Robotic Technologies in Restorative Rehabilitation

Development to implementation: clinical considerations

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Robotic Systems

- Instructional
  - socially interactive/assistive robots
  - roving system to prompt people to change their activity without direct physical contact

- Directly assisting limb movement or posture recovery through direct physical contact
  - upper limb
  - lower limb
Stroke and recovery

100,000 new stroke per year, 30,000 people left with significant disability every year

Among patients who survive at least 5 years, 25% report difficulty with arm movement

Intensity of treatment is one factor accounting for the limited impact of rehabilitation interventions

Increasing the intensity

More human resource

- NHS staff
- Family / carers
- Patient education programs
- Existing community resource (e.g. gyms)

+ use of technology
What is rehabilitation “intervention”?

Restoring functional loss
- Restorative rehabilitation treatment is about RELEARNING activities / skills (therefore an “educational process”)
  - E.g. motor, cognitive, language skills

Compensating for / adjusting to functional loss
- “Adaptive” interventions to allow people to be independent when full recovery does not occur

BOTH IMPORTANT
Rehabilitation interventions and complexity

• Apparently addressing a simple problem …… but not really

• Neurological rehabilitation interventions are complex

• Often difficult to define precisely

• Often based on empirical evidence of effect

• Links between known learning processes and intervention often not clear

• Nevertheless a reasonable body of evidence suggesting efficacy of rehabilitation interventions
Why is motor recovery limited in some people with brain injury?

- Injury severity
- Secondary effects of perception / cognition / mobility / posture
- *Adverse* effects of neuroplasticity – “learned non-use”
- Lack of *appropriate* intervention required to learn functionally useful motor skills
- Intervention applied too late

**Lack of intensity of intervention**
- people on rehabilitation units spend a large proportion of time not engaged in "rehabilitation" activities
How can technology be used in neurological rehabilitation?

**Restorative skill acquisition**
- Supported Treadmill training
- Robotic systems
- Virtual reality
- Wearable devices

**Functional / Electrical Stimulation**
- Neurapager

**Compensatory**
- Conventional orthotics
- Seating
- Assistive technology
- Smart housing
- "Helper" Robots
- Transport

**Measurement**
- Lab based or remote movement analysis
The “learning experience” within a “rehabilitation setting”

• “….most prevailing literature reviews indicate that patients sustaining a stroke must play an active role in the rehabilitation process if improvement is to occur…”

• “….learning is not a passive, imprinting process, but requires active problem-solving and experience”

• “….a connection is significantly modified only if its activation is associated with outcomes important to the person’s behavior.”

• “….important outcomes are those that are meaningful to the patient”
Stroke and upper limb impairments

- Functions of the arm
  - placement
  - dexterity

- Neurological features
  - weakness, muscle spasm
  - loss of fine / accurate movement
  - visuospatial function
  - development of inappropriate movement patterns (e.g. with effort)

- Secondary problems
  - weakness due to muscle de-conditioning
  - contracture
  - learned non-use
  - shoulder pain

- Type of activity

- Comfort, aesthetics

- Environment
MRC Complex interventions evaluation framework: Developing rehabilitation robotics

Rehabilitation Robot devices

- Pre phase 1 studies
- Phase 1/2 studies
- Phase 3/4 studies

Theory and modelling

- Exploratory trials

Safety and performance

- Clinical efficacy

Product concept

Prototype device

Refining prototypes

Production model and market placement

Large scale manufacture

Adoption by NHS

Post market surveillance

MHRA / COREC

CE marking
User engagement in device development

• Developing user engagement protocol

• Ensuring appropriate end users are engaged from the start
  – people with stroke, carers
  – health professionals/managers

• Conceptualising the key areas of research

• Involvement in project management team meetings
Robotics and upper limb skill acquisition: things to consider

Defining therapeutic exercises
- Therapist or computer defined
- Planar or 3D (abstract versus functional)
- Timing of intervention

Facilitating movement
- Active or Passive
- DoF problem (arm and hand)

Assistance
- Multi-joint or end point
- Motor, pneumatic, hydraulic

Sensing the person’s voluntary effort

Person / machine interface
- Device footprint / cost / right-left configuration

Feedback
- Tactile, visual, auditory
- Real time / end of practice

Motivation

Error correction
- Physical, verbal

Engagement
Defining the exercise and exercise workspace

Ensure that the exercise workspace has functional “meaning”
Incorporating clinical experience, expertise and feedback

Consider how the patient’s neurological features will influence (a) robot assisted exercise prescription by the clinician and (b) choice of feedback.
Feedback and robot assisted exercise

• Feedback, along with practice has a strong influence on motor skill learning
  – “task-intrinsic” (inherent) feedback, which is the sensory-perceptual information that is a natural part of performing a skill.

• However patients with cognitive and perceptual impairments may not be able to use intrinsic feedback to guide their performance

  – “augmented” feedback” (information, extrinsic or artificial feedback)
  • “augmented” refers to adding to or enhancing task-intrinsic feedback with an external source
  • external source may be a therapist or a device such as information presented on a computer screen

• Need to consider in the context of robot assisted exercise how meaningful feedback is provided
“Therapeutic” upper limb movement – the DOF problem and that does not include the hand!

“End point”

Controlling the degrees of freedom particularly relevant to those with greater arm impairment
How “working” end point movement be assisted (SP)

Single point of contact

“End point”
Single point to dual point contact devices

- Single point of contact limits control of coordination between limb segments
- Ability to deal with wide range of arm impairments
- Protection of the vulnerable shoulder
- Limited workspace
- Applications of learning algorithms

Dual point of contact systems

“End point”

iPAM

………more complicated to achieve but potentially more versatile
MRC Complex interventions evaluation framework: Evaluating rehabilitation robotics

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CE marking
Evaluation: Using the ICF to think about outcomes

International Classification of Functioning (ICF)

- Health Condition (disorder / disease)
- Body function & structure (Impairment)
- Activities (Limitation)
- Participation (Restriction)
- Environmental Factors
- Personal Factors
- Quality of life
- The Law
Evidence for single point of contact systems

Fugl – Meyer: 0.65 (-0.02, 1.33) not sig
FIM: 0.13 (-0.25, 0.50) not sig

Effects of Robot-Assisted Therapy on Upper Limb Recovery After Stroke: A Systematic Review
Gert Kwakkel, Boudewijn J. Kollen and Hermano I. Krebs
Neurorehabil Neural Repair 2008; 22; 111 originally published online Sep 17, 2007;
DOI: 10.1177/1545968307305457
Implementation in clinical settings

- understanding the patient pathway
  - where in the pathway are these devices likely to be used?
  - what infrastructure is needed to support device use?

- Adoption by NHS
  - What evidence is needed?
  - Does the device comply with NHS clinical governance?
  - Regulatory approval
  - NICE
  - PbR and PLICS
  - Commissioning
intelligent robotic system for stroke rehabilitation (iPAM) project team

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Brave new world of rehabilitation......................