Appendix: Advances in prosthetics and functional aids by decade, 1940s to 2010

1940s

First Hydraulic Knee for the Transfemoral Amputee

Hans Mauch and another German scientist Ulrich Henschke came to post-World War II America and developed a prototype for the first hydraulic knee (Mauch Laboratories; Dayton, Ohio) in the late forties. In just a few months, they designed the swing and stance control but took more than a decade to refine all the engineering and incorporate important patient feedback from the amputees

Congress Passed Legislation

Legislation was passed to start up the Department of Veterans Affairs (VA) Prosthetics and Sensory Aids Service in 1948, which celebrates its 62nd anniversary in the fall of 2010.

Amputee Clinics Across the United States

Thirty multidisciplinary amputee clinics were established across the country at strategic locations in 1949. Each clinic formed a clinical team of five, including a surgeon, a prosthetist, and physical therapist, as well as an education program for the clinical team specialists who staffed it.

1950s

Upper-Limb Prosthetics Course Initiated at University of California at Los Angeles

The course was designed for the VA clinical teams in 1952 with the help of VA funding. The course was a success, and in 1956, VA began funding a similar educational program at New York University.

The VA Prosthetics Center (VAPC), a testing and development laboratory on 23rd Street in New York City, was established in 1956. Before this date, the VA established its first prosthetics and orthotics outpatient care and Research and Development (R&D) laboratory here in 1947. In the late 1950s, the Center began to establish standards and encouraged manufacturers to use new plastic laminates instead of wood. A biophysics laboratory was set up after 1956, in a space that was once a butcher shop, with slanted floors leading to a drain. It was said that researchers, who often wrote their research proposals in this room, would slowly migrate toward the drain—not the best image to suggest a positive outcome.

Prosthetics Research Laboratory at Northwestern University

In 1956, the VA expanded its prosthetics research and funded the Prosthetics Research Laboratory in Chicago. The funds were disbursed through the VA's Prosthetics and Sensory Aids Service.

The Laboratory developed one of the first electric-powered arms in the United States (kinematically coupled, coordinated limb) designed for children born without arms. This was the precursor of many other powered limbs developed around the world during the remaining decades of the 20th century and into the 2000s.

Prosthetics research became a legal VA entity 10 years before the medical research program was written into law in 1958. That year, Congress formally recognized medical research as one of the missions of VA and authorized a portion of VA annual budget for research.

1960s

SACH Foot

The SACH (Solid Ankle Cushion Heel) foot was introduced in the 1960s and proved a valuable component for lower-limb prostheses at the time; it was used with all prostheses that required a full artificial foot.

Amputees experienced significantly less irritation of the residual limb with use of the SACH foot, especially in those persons with below-knee (BK) amputations, because of the diminished torsion upon the residual limb and less jarring from heel impact. Comfort is increased because of the cushioned heel and smooth rocker action.

Prosthetic Research Study

The Prosthetic Research Study was founded in 1964 by Dr. Ernest Burgess, chief of the clinic at the Seattle VA Medical Center, using VA funding. Burgess led a study of the practice of fitting prosthetic devices immediately after amputation, a technique eventually adopted nationwide. This innovative development was called the transtibial posterior flap surgical procedure.

Electric Elbow

Developed in the 1960s by the VA and Northwestern University, the electric elbow uses both flexion and extension motions. This was the first self-contained transradial myoelectric prosthesis.

Electromyographic Activity

An early mapping program to study electromyographic (EMG) activity in various muscle groups was developed to determine the best site(s) for EMG readouts—foundation work for later advances in functional electrical stimulation (FES).

Flexion Compensator Developed

The VAPC developed the flexion compensator, which simulates normal knee flexion during stance phase.

Closed-Circuit Television

The closed-circuit television reader for the visually impaired was thesis project by two Massachusetts Institute of Technology seniors. The VA funded R&D that led to commercial versions.

