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

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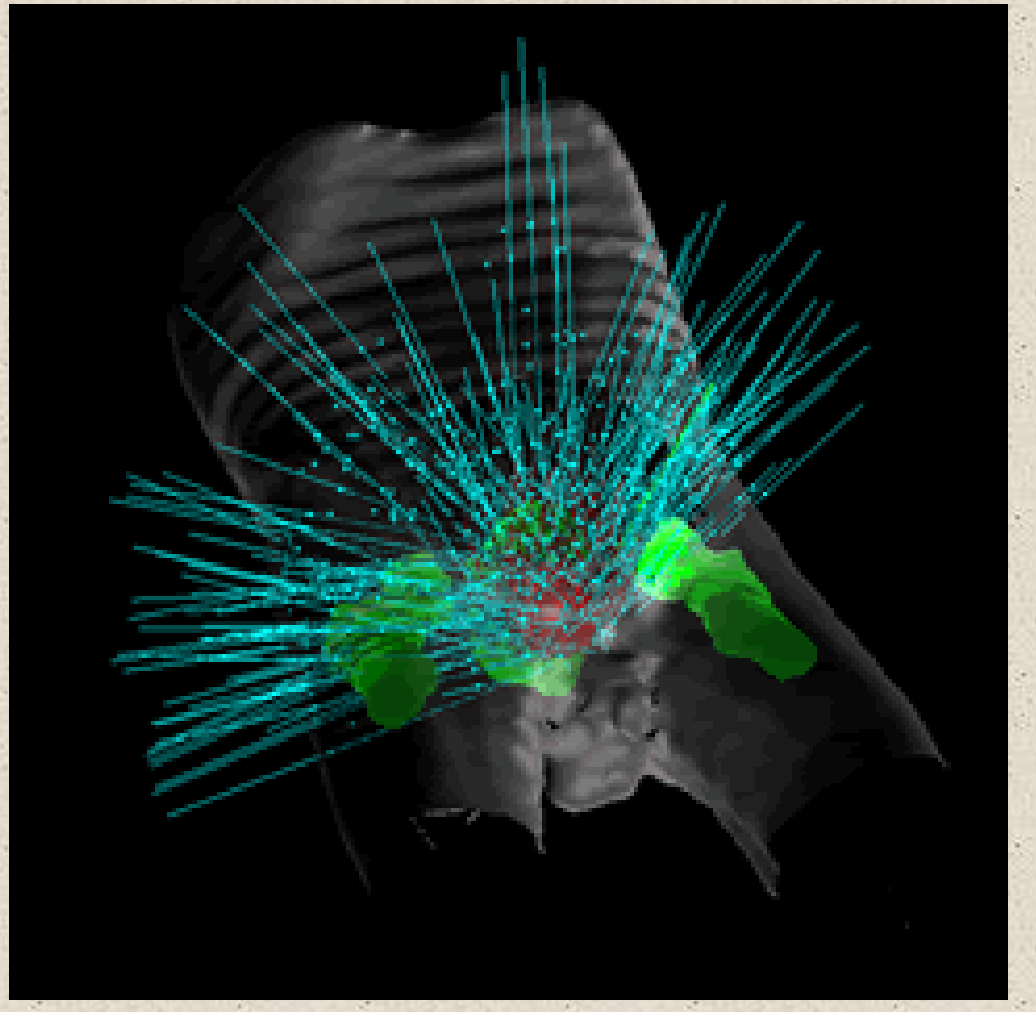
Topics

