New Developments in Prosthetics

Jeffrey Heckman, DO
Limb Loss Research and Statistics Program, 2008:
- 185,000 Americans undergo amputation each year.

Dillingham, 2002:
- 1,199,111 hospital discharges that involved amputation or congenital limb deficiency from 1988 through 1996
- 133,235 amputations per year
- 1996 annual rate of 52 amputations per 100,000 US population.
  - Upper limb amputation incidence rate was 5/100,000
  - Lower limb amputation incidence rate was 47/100,000
Prevalence of U.S. persons living with limb loss
- 1.6-1.8 million

Prevalence of U.S. persons living with SCI
- 259,000

3000 physiatrists surveyed

1 ½ times the number of Physiatrists specializing in the care of patients with SCI as there are specializing in the care of patients with prosthetic and orthotic needs.
Inpatient Rehab Consult
Inpatient Rehab Consult

- Education for patient, nurses and family
  - Post amputation dressing and management
  - Provide with materials, resources
  - Rehabilitation Team Approach

- Wound evaluation, ROM and strength testing

- PT/OT eval for assessment of self care/ ADLs, Bed Mobility, Basic Transfers, Mobility with assistive device

- Limit standing and hopping immediately post-op to avoid complications with falls and limit dependent edema
Inpatient Rehab Consult

- Post Operative Management Goals:
  - Control pain while managing constipation
  - Address psychological aspects of amputation and adjustment to disability, restore locus of control
  - Protect incision site and improve wound healing to allow for early prosthetic fitting and enable rapid return to function
  - Prevent joint contractures, bedside exercise program, pulmonary complications and pressure ulcers
  - Edema management and limb shaping
Edema management
Edema management
Ace Wrapping vs. Shrinker

- Ace wrapping preferred for the first few weeks, until sutures are removed
- Very dependent on proper technique
- Must be re-wrapped several times daily
- Shrinker is more appropriate after incision site has stabilized and started to heal
- Shrinker may be easier to use and less user-dependent
- Both devices must be used at all times except when bathing
Edema management
Bedside exercise program

1. Roll to sound side. Lift residual limb straight up and down while keeping hip straight.

2. With towel roll behind knee, gently bend and straighten knee over towel roll.

3. With towel roll between thighs, gently squeeze thighs together and down.

4. Flatten back by tightening stomach muscles and tilting hips toward waist.

5. Sitting with residual limb supported, tighten thigh muscle and push down on knee to straighten.


7. Roll to sound side. Bring knee to chest while bending knee. Reach limb back as far as possible while straightening knee.
Disposition

- Pre-prosthetic training program
- Acute Inpatient Rehabilitation
  - Qualifying Diagnosis
- Subacute Rehabilitation Facility
- Home with home care services
Prosthesis Timeline

- POD 0: Amputation surgery
- POD 1-4: Acute hospital, Post-operative management
- POD 5-21: Disposition, wound healing and pre-prosthetic training program
- POD 21-28: Suture/staple removal followed by casting/fitting of temporary prosthesis
Outpatient Clinic Visit
Re-introduce the P&O Team

- Patient
- Physiatrist
- Prosthetist
- Physical Therapist
- Occupational therapist
- Social worker
- Psychologist
- Case manager
Physiatric Approach

- History
- Physical
- Medicare Functional Classification Level (K-level)
- Prosthesis prescription
- Long term care and follow up
- Community Reintegration
- Vocational Rehabilitation
History

- HPI and PMH related to functional deficits
- Symptoms limiting ambulation or dexterity
- Diagnoses causing these symptoms
- Other co-morbidities relating to ambulatory problems or impacting the use of a new prosthesis
- Ambulatory assistive devices used
- Description of activities of daily living and how impacted by deficits
History

- Cause of amputation and duration of treatment/disability prior to amputation
- Hospital course, time frame
- Repeated surgical procedures and complications?
- Wounds and wound care, nutritional status
- Vascular bypass, skin grafts, muscle flaps
- Diagnostic studies (Arterial Doppler, Arteriogram, Cardiac Echo, renal function)
History

