearing just prior to swing phase. Besides stability, polycentric knees allow shortening of the prosthesis below the knee, which allows for clearance during swing phase. This feature also makes sitting more cosmetic for the longer transfemoral amputee. Polycentric knees can be used on bilateral amputees due to the stabilizing features.⁵

Manual Locking knees are the least desirable when looking for a smooth, energy- efficient gait. The stiff-legged gait that results from having a locked knee disrupts swing phase and forces the amputee to “pole vault” over the prosthesis. It is best to use lock knees for temporary periods of time, such as when hiking on uneven terrain or when a newer, less experienced amputee needs to stand in place for a considerable amount of time.⁵

Fluid Controlled knees have chambers in which either air (pneumatic) or oils, such as silicone (hydraulic), permit variable speed in swing phase. Pneumatic control units are more suited for moderate cadences and hydraulics for moderate to high cadences. The most advanced designs, such as the SNS, provide stance and swing control.⁵

Computer knees have onboard microprocessors, which control swing phase. These knees usually have pneumatic chambers. One knee, the C-Leg, has a hydraulic chamber and is capable of controlling swing and stance phase.

Hybrid knees combine functions of two or more of these generic groups. One design combines the stability of a polycentric knee with a pneumatic chamber to allow for variable swing to occur.⁵

Special Components

The Torque Absorber allows the leg to rotate with reference to the socket during stance phase, automatically returning the leg to the normal position during swing phase. The torque absorber is excellent in activities where rotation is important: golfing, dancing, bowling, baseball, standing and working at a bench for considerable periods of time. Generally, the shorter



the residual limb, the greater the loss of natural torsional capabilities. A torsion absorber would restore the loss of torsion.⁵

A Locking Transverse Rotation Unit is usually placed above the prosthetic knee. When the amputee is seated, the locking transverse unit can be unlocked, allowing the entire knee-shin foot assembly to rotate 90 degrees (crossing the leg) to allow getting into tight places such as an automobile, a booth in a restaurant, etc. This component can be used by almost all above-knee amputees.⁵

Shock absorbing pylons allow for telescoping of the pylon to absorb shock to the residual limb that occurs in jumping and running activities, as well as aggressive walking.

Gait Deviations

Gait deviations are abnormalities that occur during gait due to prosthetic misalignment or fit, amputation level, length of residual limb, patient weakness or lack of therapy. Gait deviations that are due to prosthetic misalignment usually can be corrected or reduced significantly by realigning the prosthesis. When the gait deviation is due to an ill-fitting socket, the socket can be modified to establish a proper fit, or the socket can be replaced.

Upper Limb Prosthetic Socket Designs

In general, upper limb prostheses are fitted to provide prehension, cosmesis, movement and balance.

At the partial hand level, most prostheses are fabricated for cosmetic purposes (passive prehension) and can include silicone finger prostheses, which are life like in appearance. When the thumb has been amputated, the main goal of the prosthetist is to provide a prosthesis that will allow for opposition to enable prehension. This can be done with a post (passive prehension). In some instances, a hook could be mounted onto the palm section of a hand wrist orthosis to permit prehension via body movement, using a harness and cable system (active prehension).

At the wrist disarticulation level, the radius and ulna are present and usually allow normal range of motion in supination and pronation. Prosthetic designs usually include a low-profile wrist unit attached to a double wall socket. The proximal trim lines of the socket usually are well below the cuboidal fold to allow for full flexion/extension and full supination/pronation of the prosthesis. The terminal device can be a hand or hook, which can be actively controlled by a cable and harness system. Additionally, the trim lines of the socket could be left higher, such as in a Northwestern University design for suspension; electrodes could be used for myoelectric control of the terminal device. This allows for complete freedom from all harnessing.

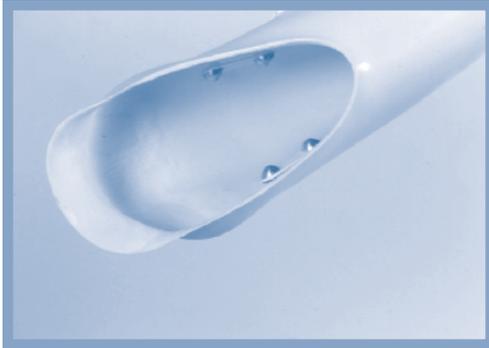


Figure 6

The transradial prosthesis is designed with a double wall socket and wrist unit. The terminal device can be either a hook or hand (passive or active). Suspension can be provided by harness or anatomically. Positioning of the terminal device is accomplished through positioning the anatomical elbow. To operate the terminal device by body movement, it is necessary to use a harness and cable system. Body movements to operate the terminal device include humeral flexion on the involved side and scapula abduction. Myoelectric or switch control also can be used to operate the terminal device.

Socket designs can incorporate anatomical suspension, such as the Northwestern University socket (*Figure 6*), and Muenster socket. Optional suspension can be achieved through differential pressure systems (suction).

The elbow disarticulation prosthesis poses special problems with regards to cosmesis and matching the mechanical elbow joints to the anatomical elbow joint to match the anatomical joint, it is necessary to use external joints. There are a limited amount of joints available and they all tend to increase the width of the prosthesis at the elbow. This especially is a cosmetic problem, since the elbow disarticulation as in the Syme amputation has a natural bulbous end due to the condylar flares. The prosthesis is suspended by harness and controlled by a dual cable system.

The transhumeral prosthesis has a socket with elbow and forearm component. The prosthesis is suspended by a harness system; the terminal device and elbow are operated through a dual cable control system. Suspension also can be achieved by differential atmospheric pressure (suction).

The shoulder disarticulation and forequarter amputee represent the most difficult levels to fit with prosthesis. Due to the high level of amputation, it is usually recommended to use external power to operate the elbow and terminal device. Even with external power, patient compliance is a problem due to the weight of the prosthesis and the inability of the prosthesis to provide high levels of function.

Myoelectric Control Systems

In many instances, prostheses incorporating myoelectric control of the terminal device can be used for the wrist disarticulation, transradial, elbow disarticulation and transhumeral level. There are several types of electrodes that can be used with either single or dual functions.



In the most basic prosthesis, a transradial, two electrodes can be used to pick up signals from the wrist extensors and wrist flexors. The electrodes are generally positioned over the muscle bellies of these two groups of antagonistic muscles. In the transhumeral prosthesis, these electrodes would be located at the muscle bellies of the triceps and biceps. The electrodes are placed on the skin and will pick up muscle signal and then amplify this signal, sending it to a motor in the terminal device for the desired operation, closing or opening.

When the upper limb amputation is a high, very short transhumeral, shoulder disarticulation or interscapular thoracic, it is not feasible to use a myoelectric system. This is due to difficulty in containing electrodes within a socket and the inability to pick up clear signals. In addition, these levels of amputation also make it difficult to get adequate body movement to operate standard harness and cable systems. At these levels, an externally-powered prosthesis using micro switches to operate the elbow and or terminal device is recommended. These switches are usually simple in design and can be referred to as pull switches. They usually provide a dual function and can be mounted onto a harness or onto the outer surface of the prosthesis. One short pull on the switch (1/16") can flex an elbow or open a terminal device, while a long pull (1/8") can extend an elbow or close a terminal device.

Upper Limb – Suspension Systems

Suspension systems may be utilized for the upper limbs. Harnessing can provide suspension and to operate body-powered components. The figure of 8 is the most popular and can be used for the transradial, elbow disarticulation and transhumeral levels. The figure of 9 and shoulder saddle are two additional types of harness. For shoulder disarticulations and interscapular Thoracic (Forequarter) levels, a chest strap is used for suspension.

To self-suspend (anatomical suspension) a transradial prosthesis, the socket must contain within it the olecranon and/or humeral condyles. The Northwestern University socket design allows for self-suspension of wrist disarticulation and long transradial prostheses. For the shorter transradial prosthesis, a Muenster socket design can be used. This design has trim lines, which are considerably higher than the cuboidal fold. Since this limits elbow flexion, the forearm is pre-flexed to enable the terminal device to reach the mouth.

As with the lower limb, differential pressure systems can be used on upper limb prostheses to create an atmospheric pressure (suction or vacuum) to maintain the prosthesis on the residual limb. Specific atmospheric designs are outlined in the Lower Limb-Suspension System section.



UPPER LIMB COMPONENTS

Terminal Devices

The most important function for the upper limb amputee is prehension, movement and cosmesis. The terminal device can be a hand or hook and either can be passive or active. A passive device does not move and can be made to be very aesthetic and life-like in appearance. Active devices move and provide function, such as grasp. To operate the active device, body power can be used through a harness system at the shoulder or electricity can be used to operate an externally powered system. Batteries are used to supply the electricity required to operate an externally powered system.