- 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

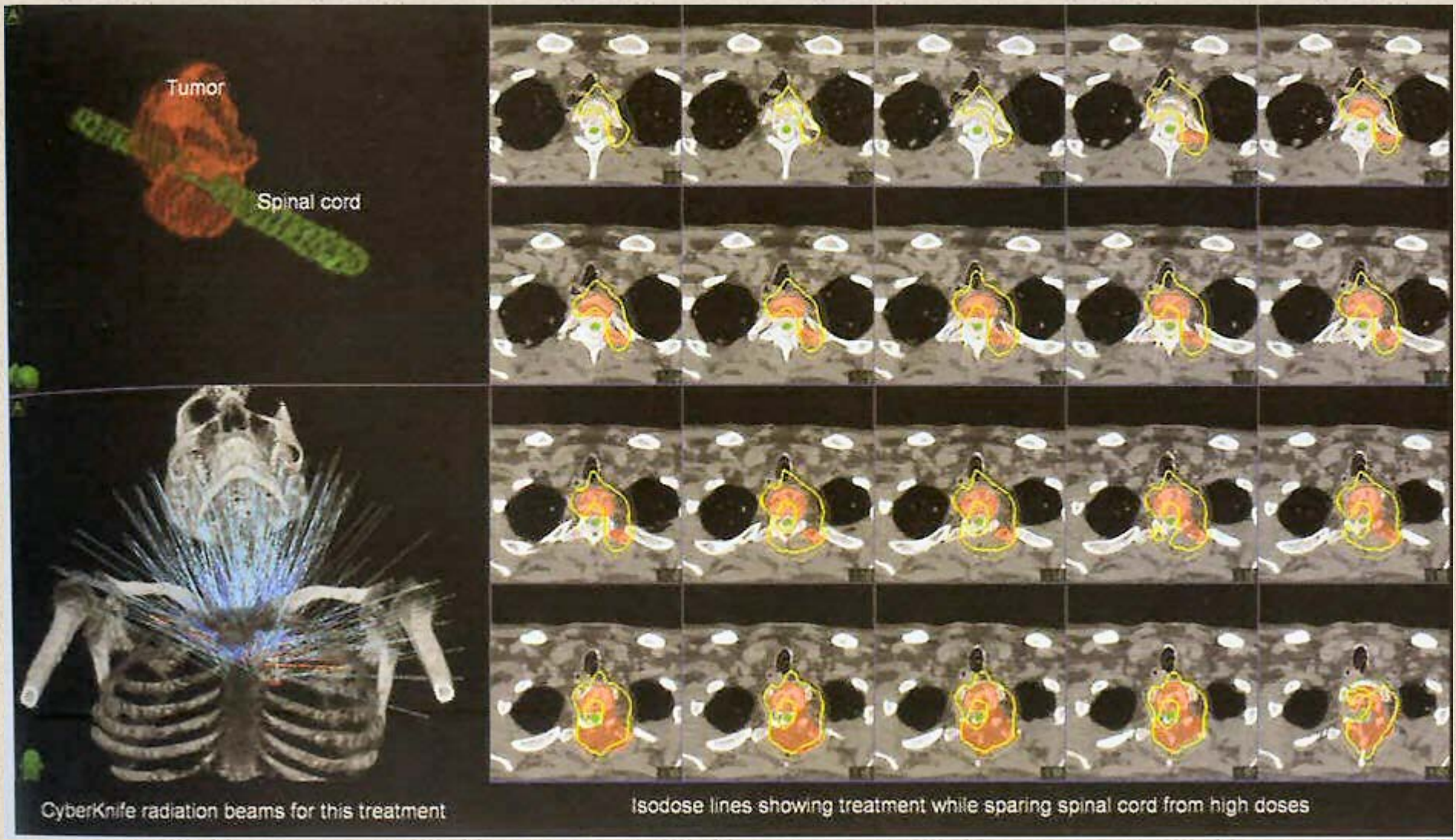
  Compute target location

  Compute correlation model

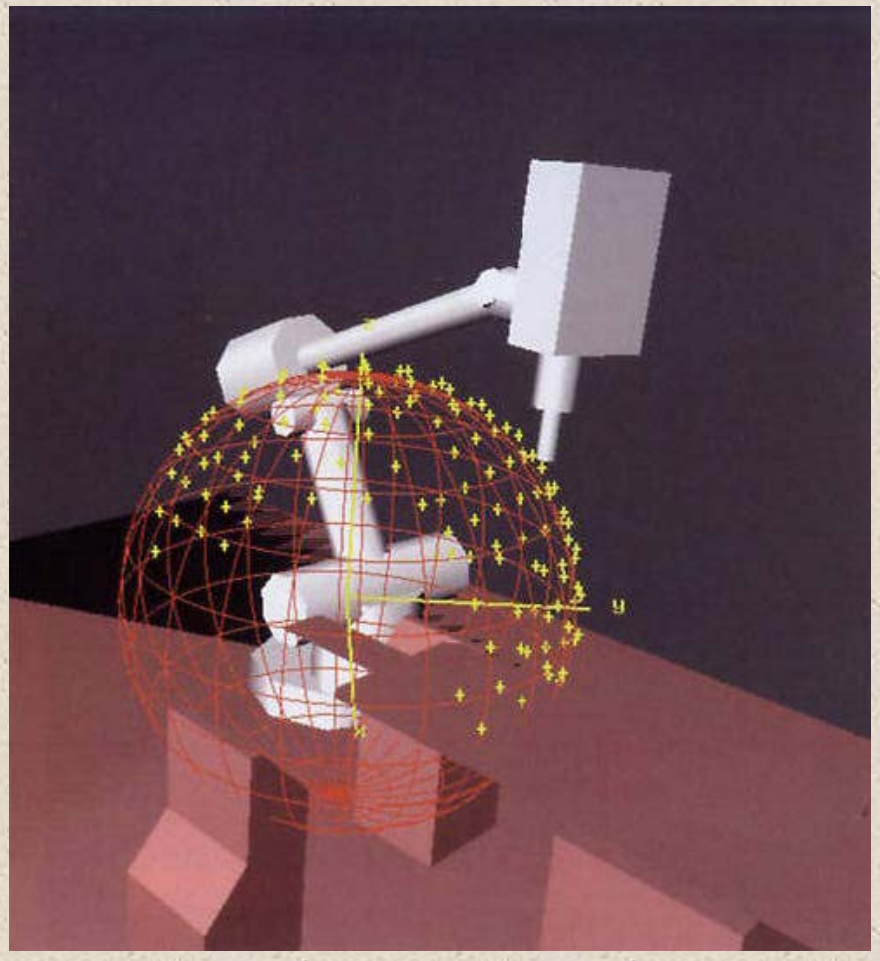