- Pain prior to amputation
- Pain related to surgery/procedures
- Phantom sensations (awareness)
- Phantom pain (disturbing)
- Treatment for each of the above
- Is the treatment working?
History

- Prior psychological issues (depression, previous disabilities)
- Current feelings about amputation
- Future concerns about function
- Body image issues
- Concepts about prosthesis
- Previous experience with prosthesis
History

- Prosthesis delivery/type
- Prosthesis wearing time
- Sock ply
- Falls
- Functional activity at home and in community and assistance required
History

- Social support system
- Involvement of support system
- Previous level of ambulation and self-care
  1. When was the last time you walked on two feet?
  2. Could you walk a block outside?
  3. Could you walk up a flight of stairs without stopping?
- Work history
- Home environment/barriers
- Patient concerns about family, friends
- Financial issues/insurance
History

- Family Responsibilities
- Previous level of ambulation
- Sports / Fitness / Exercise
- Intimacy / Sex
- Driving
- Outdoor activities (swimming)
- Hobbies, future activities
Physical

- Weight and Height, including any recent weight loss/gain
- Cardiopulmonary Examination
- Neurological Examination
  - Balance and coordination
  - Gait/Mobility/Transfer evaluation
  - Sensation
- Musculoskeletal Examination
  - Upper and lower extremity strength, range of motion
Physical

- Skin examination for pressure distribution and breakdown, skin integrity, document with pictures
- Level of amputation, Residual limb shape
- Evidence of pressure sensitive areas, Neuromas
- Contralateral limb examination
- Prosthesis evaluation/socket/liners
Inspect the hands
Medical Documentation

- “It is the treating physician’s records, not the prosthetist’s, which are used to justify payment” for a prosthesis
- The patient’s functional capabilities are crucial to establishing the medical necessity for a prosthetic device
- Many prosthetic components are restricted to specific functional levels; therefore, it is critical that physicians thoroughly document the functional capabilities of their patients, both before and after amputation
**Functional Classification**

- **K0**: The patient does not have the ability or potential to ambulate or transfer safely with or without assistance and a prosthesis does not enhance his/her quality of life or mobility.

- **K1**: The patient has the ability or potential to use a prosthesis for transfers or ambulation on level surfaces at fixed cadence.

- **K2**: The patient has the ability or potential for ambulation with the ability to traverse low level environmental barriers such as curbs, stairs, or uneven surfaces.

- **K3**: The patient has the ability or potential for ambulation with variable cadence.

- **K4**: The patient has the ability or potential for prosthetic ambulation that exceeds basic ambulation skills, exhibiting high impact, stress, or energy levels.
# LOWER LIMB PROSTHETIC PRESCRIPTION

**NAME:** ___________________________  **DOB:** ___________________________  **PRACTITIONER:** ___________________________

**REFERRING M.D./D.O.:** ___________________________  **PRESCRIBING M.D./D.O.:** ___________________________

**DIAGNOSIS:** __________________________________________________________

**AMPUTATION TYPE:** __________________________________________________

**PROGNOSIS:** _________________________________________________________

**FUNCTIONAL:** ________________________________________________________

**CONSTRUCTION:**
- Temporary  ____  Permanent  ____  Exoskeletal  ____  Endoskeletal  ____  Adjustable  ____

## ABOVE KNEE

**SOCKET:**
- Ischial Containment Total Contact:  ____
- Hip, Knee Disartic:  ____
- Quad Total Contact:  ____
- Test Socket:  ____
- Socket Replacement Only:  ____
- Flexible Socket & Rigid Frame:  ____
- Other: ___________________________

**MATERIAL:**
- Thermoplastic:  ____
- Laminated:  ____
- Other: ___________________________

**SUSPENSION:**
- Total Suction:  ____
- Silicone Gel Suction:  ____
- Semi Suction:  ____
- TES Belt:  ____
- Silesian Band:  ____
- Other: ___________________________

**COMPONENTS:**
- Titanium:  ____
- Stainless Steel:  ____
- Carbon Graphite:  ____
- Other: ___________________________

**KNEE JOINTS:**
- Manual Knee Lock:  ____
- Polycentric, 4-Bar:  ____
- Safety, Stance Control:  ____
- Hydraulic Swing Phase:  ____
- Pneumatic Swing Phase:  ____
- Hydraulic SNS:  ____
- Micro-Processor Control:  ____