Figure 7



Figure 8

Active devices include hooks and hands and either can be voluntary opening (VO) or voluntary closing (VC). To operate a voluntary opening device, the amputee exerts force on the harness system, which pulls on the control cable to open the device. Once this force is relaxed, rubber tension bands or springs will close the device for grasp. To operate a voluntary closing device, an initial pull on the harness is used to open the fingers of the device. Once the fingers are open, the amputee relaxes the pull on the harness. A second pull then is used to allow the fingers of the device to close onto an object for grasp. In this instance, the amputee is controlling the force being exerted on an object. Hooks are usually more functional and durable for manual types of functions. Hooks also provide “visual cue,” which is the ability of the amputee to see as they are attempting to pick up smaller objects. (Figure 7)

Hands with cosmetic gloves are very aesthetic and are very functional when grasping larger or spherical types of objects. (Figure 8)



Wrist Components

Wrist components are located at the distal end of the prosthesis and they allow for the attachment of the terminal device and for the pronation and supination of the terminal device. Many wrist components provide other features, such as quick-disconnect, wrist flexion, rotation and the ability to lock/unlock the terminal device in place.

Elbow Components

For the transradial amputee, flexible hinges or rigid hinges can be used to suspend the prosthesis and to provide support. The flexible design hinges, usually made from leather or plastic, allow for active pronation and supination. The rigid hinges made of metal provide maximum strength to the prosthesis and can protect the elbow. Rigid hinges can be single pivot or polycentric. For very short transradial amputations, metal set-up hinges can be used to provide additional forearm flexion. For the transhumeral amputee, there are a variety of body-powered and electrically-operated prosthetic elbows. These elbows can be locked and unlocked and usually can be manually rotated at the distal humeral section to provide internal or external placement of the elbow and forearm.

Shoulder Components

For the shoulder disarticulation, there are very few components available. The components available can provide no movement such as in a monolith construction to those that provide flexion or flexion with abduction by use of metal joints. These movements are usually all accomplished through body movement (patient leaning) or with the assist of the sound extremity.

Harnessing

Harnessing provides suspension, elbow flexion and terminal device function. Harnesses usually are designed in the figure of 8, figure of 9, or shoulder saddle. The materials used to fabricate a harness usually are made of textiles, such as webbing and leather.



GLOSSARY

Alignment – Alignment is the relationship of the socket to the prosthetic foot.

CAD/CAM – This is a method by which prostheses can be designed and manufactured by computer. There are currently four or five computer programs available for designing and fabricating prosthetic sockets.

Certified Orthotist – A Certified Orthotist is a practitioner who provides care to patients with disabling conditions of the limbs and spine by evaluating, designing, fabricating, fitting and aligning those devices known as orthoses.¹

Certified Prosthetist – A Certified Prosthetist is a practitioner who provides care to patients with partial or total absence of a limb by evaluating, designing, fabricating, fitting and aligning those devices known as prostheses.¹

Endoskeletal – A soft outer finish with an interior support.⁴ Internal components are used to provide structural support and then foam is shaped to resemble the uninvolved side. Cosmetic hose or a “skin” is applied to provide color.³

Energy Storing Foot – A prosthetic foot, that stores energy during stance phase and then due to the design, releases this energy at push-off to enable activities such as running and jumping.

Exoskeletal – A hard outer support and finish.⁴ Wood or plastic is used to provide structural support and is then shaped to resemble the uninvolved extremity. A laminate is applied to the exterior of the shaped part to provide color and additional strength.³

Externally-Powered Prosthesis – An artificial limb that has switches usually mounted on a harness, which operates an electric elbow or terminal device.

Lamination – A process by which a plastic socket is fabricated, using a liquid resin (thermoset plastic) to impregnate materials such as nylon, carbon, fiberglass, Spectra or Kevlar. A catalyst is added to the resin, which causes the resin to gel and set over a controlled period of time, usually 20-30 minutes.

Myoelectric Prosthesis – An artificial limb with electrodes that contact the skin to pick up muscular activity (signals) which is then amplified and sent to the terminal device which has a motor for opening and closing.



Orthosis – An orthopedic appliance used to support, align, prevent or correct deformities, or to improve function of movable parts of the body.²

Orthotics – The field of knowledge relating to orthoses and their use.²

Patellar Tendon-Bearing (PTB) – This socket design allows pressure to be placed onto tolerant tissue (patellar tendon, medial tibial flare and muscles) while providing relief (minimal to no contact) for sensitive tissues (bones, tendons, scars, etc.) to allow for weight bearing and socket control.

Permanent Prosthesis – An artificial limb used by amputees whose residual limb has matured and the amputee has satisfactorily completed the temporary limb phase. The socket and components are manufactured to provide lasting durability and proper cosmetic appearance.³

Preparatory Prosthesis – This is the first limb a new amputee will wear. It consists of a plaster/fiberglass cast (applied during or shortly after surgery) and basic components which easily are removed. It controls swelling and protects the residual limb, while allowing minimal (standing, touchdown weight bearing) ambulation.³

Proprioception – This the ability of the amputee to know where the prosthesis is in relationship to the body when standing and/or during ambulation, while not visually looking at the prosthesis.

Prosthesis – An artificial substitute for a missing body part, such as an arm, leg eye, or tooth used for functional and cosmetic reasons, or both.²

Prosthetics – The field of knowledge relating to prostheses, their design, use, etc.²

Quick foot-flat – The prosthetic foot-at-heel contact moves rapidly to a foot-flat. One cause could be a prosthetic heel that is too soft.

Recreational Prosthesis – An artificial limb that is specifically designed to permit the amputee to participate in a particular activity, e.g., swimming, skiing, running, etc., when a conventional prosthesis is not suitable. These prostheses are constructed in such a manner as to resist environmental conditions and/or external forces, which adversely effect conventional prosthetic designs.³

Residual Limb – The remaining limb after amputation.⁴

Supracondylar – This is an area just proximal to the femoral condyles which can have significant pressure applied for suspension of the transtibial (below-knee) prosthesis.



Supracondylar/Suprapatellar (SC/SP) or PTS – In addition to the suspension of a transtibial prosthesis proximal to the condyles, the area proximal to the patella also can be compressed to provide additional suspension and to provide control to prevent hyperextension.

Temporary Prosthesis – An artificial limb designed for the evaluation and training of a new amputee. It consists of a plastic socket attached to modular components that have alignable features. Temporary limbs are worn the first few months following amputation, until the residual has matured. Components can be adjusted or changed, until optimal function is achieved.³

Terminal Device – Artificial hands or hooks designed for use with upper limb prostheses.²

Total Contact – The total contact prosthetic socket is designed to provide minimal distal end contact to prevent edema.

Total Surface Bearing (TSB) – This design allows for the entire residual limb to be in contact with the prosthetic socket. The loading on tolerant tissue is greater than the loading on sensitive tissue.

Trim line – This is the proximal edge of a prosthesis. This can vary according to the type of socket design used.

Visual Cue – This is the ability of the upper limb amputee to see the object they are attempting to pick up with the terminal device.

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7. PROSTHETICS – ADMINISTRATIVE ISSUES

AMPUTEE CLINIC TEAMS AND ARTIFICIAL LIMBS by Fred Downs

Introduction

Artificial limbs are custom-made medical devices which require a prescription before they can be provided to a veteran. Since they are not available “off the shelf,” this process does not involve simply writing a product name, dimensions and instructions on a slip of paper to take to the pharmacy or other provider. In the Department of Veterans Affairs, artificial limbs are provided to amputees through the prescription process established by an Amputee Clinic Team. The entire process is described in the VHA Handbook Chapter 3, titled “Amputee Clinic Teams and Artificial Limbs,” which is included as **Appendix 9C**.

Amputee Clinic Teams

The Handbook establishes uniform and consistent, system-wide procedures in conducting amputee clinics and providing artificial limbs to amputee veterans. The administrative processes described in the Handbook cover the basic functions of the clinic. It is important to realize that the clinic is much more than the place where the prescriptions are written and the artificial limbs are fitted. All Amputee Clinic Team members are acutely aware of the importance of the personal perceptions of the amputee as the patient proceeds through the Amputee Clinic Team procedures. The Amputee Clinic Team is one of the crucial elements in helping the amputee through another difficult stage of adapting to life as an amputee. The team can be the key to the successful fitting of an artificial limb to an amputee.

The Amputee Clinic Team should be flexible in membership and be adjusted to meet local needs. A physician who is knowledgeable about artificial limbs always should chair the team. A prosthetist, physical therapist and others may make up the rest of the team. The chairman always should introduce the members of the team and their role. If there are students attending the session, they, too, should be introduced.

Amputation Clinic Team Functions

The Amputation Clinic Team provides evaluation, education and support during the entire process. The first time an amputee goes before the Amputation Clinic Team, the patient needs to be made to feel comfortable with the team. The patient should receive an explanation of what is going on, why the process is important and what the patient needs to do to help the team write a good prescription. The team should ask the patient questions about him/herself, activities and expectations. The patient’s loved ones should be invited to the clinic so they can listen, learn and ask questions.



It often is said that the patient is an important member of the team. However, it also must be remembered that the patient is the only member of the team who has not been trained in the patient's role as team member. The patient is not there by choice and the patient probably is apprehensive about everything concerning an artificial limb. In all probability, the patient has never seen an artificial limb. The patient certainly will not understand how it functions. The artificial limb will seem very alien to him/her. The patient's thoughts will be in turmoil as the patient contemplates the fact that the patient will have to wear a mechanical device, a cold "thing" made of metal and plastic. Something ugly will be part of the patient's body for the rest of the patient's life. The patient's instincts will be to reject wearing a limb. The leg amputee, of necessity, usually quickly accepts the fact they must have a limb if they are to become mobile. A bilateral arm amputee also recognizes the necessity of having artificial limbs if they are to be independent. However, if the unilateral arm amputee is not quickly fitted within a "Golden Period," 60 to 90 days after amputation, the patient will learn to be independent with one arm and the chances of successfully fitting the patient with an arm diminishes rapidly after the Golden Period.