- During treatment

  infer target position from infrared sensors

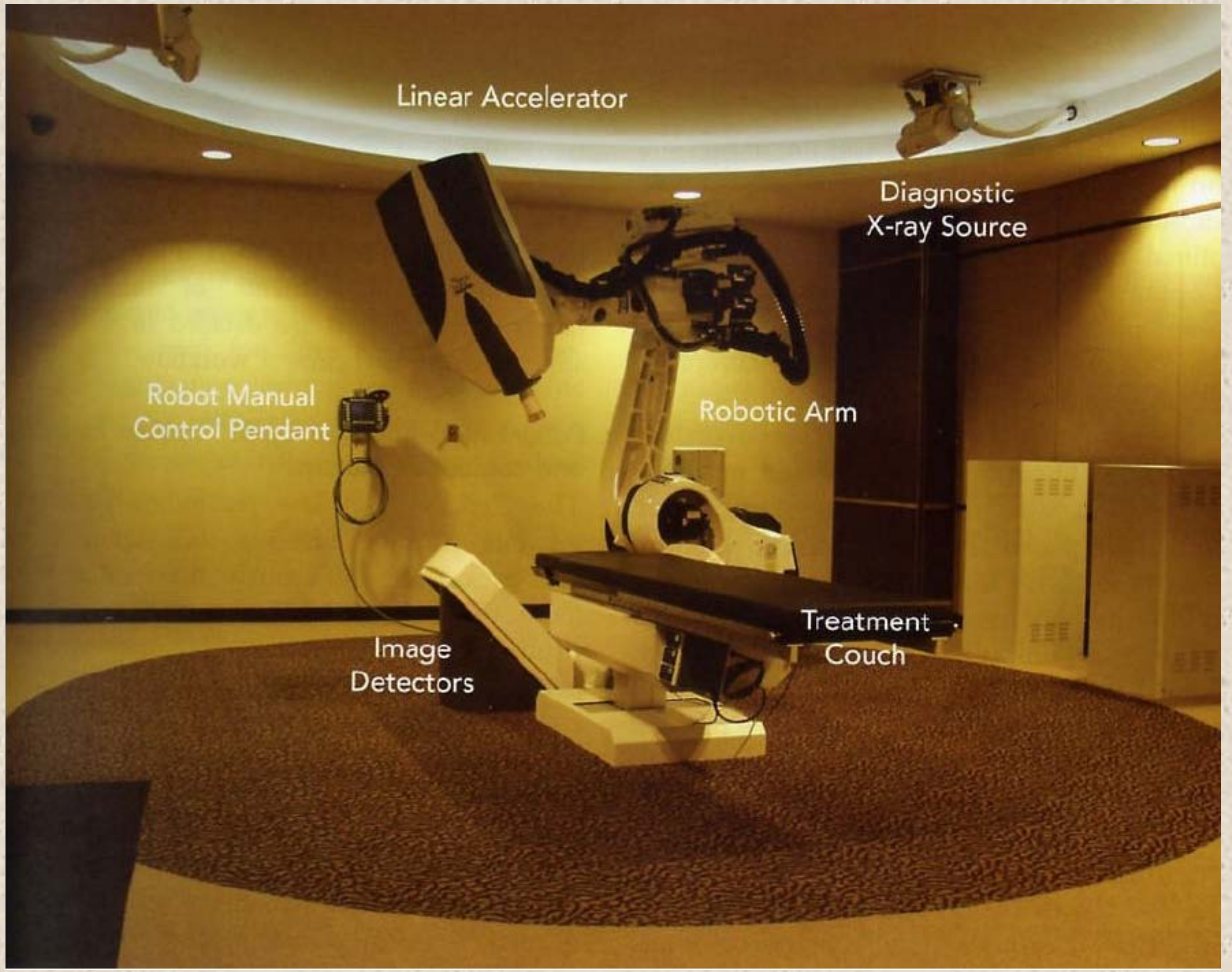
  Take new x-ray images to update correlation model