**ANKLE-FOOT:**
- Light Weight SACH:  ____
- Single Axis:  ____
- Bock Dynamic:  ____
- Greisinger:  ____
- Multi Flex:  ____
- College Park:  ____
- Seattle:  ____
- Flex Foot:  ____
- Other: ___________________________

**MISCELLANEOUS:**
- Wool stump socket:  ____
- One Ply Socks:  ____
- Nylon Sheaths:  ____
- Stump Shrinker:  ____
- Other: ___________________________

## BELOW KNEE

**SOCKET:**
- PTB, Total Contact:  ____
- Liner Material:  ____
- Test Socket:  ____
- Socket Replacement Only:  ____
- Other: ___________________________

**MATERIAL:**
- Thermoplastic:  ____
- Laminated:  ____
- Other: ___________________________

**SUSPENSION:**
- Cuff:  ____
- Supracondylar Wedge:  ____
- Supracondylar/Suprapatellar:  ____
- Silicone Suction (SS):  ____
- Custom:  ____
- Pre-Fab:  ____
- Elastic Sleeve:  ____
- Other: ___________________________

**THIGH CORSET:**
- Laced:  ____
- Velcro:  ____
- Knee Joint:  ____
- Other: ___________________________

**SYMES/PARTIAL FOOT:**
- Specify: ___________________________

**SHOES:**
- Orthopedic/Blucher:  ____
- Sneaker Style:  ____
- Surgical:  ____
- High Top:  ____
- Extra Depth:  ____
- High Toe Box:  ____
- Bunion Lasts:  ____
- Deer Skin:  ____
- Heel/Sole Lift:  ____
- Type of Sole:  ____
- Other: ___________________________

**CLOSURE TYPE:**
- Laces:  ____
- Velcro Patch:  ____
- Velcro D-Ring:  ____

**CUSTOM FOOT ORTHOTICS:**
- Left:  ____
- Right:  ____
- Accommodative:  ____
- Corrective:  ____

**MATERIAL:**
- Plastazote:  ____
- PPT:  ____
- Neoprene:  ____
- Polypropylene:  ____
- Thermocork:  ____
- Other: ___________________________

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**Special Features/Instructions:** __________________________________________________________

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The above prescribed devices are a medical necessity to increase the patient’s safety and functional status.

**Duration of Necessity:** __________________________________________________________

Date: ___________________________  **Physician Signature:** ___________________________
Trans-tibial Prosthesis

- Socket Design: PTB, total contact, total surface bearing
- Interface material: Gel liner, foam (Pelite/Bocklite), socks, leather/rubber, gel socks
- Socket materials: Thermoplastic, laminated, carbon fiber
- Suspension: Supra-condylar wedge, suspension sleeve, gel liner with pin, vacuum (passive or active)
- Pylon/connector materials: aluminum, titanium, carbon fiber, steel
- Foot/ankle componentry based upon K levels
Temporary BK Prosthesis
Permanent BK Prosthesis
Permanent BK Prosthesis
Pelite foam liner
Suprapatellar cuff suspension
Hybrid inner flexible liner
Gel sock with suspension sleeve
Gel liner
Gel liner with pin suspension
Vacuum suspension
Active vacuum suspension
Sport Specific Prostheses
Flex-run
Action of the Flex-run

• Designed for long distance running or jogging

• The athlete runs on the prosthetic toe, extending the hip throughout the support phase and achieving maximal deflection of the foot

• As the runner enters swing, the effort of jogging is minimized by allowing the foot to initiate the upward motion and as the spring effect reaches a peak, continuing the upward acceleration by flexing the hip as the limb moves into the float phase

• There is no evidence to support reduced work of running with the Flex-run; however, the “bouncy” sensation that amputee runners experience allows for a more rhythmic running pattern, helping to achieve a physiologic steady state
Cheetah Foot
Cheetah Foot