Below-Knee Prosthesis

The standard 1960s VA-developed, BK prosthesis contained a torque absorber above foot-attachment plate, which also had a cosmetic cover.

Reading Machine

The Visotactor B (Mauch Laboratories; Dayton, Ohio) reading machine was developed and evaluated by the VA's Prosthetics and Sensory Aids Service for the blind.

1970s

Synergetic Hook

VA developed prototypes of the “synergetic hook,” which was interchangeable with a prosthetic hand. An amputee attaches the hook to a prosthesis.

Computer-aided Design and Computer-Aided Manufacturing

Computer-aided design and computer-aided manufacturing (CAD-CAM) of prostheses were developed in the 1970s and 1980s and became widely used in the 1990s. CAD-CAM-generated prosthetic sockets were judged superior by users.

Upper-Body Prosthesis

An experimental prosthesis (with powered control of shoulder flexion, elbow, and hook) was evaluated by the VAPC in the early 1970s.

Powered Prosthesis

An externally powered prosthesis, controlled by low-effort shoulder motions, was evaluated by the VAPC. Full elbow flexion was achieved with light force on control cable.

Talking Brooch

The Talking Brooch was one of the earliest portable communications devices and was developed for people who could not talk but could input words on a keyboard.

1980s

Robotic Arm/Worktable

Robotic Arm/Worktable System is a computer-aided robotic arm and worktable system that allows patients who are paralyzed to feed themselves. Dual-purpose chin controller controls either robotic arm or wheelchair.

Laser Canes

Laser cane research began in the 1960s, motivated by the need to help blind veterans of the Korean war, and has continued for more than 40 years. Laser canes emit three-pitched tones that correspond with obstacles at head, waist, and curb levels. Vibrations help persons who are hearing impaired.

Seattle Limb System

The Seattle Limb System (knee, leg, and foot) was developed and evaluated by the VA during the late 1980s.

The Seattle Foot was the first component introduced in 1985, and many new models were designed and produced during the next few decades, as well as other components of the Seattle Limb System.

The Seattle Foot is a cosmetic, energy-storing prosthetic foot for individuals with a below-ankle amputation. They are designed to be aesthetically pleasing while providing comfort and support in a lightweight design. Examples of other models include the Seattle Light Foot, Low Heel Rise model, designed for all ages and activity levels for individuals with a lower-limb amputation; and the Seattle Natural Foot, a prosthetic foot designed as an alternative to the SACH foot for individuals with a lower-limb amputation.

The Seattle Foot was the first prosthetic device that attempted to replicate the natural movement of the foot during various human gaits using tested, scientific data.

Knee Prosthesis

A knee prosthesis, with computer control from multiple inputs, was developed and evaluated by the VA. Computer control of knee stability was a complex problem.

Digital Hearing Aids

Rehabilitation R&D made significant advances in digital hearing aids and cochlear implants during the 80s. More than 300,000 veterans have service-connected hearing loss; many more have age-related impairment.

1990s

Wheelchair Racing

This sport is important for many paralyzed patients—keeping them strong in body and spirit. Several peer-reviewed papers on racing techniques and wheelchair technology have appeared over several decades in *Journal of Rehabilitation Research and Development*.

Functional Electrical Stimulation

In 1991, the Cleveland FES Center opened, with a mission to regain function. Hand-grasp FES prosthesis implant with wireless on-wrist controller restores hand function. FES systems to regain lost function were pioneered over several decades by VA and VA-affiliated researchers and gained prominence in the 90s.

C-Leg (Computer Leg) Technology

This exciting technology was introduced in 1997 for the first time. It made full intelligent control of a prosthesis system and adaptation to your individual gait pattern possible. The C-Leg uses microprocessor-controlled hydraulics that adapts the system to all walking speeds in real time.

AdVAntage Arm

The AdVAntage Arm (University of Utah and Sarcos Research Corp; Salt Lake City, Utah), a prosthetic arm, was VA-funded and designed for veterans with short amputation levels. High elbow flexion angle allows full range of motion with grasping device around mouth and head area.