Tumor
Spinal cord
CyberKnife radiation beams for this treatment
Isodose lines showing treatment while sparing spinal cord from high doses

Preop computer controlled irradiation treatment protocol based on peroperative image of tumour size and precise location



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 imagesof the patient positioned via the Axum automated treatment couch

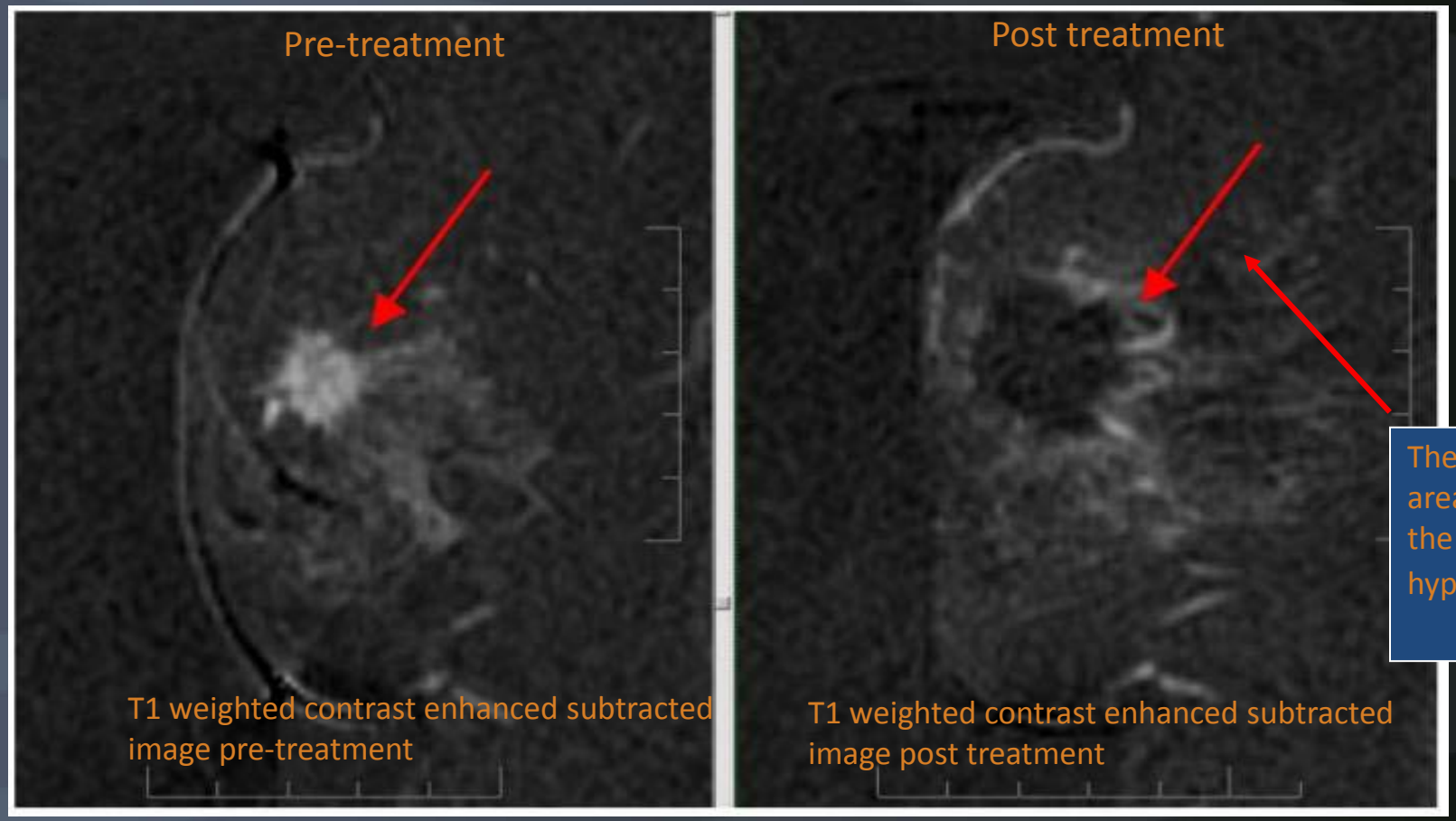
Synchrous Tumour Tracking: Combination of LED camera system, the LEDs on the patient vest, the DRR derived images and real time LAO/RAO images allow for real time dose delivery to tumour (inset)

Robots in MRI-guided interventions

- High intensity focussed ultrasound ablation of intracerebral tumours
  video
- Interventions under MRI guidance – Innomotion Robot