- Designed for sprinters
- The Cheetah is plantar flexed and does not have a heel to keep sprinters on their toes
- The distal posterior pylon is severely bowed, lengthening the foot plate to increase the moment arm for maximal deflection so that as energy is returned it will propel the athlete’s limb into acceleration of swing
- Usually taller than their walking prosthesis
- Goal is to have the pelvis level during stance and to eliminate any trunk or head movement
Bilateral TFA with C-leg
Genium Bionic Prosthetic

- Ascend stairs step over step
- Cross obstacles more smoothly
- Walk backwards, forwards—any direction
- Stand more easily
- Sit more naturally
  - If thigh is parallel to the ground with minimal weight on the leg x 2 sec, the Genium reduces resistance to take a more natural position
Bilateral TFA with Genium
Thank you
Prosthesis Prescription
# LOWER LIMB PROSTHETIC PRESCRIPTION

**NAME:** \\
**DOB:** \\
**PRACTITIONER:** \\
**REFERRING M.D./D.O.:** \\
**PRESCRIBING M.D./D.O.:** \\
**DIAGNOSIS:** \\
**AMPUTATION TYPE:** \\
**PROGNOSIS:** \\
**FUNCTIONAL:**

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<thead>
<tr>
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## ABOVE KNEE

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- Hip, Knee Disartic: ____
- Quad Total Contact: ____
- Test Socket: ____
- Socket Replacement Only: ____
- Flexible Socket & Rigid Frame: ____
- Other: ____

**MATERIAL:**
- Thermoplastic: ____
- Laminated: ____
- Other: ____

**SUSPENSION:**
- Total Suction: ____
- Silicone Gel Suction: ____
- Semi Suction: ____
- TES Belt: ____
- Silesian Band: ____
- Other: ____

**COMPONENTS:**
- Titanium: ____
- Stainless Steel: ____
- Carbon Graphite: ____
- Other: ____

**KNEE JOINTS:**
- Manual Knee Lock: ____
- Polycentric, 4-Bar: ____
- Safety, Stance Control: ____
- Hydraulic Swing Phase: ____
- Pneumatic Swing Phase: ____
- Hydraulic SNS: ____
- Micro-Processor Control: ____

**ANKLE-FOOT:**
- Light Weight SACH: ____
- Single Axis: ____
- Bock Dynamic: ____
- Greisinger: ____
- Multi Flex: ____
- College Park: ____
- Seattle: ____
- Flex Foot: ____
- Other: ____

**MICROCELL:**
- Wool Stump Socket: ____
- One Ply Socks: ____
- Nylon Sheaths: ____
- Stump Shrinker: ____
- Other: ____

## BELOW KNEE

**SOCKET:**
- PTB, Total Contact: ____
- Liner Material: ____
- Test Socket: ____
- Socket Replacement Only: ____
- Other: ____

**MATERIAL:**
- Thermoplastic: ____
- Laminated: ____
- Other: ____

**SUSPENSION:**
- Cuff: ____
- Supracondylar Wedge: ____
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- Custom: ____
- Pre-Fab: ____
- Elastic Sleeve: ____
- Other: ____

## SHOES:
- Orthopedic/Blucher: ____
- Sneaker Style: ____
- Surgical: ____
- High Top: ____
- Extra Depth: ____
- High Toe Box: ____
- Bunion Lasts: ____
- Deer Skin: ____
- Heel/Sole Lift: ____
- Type of Sole: ____
- Other: ____

## CLOSURE TYPE:
- Laces: ____
- Velcro Patch: ____
- Velcro D-Ring: ____

## CUSTOM FOOT ORTHOTICS:
- Left: ____
- Right: ____
- Accommodative: ____
- Corrective: ____

## THIGH CORSET:
- Laced: ____
- Velcro: ____
- Knee Joint: ____
- Other: ____

## SYMES/PARTIAL FOOT:
- Specify: ____
- Other: ____

**Special Features/Instructions:**

---

The above prescribed devices are a medical necessity to increase the patient’s safety and functional status.