Some amputations are very difficult to fit with limbs that are useful. Hip or shoulder disarticulations are two examples where the bodies' tolerance for pressure or gadgetry is low and expenditure of body energy to move the limbs becomes a burden for the amputee. However, in all cases, the amputee should be the one to make that decision. The Amputee Clinic Team should write the best prescription they can, and be prepared to be creative in designing the most appropriate limb for the amputee.

The new amputee feels very vulnerable. He/she does not want to be treated like "a piece of meat." The patient needs to be treated with dignity and respect. The physiological trauma of losing a limb is similar to what one experiences when diagnosed with a fatal disease. The amputee goes through the stages written about by Dr. Kubler-Ross in her book on the stages of dying. First there is denial, blame, anger, sorrow and finally acceptance. Each stage takes time. Some people pass quickly through the stages, while others may take days, weeks or perhaps months to reach acceptance. Of course, there are a few who never reach acceptance. The Amputee Clinic Team should be aware of these stages, so they are better able to assess the amputee.

After the prescription is written, the limb will be fabricated in a VA Prosthetic Shop or by a contract vendor. The amputee is fitted and adjustments made over the course of one or two visits in most cases. The Amputee Clinic Team will check to ensure the prostheses was fabricated to their prescription and it is appropriate for the patient. The first limb for an amputee is considered a temporary limb that the amputee will wear while learning to use the limb and to allow time for the residual limb to stabilize, which may take months. Depending upon the condition of the stump and the health of the patient, the amputee can be up and learning to walk within a



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60

month or so after amputation. The temporary socket will be replaced by the prosthetist as the stump shrinks. When the stump has stabilized, the final socket is fabricated and the amputee again will come before the Team for a final check. If the amputee likes the limb's fit and is satisfied, the team will sign off on it and the vender is paid. If the amputee is not satisfied, the prosthesis must be sent back to the prosthetist to redo until the amputee is satisfied.

Melding the artificial limb to the human body is an art and it takes an artist to do it well. The Amputee Clinic Team is the judge of the artist's work.



8. PRIMARY CARE ISSUES RELATED TO VETERANS WITH TRAUMATIC AMPUTATIONS

by Vic M. Malabonga, M.D.

The primary care practice of VHA clinicians may include the care of veterans who have suffered traumatic amputations from explosive munitions. The accepted standards of medical care for the general population apply equally to traumatic amputee veterans, including the VHA Prevention Index and clinical practice guidelines.¹ There is evidence in the medical literature that victims of explosive war injuries that lead to lower limb amputation are predisposed towards certain medical conditions. In this chapter, we shall review the studies that have brought this to light.

In 1979, Hrubec and Ryder presented a report to Congress on a National Academy of Sciences study of more than 12,000 American combat veterans with traumatic war injuries.² They found a greater number of deaths from ischemic heart disease (IHD) among the proximal lower limb amputee veterans, compared to distal amputee veterans and veterans with disfiguring scars as a result of their injuries. The greatest frequency of IHD-related deaths was found among bilateral above-knee amputee veterans (BAKA), where the incidence was 3.5 times that of non-amputated veterans with disfiguring scars. In a study of 4,738 Finnish World War II amputee veterans, Bakalim did not find any difference in mortality rates, compared to the general population.³ However, there was a 63.1% greater death rate from cardiac and vascular diseases among the amputee veterans. Vollmar et al., looked at 329 German World War II traumatic lower limb amputee veterans and found an increased incidence of abdominal aortic aneurysms (5.8%) among the amputee veterans, compared to veterans without amputations (1.1%).⁴ This study did not find a higher incidence of coronary artery disease (CAD) or peripheral vascular disease in the amputee population.

A number of studies were conducted subsequent to the report of Hrubec and Ryder in an attempt to identify factors contributing to the increased incidence of IHD among traumatic amputee veterans (TA). Yekutieli et al., studied Israeli veterans of the Middle East Wars with spinal cord injuries and traumatic lower limb amputations.⁵ They found an excess incidence of IHD and diabetes mellitus among the TA, but no difference in the incidence of hypertension (HTN). Rose et al., studied 31 Vietnam War veterans with TA and found a higher incidence of HTN among veterans with BAKA (47.4%) compared to those with unilateral below-elbow amputations (8.3%).⁶ Moreover, the BAKA with HTN in this study were noted to be significantly more overweight and markedly hyperinsulinemic, with reduced glucose tolerance.

A related study of the same cohort by Rose et al., found that there was a strong correlation of the percentage body fat of the study population with the systolic and diastolic blood pressure.⁷ They found the blood pressure elevation to have a strong and independent relation to body fat



and insulin levels. Modan et al., looked at 201 Israeli veterans of the Middle East Wars with traumatic lower limb amputations.⁸ These veterans also were found to be hyperinsulinemic with increased blood coagulability. In contrast to the findings by Rose et al.,⁶ Modan and her group did not find a higher incidence of HTN or obesity among the TA in their study. They ascribed this discrepancy to the difference in numbers of BAKA between the two study cohorts. Studies by Loos⁹ and Solonen et al.,¹⁰ also failed to show any higher incidence of HTN among traumatic amputee veterans.

An interesting finding of the study by Hrubec and Ryder was the early increase in mortality among veterans in the 31 - 44 year age group, where the early deaths were noted 11 - 20 years after the injury. This suggests that the pathologic process that led to accelerated atherosclerosis was probably triggered not long after the injury was sustained. Rose et al., mentioned an unpublished survey by their group of 119 Vietnam War veterans with BAKA which showed that 25% of them became obese and hypertensive within one to two years of discharge from the military hospital.⁷ A study by Kurbidaylo found a significant correlation of obesity with the level of amputation.¹¹ Obesity is an independent risk factor for the development of cardiovascular disease (CVD).¹² In the final report of the Pooling Project, the authors reported that the risk attributed to obesity in relation to CVD is greatest in the 40 - 49 year age group.¹³ It is possible that the early accumulation of excess body fat shortly after the war injury is one of the factors leading to an accelerated atherosclerotic process among traumatic lower limb amputee veterans.

Several studies noted the sedentary lifestyle of amputee veterans.^{5,7,11} Independent of a predisposition to obesity, reduced physical fitness has been implicated as a risk factor for CVD and primary cardiac arrest.^{14,15,16} Yekutieli postulated that the stress of the war injury, as well as the drastic changes in lifestyle could have led to the increased incidence of IHD among amputee veterans.⁵ Hrubec and Ryder also implicated sedentary lifestyle and increased emotional stress as factors of importance in the increased risk of CVD among traumatic lower limb amputee (TLLA) veterans in their study.² Kurbidaylo reported in his study that a regular exercise program among amputee veterans was needed in order to promote increased physical activity.¹¹ It is likely that both obesity and reduced physical fitness are significant contributors to the predisposition of TLLA to ischemic heart disease.

Some studies have reported a biochemical predisposition of TLLA to cardiovascular disease. Hyperinsulinemia is a known predictor for development of IHD.^{17,18} The study by Rose et al.,⁶ and Modan et al.,⁸ were able to demonstrate the presence of hyper-insulinemia among TLLA. In addition, Modan documented an increased mortality of traumatic amputee veterans from CVD in association with increased insulin levels and increased blood coagulability. Various hemostatic factors have been implicated in the pathogenesis of IHD.¹⁹ It is possible that these biochemical alterations contribute to the increased incidence of IHD among traumatic lower limb amputee veterans. Interestingly, alterations in the lipid profile have not been found to be different between TLLA and control groups.^{6, 8}



Summary

Veterans with traumatic lower limb amputations have a higher incidence of ischemic heart disease, especially among bilateral above-knee amputee veterans. In addition, they also have a predisposition to being overweight with reduced physical fitness. Hyperinsulinemia and increased blood coagulability appear to be more common among those with TLLA, which could contribute to the increased risk of IHD in this population. Traumatic lower limb amputee veterans, especially BAKA, have been reported to be at increased risk for abdominal aortic aneurysms. There is no conclusive evidence that traumatic amputee veterans are more prone to develop hypertension or diabetes mellitus. For the primary care providers, it will be important address the cardiovascular risk factors that are present in their individual traumatic amputee patients and to determine if the patient can benefit from a regular exercise program. Vigilant application of the VHA Prevention Index measures and clinical practice guidelines is an essential intervention in this patient population.

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9. APPENDICES

APPENDIX 9A.

ENERGY COST OF AMBULATION IN HEALTH AND DISABILITY: A LITERATURE REVIEW

Summary prepared by: Michael Howe, M.S.L.S.

Reference: Archives of Physical and Medical Rehabilitation. 1978 Mar; 59: 124-133.

