Research Recommendations for Upper Extremity Prosthetics

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Upper Extremity Research Timeline

	NOW	***5 YEARS***	***10 YEARS***
ENERGETICS		*Track commercial developments of batteries & alternative power sources →	→
CONTROL	*Pattern recognition / multi-functional control *Clinical evaluation of EPP systems	*Implantable myoelectric sensors *Close the loop using stimulations (feedback for myoelectric)	Neural control using peripheral nerves →
SUSPENSION	*Implement self-suspending (AE) techniques - Harness for control *Criteria for osseointegrated upper-limb prostheses →	*Develop models to evaluate harness and suspension techniques and physiological loading	
COSMETICS	*Durable High Definition Gloves →	→	
MECHANISMS	*Hybrid power elbows *Robust locking shoulders	*Compliant hands *3 function / 2 DOF wrists *Teach commercial developments in alternative activation technology *Lighter powered elbows with near physiological function	
OUTCOMES	*Design study to follow WRAMC amputees *Implement / adopt current evaluation techniques to this amputee population. *Develop tests to measure component outcomes →	*Create database of veterans fit with upper limb prostheses for retrospective studies of prosthetic intervention - successes / failures	

Goals for New Research

1. Give trans-radial amputees full simultaneous control of three wrist functions and at least two hand functions (e.g. implantable electrodes, pattern recognition schemes)
2. Promote investigation of nerve-muscle grafts at the trans-humeral level for control of the elbow and hand/wrist functions
3. Improve suspension methods/alternatives
4. Promote surgical/prosthetic methods to achieve active internal-external rotation of the forearm by users of trans-humeral prostheses
5. Give shoulder disarticulation amputees a functional shoulder joint
6. Improve/promote control methods that incorporate feedback of position, velocity, and force (e.g. body-powered cable systems, and powered E.P.P.-type systems, miniature cineplasty interfaces)
7. Identify power sources with greater energy density
8. Utilize WRAMC as a model to promote team approach to care of persons with arm amputations and to develop outcome measures
9. New components and coverings
10. Surgical interventions

Required to support Goal 1:
Research on Implantable Myosignal Transducers

- Will permit acquiring signals from individual superficial and deep muscles
- Potential of mapping muscles onto the control of appropriate mechanisms (e.g. supinator to control supination of wrist rotator)
- Potential for simultaneous control of multiple functions
- Available in three – five years
- Explore closing control/feedback loop with implanted stimulators (BION)
  - Five - ten years

Required to support Goal 1:
Multifunction Control for the Trans-radial

- Greater number of control sources (with implantable electrodes or pattern recognition schemes) opens up the possibility of more functions
- New wrist components
  - Powered wrist flexion; powered radial/ulnar deviation; powered pronation/supination; combined actions in single device
- Hands with separate thumb positioning and grip control
  - Compliant grasping

Required to support Goal 2:
Research to Implement Nerve-muscle Grafts

- Sponsor research on identifying functional nerve fasicles in the operating room for assisting the neurosurgeon during reimplantations and for doing these new nerve attachments
- Discover best ways to isolate reinnervated partial muscles to minimize cross talk
- Additional funding would accelerate the pace of this research
- Funding is also needed to replicate the technique at other centers

Required to support Goal 3:
Improving Suspension

- At the trans-humeral level
  - Marquardt-Neff angulation osteotomy (retains physiological humeral rotation and provides suspension)
  - implanting a titanium T in the end of the humerus (Christiansen *et al* in Norway)
- Identify appropriate levels for osseointegration
  - Trans-humeral fittings to date have been only cosmetic prostheses – why?
  - Possibilities for the shoulder disarticulation ?
- Suspension methods that do not rely on body harness would free up harness for control only could improve comfort and acceptance of user
  - Examples: suction sockets; suspension sleeves; osseointegration
- Develop models to evaluate harness and suspension techniques and physiological loading

Partly supports Goal 4:

Control of internal-external rotation

- Replace humeral rotation friction joints with lockable components
  - Both mechanical and electric lock/unlock options
- Develop electric powered positioning component
  - double no-back clutch
  - low power
- Investigate use of implanted magnet at end of the humerus to control motion of internal-external rotation

Partly supports Goal 5:

Improve the Locking Shoulder Joint

- Must be reliable for a heavy user for five years
- The lock should be as easy to operate manually or with a cable as a typical alternator
- An instant-action electric lock is also needed
- Provide a lock in abduction
- Abduction needs gravity compensation as provided in the Bock AFB

Supports Goal 6:

Force or Position Servo Control

- EPP (Extended Physiological Proprioception) Servo systems can give greater feedback to the user and are independent of myoelectric control
  - most useful when the device driven can move at physiological speeds
- Servo control requires a “sleep” or set-it-and-forget-it circuit
- This technology is ready to implement
  - A good position feedback kit for Bock hands already exists and the Boston elbow has the required circuits but should be faster for EPP

Supports Goal 7:

Energy Dense Power Sources

- Improvements in energy storage are driven by large markets like cellular phones
- Manufacturers of powered prosthetic components will monitor these developments without further outside help.

Supports Goal 8:
WRAMC as Model for Team Amputee Care

- WRAMC to use or rework existing manipulative tests to quantify current amputee performance
- Develop outcome measurement tools appropriate to the relatively smaller upper-limb amputee population.
- WRAMC/VA could track amputees for retrospective studies of success/ failure/ preferences of upper-limb prosthetic fittings
  - WRAMC fits each person with three types of prostheses (body-powered, myoelectrically-controlled, aesthetic)
    - » *Unique* opportunity unavailable at this scale in the private sector
  - Identify relevant factors when prosthesis use is abandoned
  - Identify psychological effects relevant to integration of prosthesis into body image

Supports Goal 8:
WRAMC as Model for Team Amputee Care

- Develop amputee focus groups to identify areas requiring improvement
  - User's perspective
  - Participant should have at least one year of experience using a prosthesis
    - » Allows for time to make psychosocial adjustment
    - » Judgments based on experience
      - Newly-amputated person generally has unrealistic expectations
    - » Experience helps in prioritizing importance of identified areas
- Consider use of VA QUERI group to provide ongoing review of research/procedures pertinent to WRAMC/VA needs in upper-limb amputee care

Supports Goal 9:

Components and Coverings

- Continue research on body-powered components
  - Have many features desired by users but also have deficiencies
- Existing devices need to be lighter to incorporate more active joints within a given prosthesis
- New devices need to emphasize lightweight design
  - Get input from DOD and NASA, and other government agencies / private sector manufacturers on lightweight materials
- Durable, high definition cosmetic gloves
- Hybrid elbows with power assist/body-power actuation
- Revisit VA-sponsored research from last 20 years to see which projects failed “technology transfer” and need a second try
  - Technologies come of age and become ready for implementation

Partly supports Goal 10:

Surgical Issues

- Is their value to lengthening the humerus or the radius and ulna for prosthetic fitting
  - What are the criteria?
- Educate the surgical community on the need for myodesis and myoplasty to prepare the residual limb for prosthetic fitting
- Consideration of the Krukenberg procedure or the Wilkie procedure for blinded individuals with bilateral arm amputations
  - Provides sensation
  - Could be covered with aesthetic prosthesis for social purposes

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