**Duration of Necessity:** ____________

**Date:** ____________  **Physician Signature:** ______________________

---
Trans-femoral Prosthesis

- Socket design: Ischial containment, total contact, total surface bearing, Quad socket design, High Fidelity™ design
- Interface material: Socks, gel liner, thermoplastic, foam (Pelite/Bocklite)
- Socket materials: Thermoplastic, Laminated
- Suspension: Suction, elastic belt, gel liner with pin or strap, vacuum (passive or active), hip joint and belt
- Pylon/connector materials: aluminum, titanium, carbon fiber, steel
- Rotators, quick disconnect (Ferrier coupling)
- Knee componentry and Foot componentry based on K levels
Endo vs. Exoskeletal design
Ischial containment socket
Suction suspension
Suction suspension
Gel liner with coyote lock
KISS suspension socket
KISS suspension system
Foot Selection

- Movable foot or not
- Single-axis or multi-axis movement
- Dynamic response or not (energy-storing)
- Hybrid/combo feet
- Supplemental ankle joints
- Shock and torque absorbers
- Heel height adjustable
- Cosmetic cover or shell profile
Prosthetic feet

- Non-articulated
- Articulated
Non-articulated foot

- Generally assigned to K-1 or 2 level ambulators

- Although these feet limit variation in walking speed and do not provide as much mobility as other prosthetic models, they are appropriate for an individual who will remain a household or limited community ambulator.

- Advantages of the non-articulated feet are that the models are inexpensive, durable, and virtually maintenance-free.

- SACH foot (Solid Ankle Cushion Heel) has a soft, rubber heel wedge, which compresses under load during the early part of the stance phase of walking and provides a minimal amount of ankle action. This ankle action serves to compensate for the lost tibialis anterior to slowly transition from initial contact (heel strike) to mid stance.

- Flexible keel prosthetic foot has an elastic forefoot that remains stable during standing and walking, but can also conform to uneven terrain, therefore providing longitudinal support.
Articulated feet

- Single-axis foot
- Multi-axis foot
- Energy-storing, dynamic response foot
Articulated feet

- Single-axis foot
  - A single-axis foot has an ankle joint that allows the foot to move up and down. This type of foot enhances knee stability, which is useful for higher level-amputees, because it reduces the effort required to actively control the prosthesis and prevent the knee from buckling.
Articulated feet

- Multi-axis foot
  - A multi-axis foot has both *up-and-down and side-to-side motion*. This foot provides increased mobility and promotes the ability to walk on uneven surfaces.
Articulated feet

- Energy-storing, dynamic response foot
  - An energy-storing, dynamic response foot stores and releases energy during the walking cycle. The foot is designed for more active lifestyles, and allows the individual to easily change speeds and direction. Dynamic response feet are especially appropriate for K-3 or K-4 patients because more reliance may be placed on the foot for propulsion and stability during walking, and there is less compensation at the remaining joints.
Dynamic Response Foot
Dynamic Response Feet with Shock Absorbers
Dynamic Response Foot with Shock Absorber
Torque Absorbers
Prosthetic Knees

- Designed to give support while standing, controlled motion while walking, and unrestricted movement for sitting, bending, and kneeling.

- The balance between stance phase, and swing phase, varies for each individual, so prosthetic knee models vary by the type of axis, stance control options, and swing control options.
Manual Locking Knee

- A manual lock knee is the simplest model, and least expensive.
- It uses a single axis, or a simple hinge joint, to simulate knee function.
- It has an automatic lock that can be unlocked voluntarily to facilitate ambulation.
- During ambulation, constant friction on the single axis enables swing control, and the manual lock may be self-employed for stance control.
Safety, Stance Control Knee

- Operates with a constant friction system during the swing phase, but differs from the manual lock by its use of a weight-activated locking system for stance control.

- At initial contact, when weight is loaded through the heel of the prosthesis the knee locks, and will not bend until the weight is displaced anteriorly during terminal stance.

- The knee is appropriate for less active amputees
A knee with a polycentric axis has 4 or more bars for multiple axes of rotation.

Stance control is geometric stabilizing and can provide stability on most ramps.

A standard polycentric knee appropriate for K-1 or K-2 ambulators has a simple mechanical swing control that provides an optimal single walking speed.
Pneumatic control is a type of prosthetic knee system, which supplies variable friction.