Authors: Steven V. Fisher, M.D. and Glenn Gullickson, Jr., M.D.

This paper attempts to summarize the current knowledge of the measurement of the energy expenditure (E_e) of ambulation by normal subjects and for different disabilities. Ambulation essentially involves a translation of the body's center of gravity through space along a pathway requiring the least E_e . In this paper, E_e is spoken of in terms of kcal/min and/or kcal/m.

Normal Ambulation

A review of the literature noted that the gross E_e /unit distance walked at speeds of 60-80 m/min varied little, but was least at speeds of about 80 m/min. No significant correlation was found between age or height and E_e , but weight, sex and speed of walking were important factors

Lower-Extremity Amputations

These amputations are probably the most studied disability in terms of energy requirements of ambulation, but the published data on energy cost of walking at different levels of amputation, or even at the same level of amputation, are difficult to compare and summarize because of the small numbers of subjects, varied speeds of walking and variations in experimental procedures.



Symes Amputee Veterans

When 13 Symes vascular-problem amputee veterans were studied, the investigator found that their average speed of walking was 34% less than that of normal controls and that they expended 31% more kcal/m/kg at the slower speed.

Below-Knee (BK) Amputee Veterans

Reitemeyer reported that two young adults with unilateral BK amputations walked 14% slower than normal persons and used 28% more E_e /unit distance when they walked at that speed.

In Ralston's study of the energy cost of locomotion at various speeds of two BK amputee veterans, the E_e (kcal/unit distance) was within the range for normal subjects, although in one it was at the upper limit. The author concluded that the E_e /step is substantially higher in the amputee; however, when the amputee is allowed to choose his rate, the E_e /min is similar in the amputee and a normal subject.

In reporting a treadmill study at speeds of from 50-90 m/min in BK amputee veterans, all but a few of whom were disabled because of trauma, Molen stated that at all speeds, they expended an average of 20% more kcal/min than normal subjects walking at the same speeds.

Burnin and Passmore reported that BK amputee veterans have a 10% increase in E_e (kcal/min) over normals when both walk at speeds of 70-83.3 m/min.

Gonzalez and associates studied nine BK amputee veterans and the average comfortable walking speed was 64.4 m/min, or 22% slower than the normal controls, but the E_e /min was the same for BK amputee veterans and normal subjects, although the amputee walked slower than the normal subject.

In Waters' 1973 study of 13 vascular and 14 traumatic BK amputee veterans, while the E_e /min for these amputee veterans and normals was the same, the vascular amputee's speed of walking was 41% less than the normal's and the amputee expended 55% more kcal/m/kg at that speed. The traumatic amputee veterans' speed of walking was 13% less than normal and they expended 25% more kcal/m/kg at that speed.

Above-Knee (AK) Amputee Veterans

Muller and Hettinger measured the E_e in three subjects fitted with 11 types of prosthetic knees and found that the AK amputee used 38% more E_e /unit distance than a normal person walking at the same speed. A decade later, Inman and associates reported that an AK amputee optimally



walked 20% slower and used 30% more E_e /unit distance than a normal subject who walks at his own natural, comfortable walking speed.

The results of another study showed that at speeds of 60, 67, and 80 m/min, the E_e /unit distance for AK amputee veterans when compared to normal subjects walking at the same speeds was increased by 37, 40, and 51%, respectively.

Seventeen AK amputee veterans over 50 years of age had an average walking speed of 28.2 m/min (62% less than the natural walking speed for normal adults), and their E_e was stated to be 55% greater than that of normals.

Ganguli's group described six AK amputee veterans aged 21 to 34 years in comparison with 16 normal adult males, finding that both groups walked 1 km at the previously established speed of 50 m/min. Both groups walked the same distance at the same speed and a 100% increase in E_e occurred both in terms of kcal/unit distance and kcal/unit time of AK amputee veterans, compared to normals walking at the same speed.

Traugh studied nine AK amputee veterans and found that their average walking speed was 53% slower than the comfortable walking speed of normal adults. The AK amputee veterans used 65% more E_e /unit distance at that speed than normal subjects walking at their own comfortable walking speed.

In James' report, 37 AK amputee veterans walked 30% slower than normals. At this, their most efficient speed, the E_e /unit distance of these amputee veterans was on average 40% more than a normal subject at his normal walking speed. Their E_e /unit time, however, was the same as that of the normal controls.

In a study of 13 vascular and 15 traumatic AK amputee veterans, vascular amputee veterans walked 66% slower than normal controls and expended on the average 120% more kcal/m/kg at that speed. The traumatic AK amputee walked 37% slower than the normal control speed and expended 53% more kcal/m/kg. Unlike the BK amputee, the vascular AK amputee could not slow down enough to lower his kcal/min E_e to the level normal persons expended at their most efficient speed.

Assistive Devices

In Inman's group study of forearm crutches, the amputee's natural or optimal speed of walking with forearm crutches was 40% slower and required 70% more kcal/unit distance than walking by a normal person. The forearm crutch user walked about 33% slower than did a prosthetic user and utilized approximately 40% more kcal/unit distance.



In contrast, Erdman and co-workers compared underarm crutch walking of AK amputee veterans with prosthetic walking of these amputee veterans and concluded that no significant difference in E_c was demonstrated between the two methods of ambulating.

Trough's group found that axillary crutch ambulation required 6% less E_c /min overall when compared to the prosthetic AK amputee's ambulation. Waters found that the E_c /min was less in all groups of amputee veterans when using a prosthesis than when using crutches, with the exception of the vascular AK amputee.

Ganguli compared normal ambulators and the E_c in 10 AK amputee veterans using axillary crutches. The axillary crutch ambulation of the amputee required 46.5% more kcal/min than normal ambulation at the same speed. In another report, he studied the AK amputee using a prosthesis. A combination of his two studies indicated that walking at 50 m/min with a prosthesis requires 35% more E_c /unit time than axillary crutch ambulation at the same speed.

McBeath and associates, however, comparing the effects of forearm and axillary crutches on the energy requirements of ambulation using normal adults, found that both types of crutches required about the same amount of E_c /min for a swing-through gait. Both were most efficient at approximately 70 m/min.

Hemiplegics

In a study with three hemiplegics, Bard and Ralston reported that one had considerable return of function and her E_c /unit distance was less than that of normals up to a speed of 73 m/min; a second, requiring a brace and cane, could walk only at 28 m/min; however, his E_c /unit distance fell within normal limits; a third patient, who also required a cane, walked at 49 m/min and utilized 25% more E_c /unit distance than normal persons.

In a later study, Bard found that severely spastic patients required more E_c /unit distance than normal persons, the moderately spastic required the same amount of energy as normals, and the minimally spastic required less energy than normals.

Corcoran and associates studied 15 hemiparetic patients without an orthosis and with both plastic and metal drop-foot, short-leg orthosis. The average comfortable speed without bracing was 41 m/min, or 46% slower than the 83 m/min comfortable walking speed for normals. The hemiparetic used 64% more E_c /unit time at this speed than did the normals at the same speed. With either metal or plastic bracing, the speed of walking improved 17% to 49 m/min and the E_c /unit time also was significantly reduced from 10% to 13%.



Gersten and Orr measured external mechanical work, using accelerometric records of 15 hemiplegic patients, noting a 100% increase in E_e /unit distance in hemiplegics as compared to normals.

Paraplegics

More of the determinants of gait are lost in paraplegics than in amputee veterans or hemiplegics and one would, therefore, expect their energy cost of ambulation to be higher and this is the case. It has been shown that the proper prescription of braces in paraplegia reduces energy consumption. The use of anterior ankle stops, as well as trunk support for high paraplegics has been emphasized. However, no matter how well prescribed and fitted the braces, a severe loss of function will still exist and, therefore, the E_e of ambulation is very large.

Wheelchair Locomotion

Wheelchair locomotion offers an alternative to ambulation and a linear relationship exists between speed of wheelchair locomotion and E_e .

Glaser and colleagues studied nine able-bodied males, both walking and propelling a wheelchair at 53, 70 and 83.3 m/min. The E_e propelling the wheelchair at each of these speeds was not significantly different from that of walking. Traugh found the wheelchair locomotion required 9% more kcal/min than normal ambulation. Therefore, wheelchair locomotion seems not only to be safe, but also to require approximately the same energy as normal ambulation.

Conclusions

Since the disabled person, like the normal subject, tends to choose his most efficient speed of ambulation, it seems appropriate to let the subject pick his own speed, instead of imposing an unnatural speed of walking for the researcher's convenience. Some general conclusions can be drawn from the averaging of the results of studies in which the subjects did choose their own speed. However, the results given should be taken as approximations and generalizations.

1. The normal person walks 83 m/min and expends 0.063 kcal/min/kg and 0.000764 kcal/m/kg.
2. The average BK amputee walks 43% slower, and expends five% less kcal/min and 89% more kcal/m than the normal person.



Traumatic Amputation And Prosthetics



3. The hemiplegic walks 46% slower and expends 16% less kcal/min and 63% more kcal/m than normals.
4. Normal and disabled persons naturally attempt to walk at a speed which is most efficient in terms of E_e /kcal/min.
5. Disabled persons decrease their speed of walking, so that their E_e /kcal/min decreases toward the normal range.
6. The more disabled a person, the more determinants of gait are lost; therefore, the more E_e /unit distance is used in ambulating and the less efficient is the gait.