ExAblate 2000
ExAblate2000 for Breast Cancer
Current status
Offer your patients cutting edge technology.... without the cutting
InSightec
Bringing therapy into focus

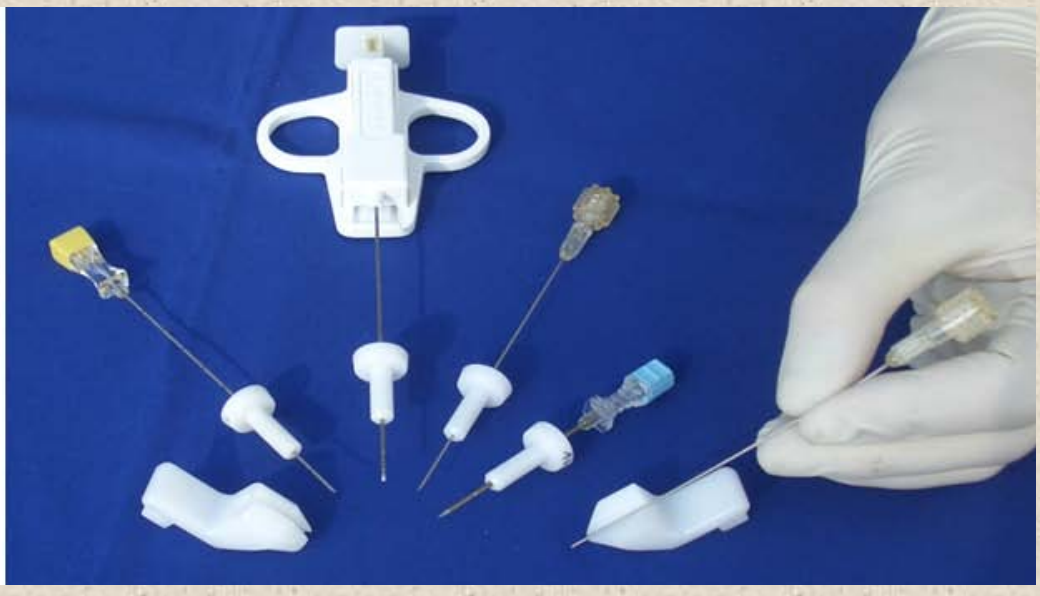
MRgFUS for Breast Cancer



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

Courtesy of Breastopia Namba Medical Center, Miyazaki, Japan

Innomotion MRI inreventional robot



Comparison of intra-corporeal suturing: hand versus MSM (Da Vinci)