The control system compresses air as the knee is flexed, stores the energy, then returns the energy as the knee moves into extension.

The system makes it possible to ambulate at different speeds, a set-up appropriate for K-3 or 4 patients.
A hydraulic-controlled knee uses a similar variable friction system as a pneumatic knee, but with a liquid-medium instead of air.

Hydraulic knees provide a more superior function and a smoother gait than pneumatic knees, and are especially appropriate for active amputees.

However, they are also heavier, require more maintenance, and have a higher initial cost.
Microprocessor Knee

- Appropriate for K3, K4 level ambulators
- Microprocessor knees lower the amount of effort that amputees require for ambulation because they use sensors to detect movement and timing and automatically adjust a hydraulic or pneumatic cylinder as necessary
## Table 1: Commonly used MPK knee units

<table>
<thead>
<tr>
<th>Product Name</th>
<th>Manufacturer</th>
<th>Cadence Control Medium</th>
<th>Processor Speed</th>
<th>Features</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>C-Leg</td>
<td>Otto Bock</td>
<td>Hydraulics</td>
<td>50 Hz</td>
<td>Offers several functional modes. The first 2 modes can be set for various activities. A new “standing” mode lets you lock the leg between 7 and 70°. Switch between modes with a wireless handheld control</td>
<td><a href="http://www.ottomed.com">http://www.ottomed.com</a></td>
</tr>
<tr>
<td>Rheo</td>
<td>Ossur</td>
<td>Magnetorheological</td>
<td>1000 Hz</td>
<td>MR fluid moves between blades that, when charged, bind the MR fluid for resistance. The advantage is that with slow movements in confined quarters, there is no minimum resistance as with fluids that move through ports and cylinders</td>
<td><a href="http://www.ossur.com">http://www.ossur.com</a></td>
</tr>
<tr>
<td>Adaptive</td>
<td>Blatchfords</td>
<td>Hybrid (hydraulic/pneumatic)</td>
<td>62.5 Hz</td>
<td>Two stepper motor valves operated by the microprocessor. The hydraulic part of the system controls stance, flexion, and terminal impact. The pneumatic part of the system controls swing phase and extension assistance</td>
<td><a href="http://www.asmj.com">http://www.asmj.com</a></td>
</tr>
<tr>
<td>Agility</td>
<td>Freedom</td>
<td>Hydraulics</td>
<td>1000 Hz</td>
<td>Actuator response time (ART), supported by advanced microprocessor programming, allows the knee to make nearly instantaneous adjustments to knee position and velocity. Increased water resistance</td>
<td><a href="http://www.freedom.com">http://www.freedom.com</a></td>
</tr>
</tbody>
</table>
Ideal Candidate for Micro-Processor Control Knee

- Active adult who ambulates indoors and outdoors on uneven terrain regularly without an assistive device
- High risk adult who cannot tolerate a fall or the consequence of a fall
- Young, healthy adult with bilateral AKA
Bilateral TFA with C-leg
Genium Bionic Prosthetic

- Ascend stairs step over step
- Cross obstacles more smoothly
- Walk backwards, forwards—any direction
- Stand more easily
- Sit more naturally
  - If thigh is parallel to the ground with minimal weight on the leg x 2 sec the Genium reduces resistance to take a more natural position
Bilateral TFA with Genium
Next Generation of Components

- Power knees: Electric motors which boost knee extension for stairs and hills
- Power ankles: Electric motors for active plantarflexion in late stance phase, and active dorsiflexion in swing phase
- Hydraulic ankles
Conclusions

- Ultimately, the patient’s use of the prosthesis and functional outcome depend most on good socket fit and proper training.

- Proper selection of prosthetic components is based on the patient’s functional needs and limitations.
• New Developments in Prosthetics
  • Surgical Technique
    • Osseointegration
  • Socket
    • Hi-fi
  • Suspension
    • Harmony P3 pump
  • Componentry
    • Power Foot/Ankle (Proprio)
    • Power Knee
    • MPK (Genium, X2)
    • Sport Specific (Cheetah, Flex foot)
Osseointegration
Osseointegration
Hi-Fi Socket Design
Hi-Fi Socket Design