APPENDIX 9B.

LONG-TERM FOLLOW-UP STUDY OF BILATERAL ABOVE-THE-KNEE AMPUTEES FROM THE VIETNAM WAR

Summary prepared by: Michael Howe, M.S.L.S.

Reference: The Journal of Bone and Joint Surgery. 1999 Oct; 81-A(10): 1384-1390.

Author: Lieutenant Colonel Paul J. Dougherty, United States Army Medical Corps

Background

Amputation for battle casualties is carried out in two stages: (1) the goal of the first stage is to prepare the patient for safe transportation by removing dead tissue, allowing for wide drainage of the residual limb and preserving length, and (2) the goal of the second stage is to prepare the residual limb for a prosthesis of the appropriate length and shape. This study is the first to document the long-term outcome for patients who sustained a bilateral above-the-knee amputation during battle and were managed for this unusual injury at an Army General Hospital that provided specialty care for amputee veterans. It also is the largest series of bilateral above-the-knee amputations that has been documented.

Materials and Methods

A review of the records of 484 battle amputee veterans who were patients at Valley Forge General Hospital during the Vietnam War identified 30 patients (six %) who had sustained a bilateral above-the-knee amputation. After informed consent had been obtained, a survey consisting of a questionnaire (specifically designed for this study) and the Short Form-36 (SF-36) Health Survey were administered. The responses of the patients on the SF-36 were compared with those of a group (145 individuals) of age and gender-matched controls who had completed the SF-36 as part of the National Survey of Functional Health Status in 1990.

Results

Twenty-six patients (87 %) had been injured by an unconventional land mine or booby trap; three (10 %) by artillery or mortar fire; and one (three %), by multiple bullets that had been fired from a machine gun. Fifty-three (88 %) of the sixty lower extremities had a partial or complete traumatic amputation that was treated with debridement and completion of the



stump as the initial operative procedure. The other seven lower extremities (12 %) were amputated secondarily because of infection. Although it is recommended that skin traction be applied at the time of the initial operative treatment and continued throughout the evacuation chain, this protocol was used for only 26 (43 %) of the 60 residual limbs. All of the residual limbs were placed in skin traction once the patients reached the Valley Forge General Hospital. The patients were fitted for pylons or stubbies as soon as possible, so that they could begin gait-training. The 23 patients (77 %) for whom such data were available were fitted for these devices at an average of 8.3 weeks (range, three to 20 weeks) after the injury. Staff encouraged patients to bear increasing weight on the extremities. After the wounds had closed and edema had subsided, the patients were fitted for permanent prostheses. The 17 patients (57 %) for whom such data were available were fitted for permanent prostheses at an average of 6.4 months (range, six weeks to 14 months) after the injury.

More than one-third of the 23 respondents in the present study reported that they continued to use prostheses with some regularity, and 10 respondents (43 %) reported that they had used prostheses for walking for an average of 12.9 years after they had been fitted. Walking with use of prostheses may have become more difficult as the patients gained weight or sustained injuries of the shoulder. Seventy percent of the respondents were or had been employed outside their homes. The physical functioning seen on the SF-36 questionnaire was significantly lower than the comparison group, but no statistically significant differences could be detected with respect to physical role functioning, body pain, general health, vitality, social functioning, emotional role functioning, or mental health.

Discussion

Previous military conflicts demonstrated that amputee centers were needed in order to consolidate the skills of surgeons, prosthetists, nurses and therapists. During the Vietnam War, the Wound Data and Munitions Effectiveness Team studied approximately 5,000 casualties and found that 14 of 19 patients who had sustained a bilateral above-the-knee amputation died before hospitalization, despite prompt medical care and timely evacuation.

Most bilateral above-the-knee amputations noted in the study summarized here were caused by unconventional land mines and booby traps or by weapons fabricated from locally available materials or from another piece of ordnance, such as a cannon shell. A psychiatrist assigned to the Valley Forge General Hospital described three phases of treatment: (1) stabilization and wound-healing, during which patients were taught and encouraged to change their own dressings, (2) walking with use of prostheses, and (3) transition to outpatient status.



Because of lack of practice, it is unlikely that the reality of rehabilitation at Valley Forge General Hospital could be equaled at a military facility today. Caring for patients who have sustained an amputation during battle is a discontinuous practice in the military. Documenting the stages in the rehabilitation process is essential for facilitating the inevitable relearning process that is forced on each generation of orthopaedic surgeons who must care for such patients. The fact that graduate medical education programs in orthopaedic surgery have de-emphasized amputee care further increases the need for learning.

Two courses of action could help to minimize the learning curve in future conflicts. The first component is the assignment of military medical personnel to Department of Veterans Affairs hospitals so that they can gain experience in working with amputee veterans. The second component is the rotation of military medical personnel to hospitals in regions where large numbers of patients are injured by residual land mines, such as Asia, Africa and the Balkans, so that military surgeons can gain experience in the treatment of amputations.

Future research should be directed toward preventing death on the battlefield by improving local resuscitative measures that can be applied immediately after soldiers are wounded. Efforts should be made in other areas as well. For example, because most patients who have sustained a bilateral above-the-knee amputation use a wheelchair for moving about, prosthetics research should be directed toward providing a more energy-efficient means of locomotion that duplicates normal gait as much as possible.

This study has several limitations. First, a comparison of the responses of the patients in the study group with those individuals who were managed for a bilateral above-the-knee amputation at other military hospitals during the Vietnam War would have provided an excellent basis for conclusions. The second limitation is related to the image of heroism associated with the type of injury in the military setting. The third limitation of this study concerns the question of whether the SF-36 is appropriate for the assessment of amputee veterans.

Wartime amputations remain an important clinical problem for the United States Army Medical Department. Veterans who have sustained a bilateral above-the-knee amputation have one of the most challenging types of injuries not often seen in civilian practice, but this study provides evidence that those who have sustained a bilateral above-the-knee amputation on the battlefield are not automatically condemned to live with severe physical and emotional difficulties. The patients in this long-term, follow-up study have led relatively normal, productive lives within the context of their physical limitations.



APPENDIX 9C.

Department of Veterans Affairs
Veterans Health Administration
Washington, D.C. 20420

VHA HANDBOOK 1173.3
Transmittal Sheet
November 2, 2000

AMPUTEE CLINIC TEAMS AND ARTIFICIAL LIMBS

- 1. REASON FOR ISSUE:** This Veterans Health Administration (VHA) Handbook updates the previous procedures for the Department of Veterans Affairs (VA) in administering amputee clinic teams and providing artificial limbs to veteran beneficiaries.
- 2. SUMMARY OF CHANGES:** This Handbook updates current policies and procedures.
- 3. RELATED ISSUES:** VHA Directive 1173, and VHA Handbooks 1173.1 through 1173.15.
- 4. RESPONSIBLE OFFICE:** The Chief Consultant, Prosthetic and Sensory Aids Service Strategic Healthcare Group (113), is responsible for the contents of this VHA Handbook. Questions may be referred to 202-273-8515.
- 5. RESCISSIONS:** VHA Manual M-2, Part IX, Chapter 2 and Chapter 6 are rescinded.
- 6. RECERTIFICATION:** This document is scheduled for recertification on or before the last working day of July 2005.

Thomas L. Garthwaite, M.D.
Under Secretary for Health

Distribution: **RPC: 0005**
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AMPUTEE CLINIC TEAMS AND ARTIFICIAL LIMBS

1. PURPOSE

This Veterans Health Administration (VHA) Handbook establishes uniform and consistent system-wide procedures in conducting amputee clinics and providing artificial limbs to amputee veterans.

2. AMPUTEE CLINIC TEAMS

a. Purpose

(1) Amputee Clinic Teams provide treatment for amputee veterans. These clinics perform the following; they:

(a) Examine VA beneficiaries requesting or requiring major prosthetic appliances.

(b) Determine that an appliance is no longer serviceable and should be replaced.

(c) Conduct closely controlled clinical evaluations on new techniques or componentry under policies and procedures announced by the Chief Consultant, Prosthetic and Sensory Aids Service Strategic Healthcare Group (SHG).

(d) Inspect and evaluate new prostheses.

(e) Conduct follow-up examination and treatment of beneficiaries who have received prescriptions through the clinic team.

(2) Amputee Clinic Teams are established in selected field facilities under the supervision of a physician who is knowledgeable about prosthetics and physical disabilities.

b. Responsibility

(1) The Chairman, Amputee Clinic Team, will be charged with the direct responsibility for the treatment of all patients referred to the team. The Chairman will normally serve on an attending or consultant basis and will be appointed by the Chief of Staff.

(2) The Chief, Prosthetic and Sensory Aids Service, at a facility in which an Amputee Clinic Team is located, will be responsible for the overall administrative management of the



team. The prosthetic manager serves as coordinator, technical advisor, and designee to inspect and evaluate all appliances prescribed by the Clinic.