- Difficult intracoporeal 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

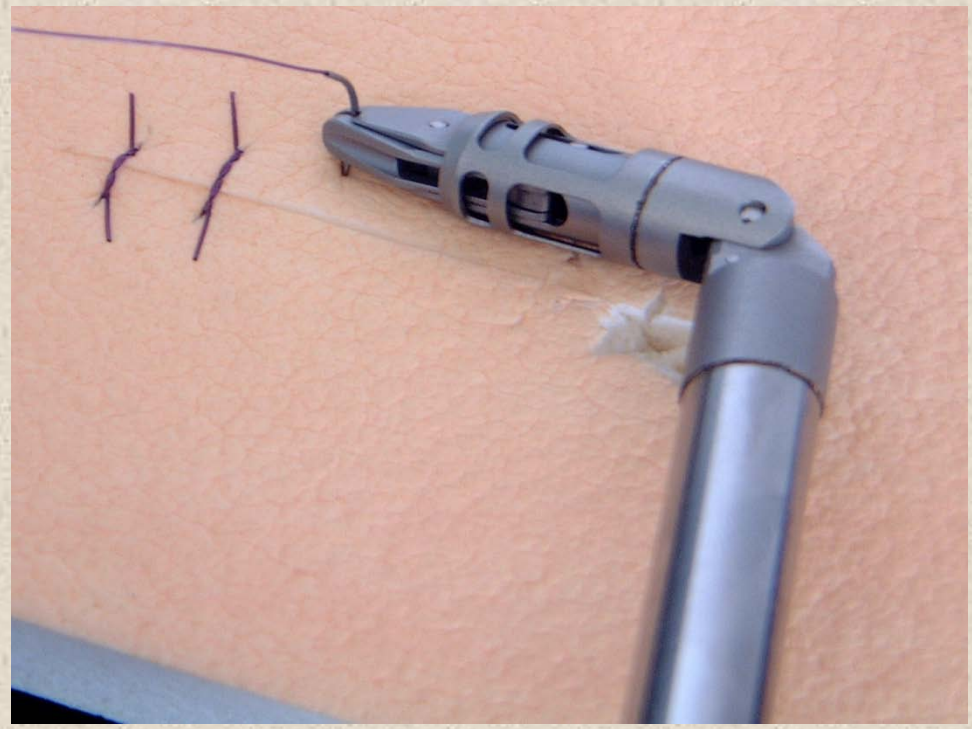
Radius system

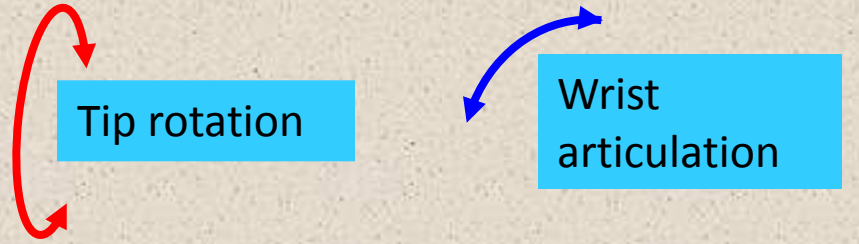
Video 5

DARES: wheel and joystick control

video

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

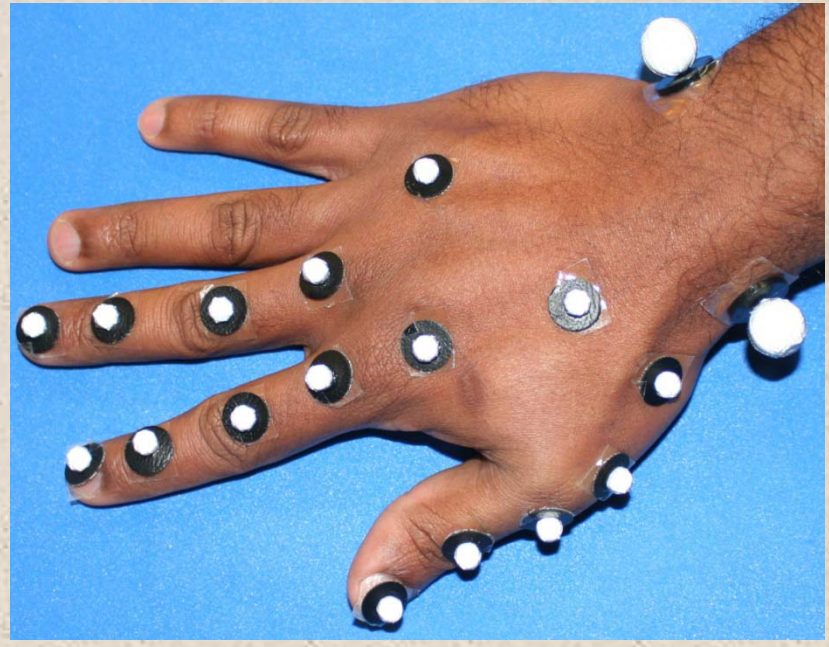




Trunk-arm-hand-wrist-palm-fingers-motion analysis

Vicon motion capture system

Markers on wrist, palm and fingers

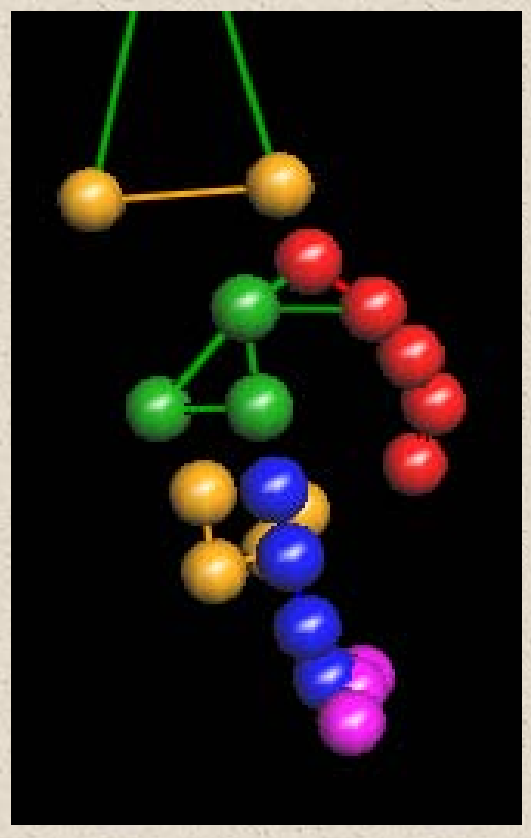


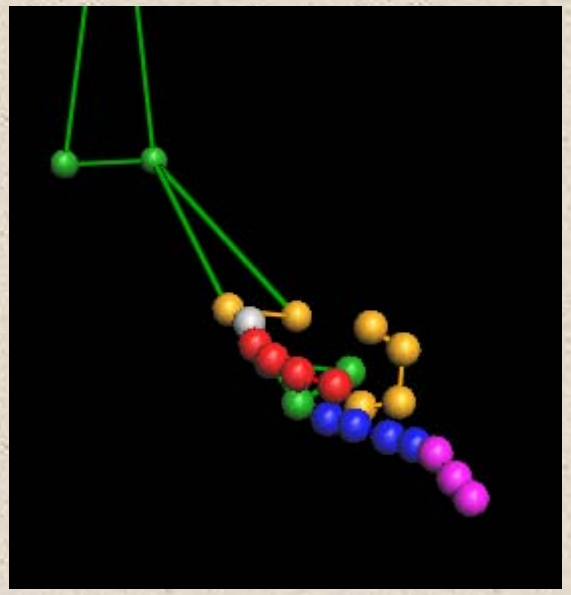
Hand-held manipulators studied by Vicon system during endoscopic dissection tasks