2000s

Exercise for Wheelchair Users

A home aerobic exercise program developed in the 90s for manual wheelchair users was evaluated through research and was shown to improve their upper-body endurance.

Research also demonstrated that intensive exercise protocols could help patients with spinal cord injury (SCI) regain some function.

Rehab Shower/Commode Wheelchair

An advanced rehab shower/commode wheelchair was designed and developed by the VA for patients with SCI. Patients and caregivers were an integral part of the design process.

Regeneration of Nerve Tissue

Regeneration of damaged or destroyed nerve tissue holds great promise for persons who are paralyzed. Transplantation of adult human neural precursor cells in demyelinated axons has led to remyelinated axons in animal studies.

Pedestrian WALK Signals

Light-emitting diode pedestrian WALK signals with animated “eyes” were designed for people with low vision. Such signal displays significantly improve recognition distance for persons with visual impairment.

Titanium to Bone

“Osseointegration” (the stable fixation of titanium to bone tissue) was used on thumb and finger amputees to return full hand function.

2009–2010 Generation II DEKA Arm

The VA has announced a 3-year study of an advanced artificial arm that easily allows those with limb loss to hold and write with a pencil or pick up and use a key in a lock.

In collaboration with the Defense Advanced Research Projects Agency, the study marks the first large-scale testing of the arm. This prosthetic arm is the first that allows amputees (who have lost a limb up to their shoulder joint) to perform movements while reaching over their heads, a previously impossible maneuver for those fitted with earlier arms.

2005–2010 BrainGate2 Neural Interface System

VA researchers also are exploring different ways to control the prosthesis through neural interfaces. This R&D has progressed through the 2000s.

The BrainGate System decodes signals recorded directly from the brain to control external devices. Subjects during research have used the BrainGate to control computer cursors and powered wheelchairs. This system helps people move who are paralyzed, have other disorders, or have lost limbs. Future research will determine if it can also control prosthetic limbs.

“The emphasis for our research,” says Dr. John Donoghue, Chairman of the Department of Neuroscience at Brown University, “is to find out how to get those signals out of the brain, what kind of signals to pick up, and how to best turn them into useful command signals.”

The team is working with funding from the National Institutes of Health to develop a wireless system. Development of the technology, researchers agree, is several years away.

The ultimate goal is to help patients with SCI, stroke, muscular dystrophy, amyotrophic lateral sclerosis also known as ALS, or limb loss turn their thoughts into actions, restoring independence, mobility, and communication.

“Everyone who is paralyzed could potentially benefit from this technology,” Donoghue said.

While total control of paralyzed limbs is still years away, Donoghue believes this technology will be useful to control advanced prosthetic devices such as the Generation II DEKA Arm.

2007 New Developments in Prosthetic Hands Touch Bionics

A Scottish company released the i-LIMB hand in mid-2007—the first prosthetic hand that enabled the movement of individual fingers by using five small, battery-powered motors embedded in each finger.

The Fluidhand, another state-of-the-art prosthetic hand, was also released in 2007. It uses lightweight miniature hydraulics to articulate the fingers. According to its developers, this hand is lighter, behaves more naturally, and has greater flexibility than artificial hands that use motorized fingers (*Source*: “Jamaican News Bulletin”).

2007 Proprio Foot

The Proprio Foot is a bionic foot designed for individuals with lower-limb amputation. This intelligent foot module for transtibial amputees provides a more balanced and symmetric gait as it responds to changing terrain, stairs, and slopes with automatic ankle flexion. An accelerometer tracks the path of the ankle through space, timing gait characteristics, and events, including heel strike and toe-off. For each stride, the device constructs its path by continuous data feedback.

Over the past decade, product choices in prosthetic feet have expanded to more than 50 different models. Today, amputees have a wide array of feet to choose from, designed for many specific sports such as running, biking, swimming, and snow skiing.