(3) The organization of the Amputee Clinic Team will remain flexible and be adjusted to meet local needs. Members may include physicians from Orthopedics, Vascular, Physical Medicine and Rehabilitation Services, a podiatrist, physical therapist, the Preservation Amputation Care and Treatment (PACT) coordinator, a Department of Veterans Affairs (VA) and/or a commercial prosthetist, and other medical specialists as required. No more than one qualified prosthetist from each local commercial provider with a limb contract will be invited to participate in the clinic meetings. **NOTE:** *Every effort will be made to limit the size of the clinic team to a maximum of eight people.*

(4) All assignments of VA personnel to Amputee Clinic Teams will be in addition to other duties.

(5) The Amputee Clinic Team will orient and train medical residents who have an interest in prosthetics.

c. Procedures

(1) Beneficiaries requiring artificial limbs will be referred to the nearest Amputee Clinic Team when:

(a) Residing within the Prosthetic Primary Service Area (PSA) of the facility in which the clinic team is located.

(b) Residing within the PSA of another VA facility which does not have an Amputee Clinic Team or has been unable to resolve the patient's prosthetic problem.

(c) Determined to be a good candidate for a special or experimental type appliance which may only be prescribed by the team.

(2) Hospitalized or domiciled beneficiaries may be referred to Amputee Clinic Teams at other facilities after appropriate arrangements have been made with the prosthetic representative of the facility in which the team is located. In such cases, a brief review of the beneficiary's problem, the local medical recommendation, and the objective expected to be accomplished will be provided.



d. Scheduling of Appointments and Preparation of Records

(1) The Prosthetic Representative of each Amputee Clinic Team will arrange appointments for veterans to appear before the Clinic team. A Veterans Health Information Systems and Technology Architecture (VISTA) appointment management entry will be established for each patient scheduled with the Amputee Clinic.

(2) Field facilities referring patients to the Clinic team will request appointments by use of consult (Standard Form 513, Medical Record – Consultation Sheet) or VA Form 10-2529-3, Request and/or Receipt for Prosthetic Appliances or Services.

e. Conduct of Clinic Team Meetings

(1) The patient will be treated with courtesy, respect, and empathy. The patient's personal preferences will be solicited and considered before a final decision is made.

(2) Before each patient is called for examination, a brief verbal summary of the case for the benefit of the members of the team and any medical residents who may be attending as observers will be presented. This summary will consist of:

- (a) The patient's name;
- (b) The patient's age;
- (c) The patient's disability and current occupation;
- (d) The type, age and condition of prosthesis being worn;
- (e) Previous major difficulties experienced with prostheses;
- (f) Reason for present examination, and
- (g) Recommendations when indicated.

(3) Each beneficiary will be carefully examined in a private room by the entire clinic team to assess the patient's needs. If a new or replacement prosthesis is indicated, the advantages of new technology will be fully explained to the patient. However, if a patient has worn or used a particular type of appliance for several years without difficulty, and wishes on an identical replacement, the patient's wishes will be honored unless there are definite medical contraindications.



(4) In amputee evaluations, the medical findings and recommendations of the clinic team, with a specific component prescription for an artificial limb or major repair, will be included in the patient's Consolidated Health Record (CHR). If additional treatment is indicated prior to prescription of the prosthesis, the provision of the limb will be deferred pending treatment outcome.

f. **Action Following Meeting of Clinic Team.** When the meeting of the clinic team is adjourned, the prosthetic representative will be responsible for the following actions:

(1) Upon receipt of the prescription and contractor selection, the veteran will be provided specific instructions regarding travel, delivery, training and follow-up. When pricing for the prescribed limb is not determined in the clinic, VA Form Letter (FL)10-90 (ADP), Request for Firm to Submit Estimated Cost of Prosthetic Appliance, or contractor's letterhead quote will be necessary before procurement can be completed.

(2) In the event that a beneficiary fails to appear for a scheduled appointment without contacting the clinic coordinator, the referring facility will be advised that the appointment was not kept and that a future appointment must be scheduled as though it were an original request.

(3) In the case of beneficiaries referred from other field facilities and examined by the clinic team, a Standard Form (SF) 509 Medical Record – Progress Note, will be prepared, in duplicate, and the original will be immediately forwarded to the facility from which the beneficiary was referred. The remaining copy will be retained for the clinic team file.

(4) Appliances or repairs prescribed by the clinic team will be obtained, inspected, evaluated and delivered in accordance with procedures outlined in this manual.

3. DEFINITIONS

AFMA Host Facility. A Prosthetic Referral Center equipped with AFMA technology and designated as a central fabrication center to fabricate sockets for other VA Orthotic Labs.

Artificial Limb Contract. A competitively bid contract locally awarded to preferred providers and used by VA personnel for the purchase of artificial limbs.

Automated Fabrication of Mobility Aids (AFMA). A process of fabricating and fitting artificial limbs using computer aided design and manufacturing.



Endoskeletal Prosthesis. Artificial limbs whose cosmetic and structural components are separate. Internal components are used to provide structural support and then foam is shaped to resemble the uninvolved side. Cosmetic hose or a “skin” is applied to provide color.

Exoskeletal Prosthesis. Artificial limbs whose cosmetic and structural components are combined. Wood or plastic is used to provide structural support and is then shaped to resemble the uninvolved side. A laminate is applied to the exterior of the shaped part to provide color and additional strength.

Non-contract Artificial Limb. A commercially available artificial limb, which is not on the current Artificial Limb Contract.

Permanent Prosthesis. An artificial limb used by amputee veterans whose residual limb has matured and the amputee has satisfactorily completed the temporary limb phase. The socket and components are manufactured to provide lasting durability and a proper cosmetic appearance.

Preparatory Prosthesis. This is the first limb a new amputee will wear. It consists of a plaster/fiberglass cast (applied during or shortly after surgery) and basic components which are easily removed. It controls swelling and protects the residual limb while allowing minimal (standing, touchdown weight-bearing) ambulation.

Prosthetic Sheath. A sock-like item made of synthetic materials manufactured in one thickness, which is worn over the residual limb to reduce abrasion.

Prosthetic Sock. A soft fabric that is applied directly to the residual limb and acts as an interface between the residual limb and the prosthetic socket. Socks are used to provide comfort, absorb perspiration, reduce irritation and re-establish proper fit of the socket. Prosthetic socks come in varying thicknesses called ply (usually from one to eight ply) and in varying materials (usually wool, cotton, nylon, or a blend of man-made materials). In addition, they are available with varying thickness of silicone gel impregnated into the fabric.

Prosthetist and/or Orthotist. An individual trained in mechanics and biomechanics to manufacture and fit custom or non-custom devices and assist physicians in prescribing these devices.

Recreational Prosthesis. An artificial limb that is specifically designed to permit the amputee to participate in a particular activity, e.g., swimming, skiing, running, etc., when a conventional prosthesis is not suitable. These prostheses are constructed in such a manner as to resist environmental conditions and/or external forces, which would adversely effect conventional



prosthetic designs.

Temporary Prosthesis. An artificial limb designed for the evaluation and training of a new amputee. It consists of a plastic socket attached to modular (alignable) components. Temporary limbs are worn the first few months following amputation until the residual limb has matured. Components will be adjusted or changed until optimal function is achieved.

Terminal Devices. Artificial hands or hooks designed for use with upper extremity prostheses.

VA Orthotic Lab. A VA facility employing at least one orthotist and or prosthetist equipped to provide custom mobility aids such as artificial limbs, orthotic devices, power or manual wheelchairs and non-custom items like cervical collars, elastic hose or crutches.

4. ARTIFICIAL LIMBS

a. Artificial limbs, components, parts and repairs will be procured, fabricated and issued to eligible beneficiaries upon prescription from a designated physician/podiatrist of the Amputee Clinic Team or the Prosthetic Representative in accordance with the policies and procedures outlined herein and in VHA Handbook 1173.1 and VHA Handbook 1173.2.

b. These appliances should be from commercial vendors where adequate facilities are available, the time required obtained for delivery is not excessive for patients, and the prices charged for such appliances are reasonable. VA Orthotic Laboratories with a prosthetist may also be used as a source in the fabrication of preparatory, temporary and permanent artificial limbs.

c. Eligible veterans, as identified in VHA Handbook 1173.1, who have previously received artificial limbs from commercial sources, will continue to have their choice of vendors on contract with VA or their non-contract prosthetist, providing the prosthetist will accept the VA preferred provider rate for the geographic area. VA facilities with Orthotic Laboratories, or facilities with access to a VA Laboratory, will provide new amputee veterans with the preparatory or temporary prosthesis and permanent limbs. When the patient has achieved appropriate shrinkage and is ready for a permanent prosthesis, the preparatory or temporary prosthesis will be replaced.

d. Terminal devices, i.e., hooks, hands, will be provided with replacement artificial arms. When a terminal device is prescribed, the selection of a particular type of hook and/or hand will be based upon a patient's lifestyle or vocational needs.

e. Recreational Artificial Limbs, which allow an amputee to participate in a specific recreational or athletic activity, may be provided. The following general guidelines should be followed whenever the issue of a recreational prosthetic appliance is contemplated:



- (1) The physician or podiatrist of the Amputee Clinic Team must prescribe the prosthesis.
- (2) The prescription must indicate the therapeutic, rehabilitative or psychological benefit to be expected or achieved through participation in this specialized activity.
- (3) The prescription must indicate that a conventional prosthesis which is worn daily is unsuitable for use in the recreational activity either because of environmental factors which would affect the prosthesis or because a specialized function not available in the conventional limb is required in the activity.
- (4) Frequently required prosthetic components (within the limitation of the storage area provided to the Prosthetic and Sensory Aids Department and the Orthotic Laboratories) will be stocked to expedite patient care.