Wheel translation mechanism

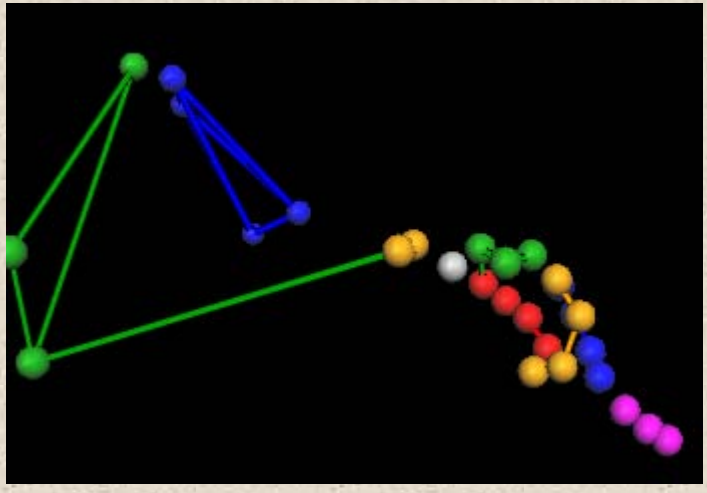
Joystick translation mechanism

Vicon analysis: extreme wrist movements by joystick manipulator



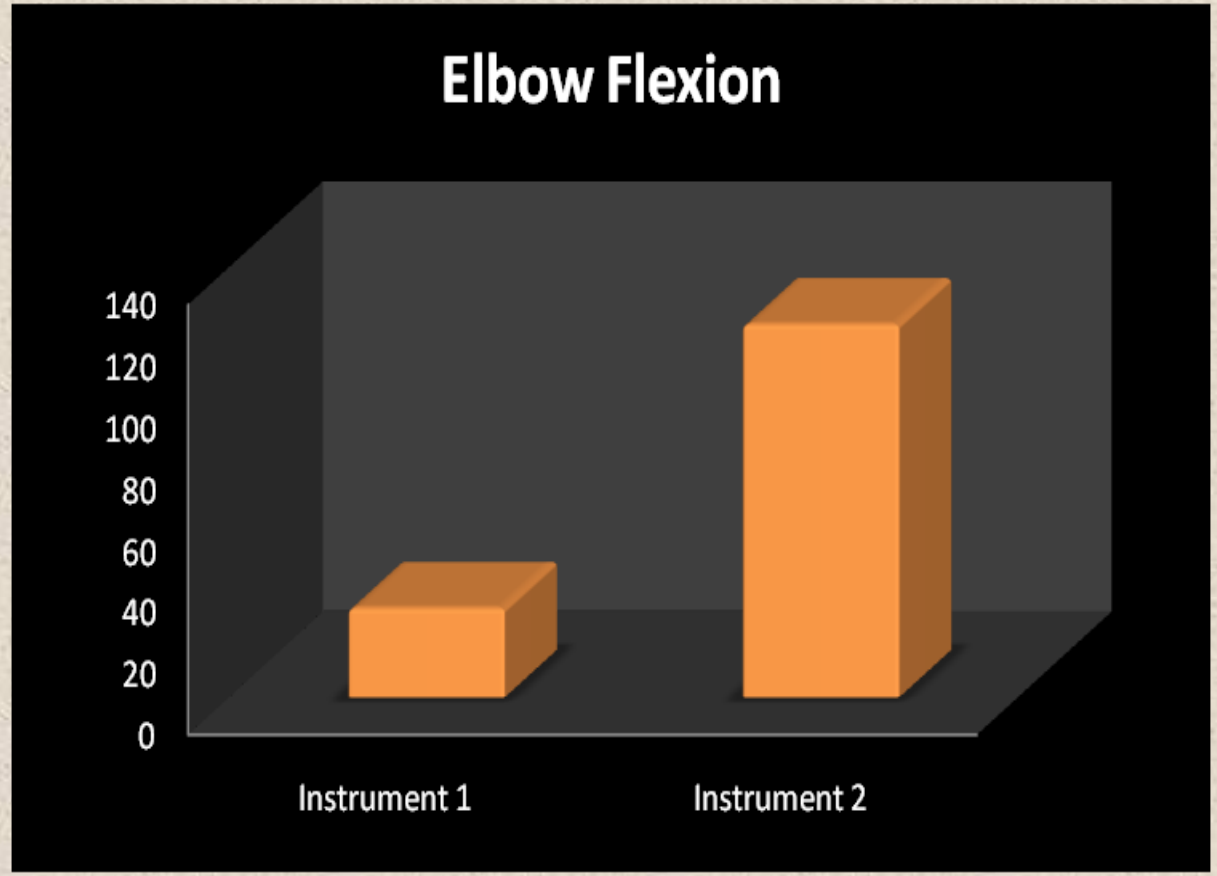


