Robotics and hand-held manipulators in surgery – requirements for the future

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Topics

- Clinical interventions which benefit from the use of robots
- Examples of current robotic devices
- Disadvantages of the current generation of master slave manipulators for surgical interventions and how these can guide the development of the next generation of robots exemplified by the EU ARAKNES system
- Alternatives to robotic master slave manipulators
- Likely evolution of minimal access therapy
Clinical Scenarios which benefit from use of robotic assistance

- Procedure exposes staff to harmful ionizing radiation – orthopaedic fracture surgery
- Procedure is very complex requiring fast computer processing and precision which humans cannot manage in the time frame required
- Procedures where accuracy is vital to avoid collateral damage to important structures/tissues – image guided interventions of the CNS (brain and spinal cord)
- MAS procedures or component steps of the procedures which are difficult to execute by hand-held instruments with limited d.o.f.
- MAS procedures in which the operative field is small and restricts manipulations by hand-held instruments
Principle of Gamma Knife  precise tumour ablation
Robotic Radiosurgery (CyberKnife System)

• Pre-treatment planning
  CT acquisition
  Compute interpolated CT
  Compute digitally reconstructed radiographs (DRR)

• Start of treatment
  Take series of x-ray images (synchronized with infrared)
  Match DRRs
  Compute target location
  Compute correlation model

• During treatment
  infer target position from infrared sensors
  Take new x-ray images to update correlation model
Sample of available nodal locations within a partial spherical surface around the patient for an intracranial radiosurgical procedure.
CyberKnife – Robotic Stereotactic and localization Setup. Two x-ray images of the patient positioned via the Axum automated treatment couch.
Synchrous Tumour Tracking: Combination of LED camera system, the LEDs on the patient vest, the DRR derived images and real time LAO/RAO images allow for real time dose delivery to tumour (inset)
Robots in MRI-guided interventions

- High intensity focused ultrasound ablation of intracerebral tumours
  video
- Interventions under MRI guidance – Innomotion Robot
ExAblate2000 for Breast Cancer
Current status

Offer your patients cutting edge technology.... without the cutting
MRgFUS for Breast Cancer

The hyper-intense area in the edges of the treated region is hyperemia.

Pre-treatment
T1 weighted contrast enhanced subtracted image pre-treatment

Post treatment
T1 weighted contrast enhanced subtracted image post treatment

Courtesy of Breastopia Namba Medical Center, Miyazaki, Japan
Innomotion MRI intervention robotic system

Images show the Innomotion MRI intervention robotic system, including medical equipment and tools used in interventional procedures.
Comparison of intra-corporeal suturing: hand versus MSM (Da Vinci)

- Difficult intracorporeal suturing – bilio-enteric anastomosis  
  Video 1
- Suturing with DaVinci – video  
  Video 2
Advantages of DaVinci system

- Intuitive – surgeon uses movements he normally uses
- 3-D vision
- Surgeon comfort
- Precision of manipulations internal wrist of endo-effectors
  Video 3
  motion scaling - eliminates tremor
Disadvantages of current surgical master slave manipulators

- Not fit for purpose - developed by Standford University on a grant by DARPA for the US army specifically or Tele-presence surgery
- Bulky - take a lot of the space available in the OR
- Setting up time to cover the robotic arms (n = 4) with sterile plastic covers
- Limits access by the anaesthetist to the patient
- Distances surgeon from the patient and requires an assistant surgeon by the operating table to change endo-effectors
- High operating and maintenance costs

Video 4
Hand held manipulators

- Low cost option - held and operated directed by surgeon
- Internal wrist with 6.d.o.f.
- Different transmission and drive systems
- Facilitate complex tasks such as intracorporeal suturing during MAS
- Available system
  Radius – Tuebingen Scientific
  DARES – Dundee-Storz
Radius system

Video 5
DARES: wheel and joystick control

video
DARES hand-held manipulator (6 d.o.f.)

Tip rotation

Wrist articulation
Trunk-arm-hand-wrist-palm-fingers-motion analysis
Vicon motion capture system
Markers on wrist, palm and fingers
Hand-held manipulators studied by Vicon system during endoscopic dissection tasks

Wheel translation mechanism

Joystick translation mechanism
Vicon analysis: extreme wrist movements by joystick manipulator

Extreme wrist flexion with joystick manipulator

Extreme wrist supination with joystick manipulator

Extreme wrist flexion with joystick manipulator
Vicon analysis: elbow flexion with the two manipulators

Instrument 1 = wheel
Instrument 1 = joystick
Vicon analysis: wrist palmar flexion and ulnar deviation with the two manipulators

Instrument 1 = wheel, instrument 2 = joystick
Vicon analysis: maximum acceleration with the two manipulators

Instrument 1 = wheel
Instrument 1 = joystick
Vicon analysis: trunk movements with the two manipulators

Instrument 1 = wheel, instrument 2 = joystick
Vicon analysis: maximum velocity with the two manipulators

Instrument 1 = wheel

Instrument 1 = joystick
VAS Scores by participating surgeons (n = 20) for the two manipulators
Problems with hand-held manipulators

- No motion scaling - tremor persists
- Inefficient force transmission
- Actuation
- Non-intuitive manipulations
- Hand and wrist fatigue
The future

- Interventions rather than operations
- Computer assisted intra-operative guidance/ tracking/ augmented reality
  [Video 6](#)
- Minimal Access Therapy (MAT) with its 3 component therapeutic modalities will replace the practice of surgery as we know it
- MAT will be practised by M-DTGs - approach and modality individualised
- Excision will be replaced by ablation or vaporisation
- Operating rooms replaced by interventional therapy clusters
Medical Robots

- Should not occupy large volumes of space
- Should improve on and not just equal quality of medical care
- Place of humanoid robots in aspects in healthcare
- Should enable intuitive use by the medical practitioners
- Should be totally robust (fail safe)
- Should be *cost effective*
- Should permit *effectiveness*