5. VA SOURCE

a. The VA Artificial Limb Contract will be used as a primary source in custom fabrication for artificial limbs purchased for VA beneficiaries. However, fabrication may be from VA Orthotic Laboratories where adequate facilities are conveniently available and qualified staff is available to patients and prescribing physicians, the time required for delivery is not excessive or will not result in prolonged hospital stay for patients, and the prices charged for such appliances are reasonable.

b. Work for Other Stations

(1) Facilities with the AFMA remote system requiring the services of a VA Orthotic Laboratory AFMA host system must determine whether the desired appliance can be fabricated utilizing the AFMA system or if the beneficiary will be required to travel to the receiving station. The referring facility will confirm an appointment prior to sending a beneficiary to the laboratory in order to avoid delays and backlogs in the laboratory's production schedule. Orders will be processed on a first in/first out basis, regardless of origin.

(2) AFMA host facilities which fabricate sockets for distant facilities, where the patient will not be seen and is not in their VISTA system, will receive a VA Form 10-2529-3 from the referring station utilizing the remote order section of the electronic – 3 package. Reimbursement costs will be negotiated between the facilities and/or VISNs involved.



6. RESIDUAL LIMB SOCK

a. Residual limb socks, sheaths, and other socket interface products will be furnished to eligible amputee veterans, VA Orthotic Laboratories and VA medical centers by the Denver Distribution Center (DDC), Denver, CO.

b. Veterans residing in the United States (U.S.), U.S. possessions, or Puerto Rico will be furnished residual limb socks directly by initiating a request into the Remote Order Entry System (ROES) to the DDC, Denver, Colorado.

c. Veterans whose eligibility is based upon enrollment will be monitored biennially, and the DDC will be informed of any change. The ROES electronic order will be generated by the facility which has the responsibility of maintaining the veteran's VA Form 10-2319, Record of Prosthetic Service. The ROES order will be transmitted to the DDC on all initial cases and the VA Form 10-2319 annotated appropriately.

d. Veterans residing in a foreign country will receive direct mail orders through the local consular office of the U.S. State Department. VA Form 10-2345, Veterans Request for Residual limb Socks, will be provided with all issues for the purpose of ordering future supplies. Veterans should be advised that the VA Form 2345 must be mailed in an envelope with the necessary foreign postage when mailed through their postal service. Repairs to artificial limbs should be directed to the Health Administration Center, Denver, CO.

(1) Allied veterans residing in the U.S. or Puerto Rico. Issues will be made as indicated in preceding subparagraph 6a. The original or certified copy of the letter of authorization from the allied government must be on file at the DDC to indicate eligibility for continuing services.

(2) Residual limb socks may be stocked at VA facilities for issuance to eligible beneficiaries where there is an active amputee rehabilitation program requiring immediate access for post-operative and temporary limb fitting.

7. COMMERCIAL SOURCES

The local Artificial Limb contract will be used as the primary source for commercial procurement of limbs purchased for VA beneficiaries. Prosthetics representatives are responsible for compliance with the terms and conditions of this contract. They will perform inspections of contractor facilities. Any changes in qualified personnel, i.e., regarding certified prosthetists or VA qualified prosthetists, which occur during the contract year, will be reported to the contracting officer at the local facility.

a. Eligible veterans will be permitted to obtain authorized artificial limbs and/or terminal



devices from any commercial artificial limb dealer who is under a current local contract to the VA or the veteran's preferred prosthetist who agrees to accept the preferred provider rate. Such procurements are subject to the following restrictions and limitations:

(1) The artificial limb and/or components provided to a veteran will be limited to the type recommended by the prescribing physician. The physician's prescription will be specific as to the type of limb recommended and will include specific instructions as to the components to be used; e.g., type of knee joints, type of foot, etc. Any changes to the prescription, deemed necessary by the prosthetist, will be presented to the prescribing physician for approval.

(2) The veteran's choice of an approved contractor will normally be limited to those in the immediate geographical area.

(a) If the prescribed limb is not available from any of the local contractors, but is available under contract in a more distant city, the facility will take appropriate action in favor of the veteran and VA.

(b) If a veteran selects an approved contractor other than a contractor in the local geographical area, any travel costs incurred will be at the veteran's own expense. Exceptions will only be made in those instances when it is clearly indicated that it is in the best interest of both the veteran and VA.

b. All eligible veterans authorized permanent artificial limbs using a commercial contractor will be provided a current list of approved contractors in the immediate geographical area to assist them in their selection of a contractor. Included in this list will be the VA Prosthetic-Orthotic Laboratory when applicable. VA personnel will not direct, guide or prompt a veteran to go to a specific contractor except in those rare instances where a physician determines it to be necessary for the proper medical treatment of the veteran. A rotating contractor schedule will not be used as a method of selecting a contractor for the fabrication of a limb.

(1) The list of VA contractors (in alphabetical order) will be developed locally and include all contractors having a current VA contract which are located in the facility's area of prosthetic jurisdiction.

(2) Each list will contain the following statement in bold face type:

YOU HAVE THE RIGHT TO SELECT THE ARTIFICIAL LIMB CONTRACTOR OF YOUR CHOICE FROM ANY OF THE BELOW LISTED VA APPROVED CONTRACTORS. ANY ATTEMPT TO INFLUENCE YOUR DECISION, OR TO DIRECT YOU TO ANY PARTICULAR CONTRACTOR, SHOULD BE REPORTED TO THE DIRECTOR OF THIS FACILITY.



c. When the designated physician of the Amputee Clinic Team prescribes a limb not currently covered by a VA contract or if a veteran requests a qualified contractor not under a current contract, the limb may be approved locally, provided charges do not exceed the average discount price of preferred vendors. Appropriate non-contract components (which are commercially available) may be added to a contract limb and approved locally, provided the cost of the component does not exceed the dollar limitation stated in the current Health Care Financing Administration (HCFA) schedule plus the discount.

d. Veterans residing in Alaska, Hawaii, and San Juan may have a choice of contractors located within their respective states. Selection of a contractor located in the continental United States will be permitted only when the prescribed limb is not available from a contractor in the state where the veteran resides. The contractor selected will be located nearest to the principal point of entry within the 48 States. Veterans who (as a matter of personal preference) desire to select a contractor located at points more distant than those indicated above, may do so provided the dealer is under contract for the limb prescribed and the veteran agrees to any additional travel beyond the point of entry at no expense to the Government.

8. REPLACEMENTS

a. An artificial limb or prosthetic component (issued to an eligible beneficiary by VA) will be replaced after it is determined that the limb or component is no longer serviceable (due to fair wear and tear) or that physical changes of the beneficiary's residual limb renders the appliance unsuitable for further use. Appliances in serviceable condition will be used for as long as it is feasibly possible. Useful life through repair will always be investigated before a new appliance is authorized.

b. The determination of need for the replacement of a prosthetic appliance will be made and documented in the veteran's consolidated health record by the Chief, Prosthetic and Sensory Aids Service, based upon physical examination of the appliance for which a replacement is requested. The progress note will document that the appliance has been examined and is unsatisfactory for future use due to fair wear and tear, or that a replacement is necessary due to physical changes in the beneficiary's condition.

c. If a beneficiary claims that a prosthesis is lost or destroyed, or if it is determined by examination that the appliance has been damaged through other than fair wear and tear, the Chief, Prosthetic and Sensory Aids Service, may cause an inquiry to be made into the facts of the case. If findings indicate the appliance has been willfully damaged or destroyed, such appliance will not be replaced until the beneficiary receives adequate counseling.



9. SPARE ARTIFICIAL LIMBS

Spare artificial limbs and terminal devices may be furnished to eligible veterans after clinical determination of need in each case. Such determination will be based upon the environmental factors, where the veteran lives or works, the availability of repair facilities and the particular needs of the beneficiary concerned. It is not intended that the second prosthesis be in such a condition that it is suitable for constant use, but only that it be in sufficiently good condition for temporary use whenever the regular limb requires repairs.

10. REPAIRS

a. Commercial

(1) The procedures outlined in Handbook 1173.2 are applicable to the furnishing of repairs to artificial limbs and limb components.

(2) Repairs may be obtained through commercial sources with the authority of VA Form 10-2501, the Prosthetic Service Card, (PSC), not to exceed \$300, or VA Form 10-2421, ADP Prosthetic Authorization for Items or Services, when authorized by the Chief, Prosthetic and Sensory Aids Service, or designee.

(3) Prosthetic and/or orthotic appliances may be repaired if the cost of the repair is less than one-half the cost of replacement. The Chief, Prosthetic and Sensory Aids Service, or designee, will determine whether it is more practical, from an economic point of view, to repair or replace the appliance.

(4) A veteran wearing an artificial limb will be encouraged to have repairs and/or adjustments made to the appliance by the contractor or vendor who fabricated the item. If eligible for a PSC, the veteran should be encouraged to use the card whenever possible and practical.

(5) Whenever repairs or adjustments to an artificial limb or terminal device are required within 1 year after delivery of the item, care should be exercised to determine whether the repairs or adjustments are necessitated because of defective materials and/or workmanship. If so determined, the guarantee provisions of the contract or warranty period under which the item was procured will be enforced.

b. VA. VA Orthotic Laboratories may be utilized to furnish repairs to artificial limbs if adequate parts and qualified manpower are available. Procedures outlined in VHA Handbook 1173.2 and VHA Handbook 1173.6 will be followed.



Independent Study Test Questions for CME Credit

Using the **Independent Study Participant Registration/Answer Sheet**, please circle the letter corresponding with the correct answer.

1. What is the purpose of the Amputee Clinic Team?

- a) To evaluate the amputee patient for economic status
- b) To evaluate the amputee patient for prosthetic prescription
- c) To evaluate the amputee patient's social life
- d) To evaluate handicap parking at Rehabilitation Center
- e) None of the above

2. Which of the following statements is/are TRUE?

- a) Veterans with traumatic lower limb amputations have a higher incidence of ischemic heart disease.
- b) Traumatic lower limb amputee veterans have a predisposition to obesity.
- c) Traumatic lower limb amputee veterans tend to have sedentary lifestyles.
- d) All of the above.
- e) None of the above.

3. The type of traumatic amputation with the greatest reported risk for ischemic heart disease and abdominal aortic aneurysms is/are:

- a) Unilateral lower limb amputation.
- b) Distal upper extremity amputation.
- c) Bilateral above-knee amputation.
- d) All of the above.
- e) None of the above.



- 4. Which of the following statements about traumatic lower limb amputee veterans is/are TRUE:**
 - a) Traumatic lower limb amputee veterans tend to have reduced insulin levels.
 - b) Traumatic lower limb amputee veterans have been reported to have decreased blood coagulability.
 - c) There is no conclusive evidence that traumatic amputee veterans are more prone to develop hypertension.
 - d) All of the above.
 - e) None of the above.

- 5. Cardiovascular disease risk factors that traumatic amputee veterans could be exposed to include which of the following:**
 - a) Obesity.
 - b) Reduced physical fitness.
 - c) Hyperinsulinism.
 - d) All of the above.
 - e) None of the above.

- 6. Which of the following statements regarding post-operative residual limb care is TRUE?**
 - a) Narcotic medications are never required for pain control.
 - b) Knee and hip joints should be maintained in a flexed position.
 - c) Casts or rigid dressing are never used.
 - d) Activity and physical therapy is not started until the wound is completely healed.
 - e) Control of residual limb edema results in decreased pain and enhances wound healing.

- 7. During the prosthetic fitting and training period, the soldier with an amputation:**
 - a) Should not be allowed to interact with other amputee veterans.
 - b) Learns to recognize prosthetic fit problems and when to seek professional evaluation.
 - c) Will receive his definitive prosthetic device.
 - d) Is told that changes in body weight will not affect prosthetic fit and function.
 - e) Does not need vocational counseling, since the patient will be totally and permanently disabled.



8. A soldier who has sustained a transhumeral amputation of the dominant limb will:

- a) Learn to write with the prosthesis.
- b) Most likely return to active duty.
- c) Switch hand dominance.
- d) Be dependent on others for self-care activities, such as hygiene and dressing.
- e) Cannot drive a car.

9. Single digit amputations:

- a) Have no functional significance, regardless of which digit is lost.
- b) Do not require a prosthetic device, regardless of which digit is lost.
- c) Result in complete loss of prehension, regardless of which digit is lost.
- d) Are amenable to cosmetic restoration.
- e) Require switching of hand dominance regardless of which digit is lost.

10. The energy cost of ambulation is:

- a) Generally reported as energy expenditure per kilogram per minute.
- b) Dependent on the path taken by the center of mass of the body.
- c) Increases as the level of amputation moves more proximally.
- d) Increased for lower limb amputee veterans and compensated for by slowing walking speed.
- e) All of the above.

11. A 78-year-old veteran who sustained a transfemoral amputation in WWII presents to your primary care clinic for initial evaluation c/o difficulty walking. He gets short of breath and must stop to rest about every 200 feet. He feels that his previously satisfactory prosthesis is suddenly too heavy and too long. On initial examination you note that he has 3+ pitting edema of his remaining foot. Management should initially begin with:

- a) Referral to prosthetics service for a newer, lighter and shorter prosthesis.
- b) Tell the veteran he is just getting older and to adjust.



- c) Request an electric scooter for the veteran.
- d) Evaluate and treat causes of fluid retention.

12. A 55-year-old veteran with traumatic transtibial amputation presents to the primary care clinic three days after receiving a new prosthesis. He complains of ulceration over the end of his residual tibia. The veteran should:

- a) Have cleansing and debridement of the wound, as needed.
- b) Discontinue prosthetic use until the wound is healed.
- c) After the wound is healed, return to the prosthetist for modification of the new prosthesis.
- d) All of the above.

13. A 65-year-old sustained traumatic transfemoral amputation 40 years ago. He has had persistent but not bothersome phantom sensation since that time. Three weeks ago, he fell and had immediate onset of low back pain radiating to his phantom great toe. Pain is made worse by movement, coughing and sneezing. The best initial evaluation/management would involve:

- a) Prescribe dilantin for central pain syndrome.
- b) Refer to pain clinic.
- c) Refer to psychiatry.
- d) Investigate possible non-amputation related etiologies of pain, such as lumbosacral radiculopathy.
- e) Treat acute pain and investigate possible non-amputation related etiologies of pain, such as lumbosacral radiculopathy.

14. A 75-year-old transfemoral amputee has been ambulatory with a prosthesis since his injury in 1946. He was admitted with myocardial infarction, complicated by severe congestive heart failure and respiratory failure requiring ventilator support for several days. He has an ejection fraction of 25% and gets short of breath with stand pivot transfers. If his cardiac status does not improve, this patient:

- a) Has the same potential for ambulation as some one without an amputation.
- b) Will be able to walk as before, but will need a new, lighter prosthesis.
- c) Will be bed-bound.
- d) May be a candidate for a motorized wheel chair.

15. Select the statement that is FALSE. Neuromas:

- a) Occur every time a nerve is cut.



- b) Are always painful.
- c) Are best managed by prosthetic socket modification.
- d) May exhibit a Tinnel's sign.
- e) Symptoms may be treated pharmacologically with antidepressants, anticonvulsants and non-narcotic analgesics.

16. What were the principal causes of traumatic amputations during the Vietnam War?

- a) Aerial bombing and artillery.
- b) Rockets and mortars.
- c) Land mines and booby traps.
- d) Answers (a) and (b), but not (c).

17. What is the preferred surgical approach for performing amputations on the battlefield?

- a) Open circular
- b) Closed circular
- c) Convex triangular
- d) Immediate prosthetic implantation

18. Which of the following is/are important treatment practices, following battlefield amputations?

- a) Skin traction during evacuation
- b) Transportation casts
- c) Intravenous prophylactic heparin
- d) (a) and (b), but not (c)



- 19. Which of the following is/are benefits of early weight bearing, following a traumatic lower limb amputation and fitting with a hard plaster shell and pylon?**
- a) Faster redevelopment of a proprioceptive sense
 - b) Reduction of edema and swelling
 - c) Improved mental status
 - d) All of the above
- 20. Useful approaches to emotional support of the amputee may include:**
- a) Provide education about amputation to the patient.
 - b) Encourage patients to identify specific goals for their rehabilitation.
 - c) Obtain information from others who have experienced amputations.
 - d) All of the above.
- 21. Which of the following may be useful initial drug(s) for treating “phantom pain” following amputation?**
- a) Anticonvulsants
 - b) Low-dose tricyclic antidepressants
 - c) Intravenous morphine
 - d) Answers (a) and (b), but not (c)
- 22. How do amputees tend to view the severity of their problems, compared to rating by their spouses and the general public?**
- a) Worse
 - b) Better
 - c) About the same
 - d) Answers (a) and (b), but not (c)



23. How do lower limb amputees frequently adjust for increased energy expenditure associated with ambulation?

- a) Walk slower
- b) Use a wheelchair
- c) Walk faster
- d) Answers (a) and (b), but not (c)

24. How does the aging process often affect amputees?

- a) Frequently improves their impairment
- b) Frequently worsens their impairment
- c) Usually has no effect on their impairment
- d) Answers (a) and (b), but not (c)

25. The functional level of an amputee may depend upon:

- a) General physical condition.
- b) Presence or absence of cardiac, respiratory, vascular and visual problems.
- c) Motivation and support system.
- d) All of the above.

26. Lower limb prostheses may provide:

- a) Weight bearing.
- b) Balance and ambulation.
- c) Cosmesis.
- d) All of the above

27. Upper limb prostheses may provide:

- a) Prehension.
- b) Cosmesis.
- c) Movement and balance.
- d) All of the above.