Extreme wrist supination with joystick manipulator



Extreme wrist flexion with joystick manipulator

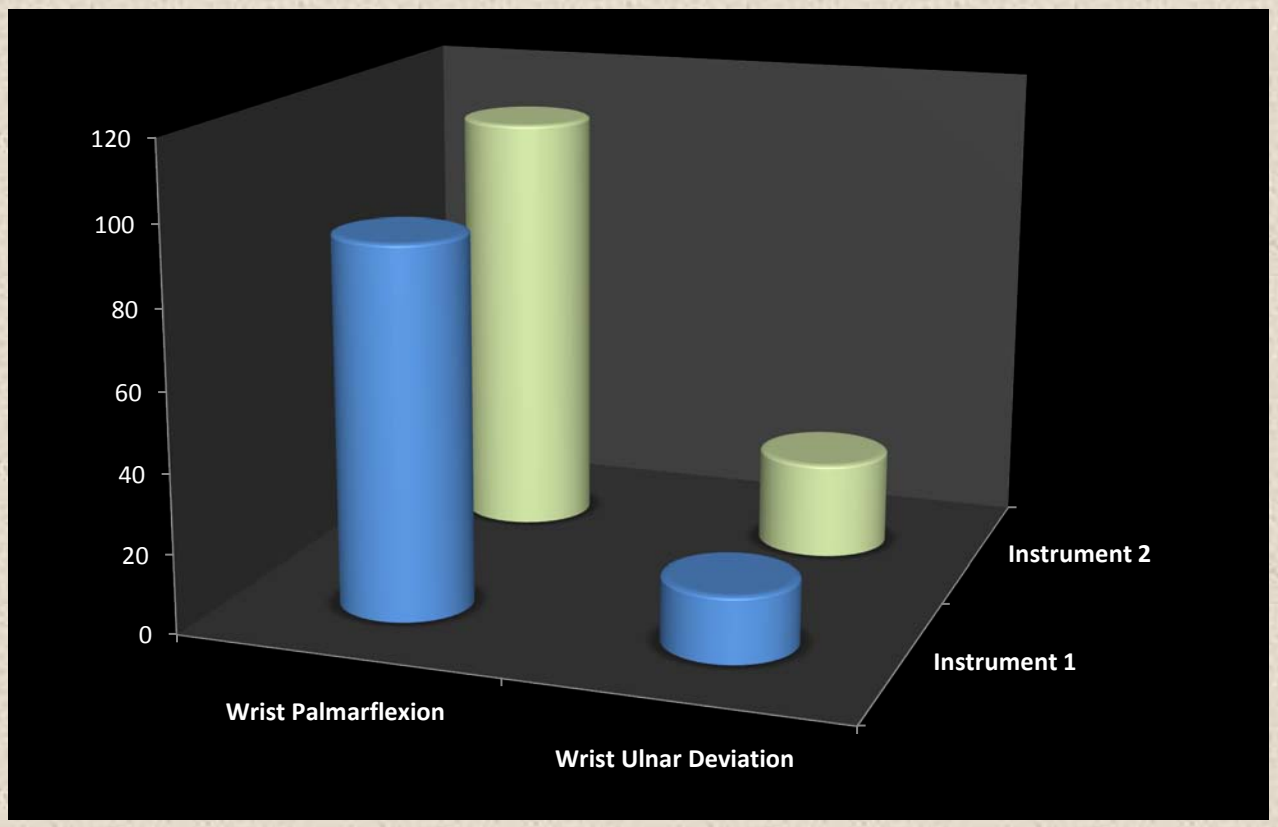
Vicon analysis: elbow flexion with the two manipulators



Instrument 1 = wheel

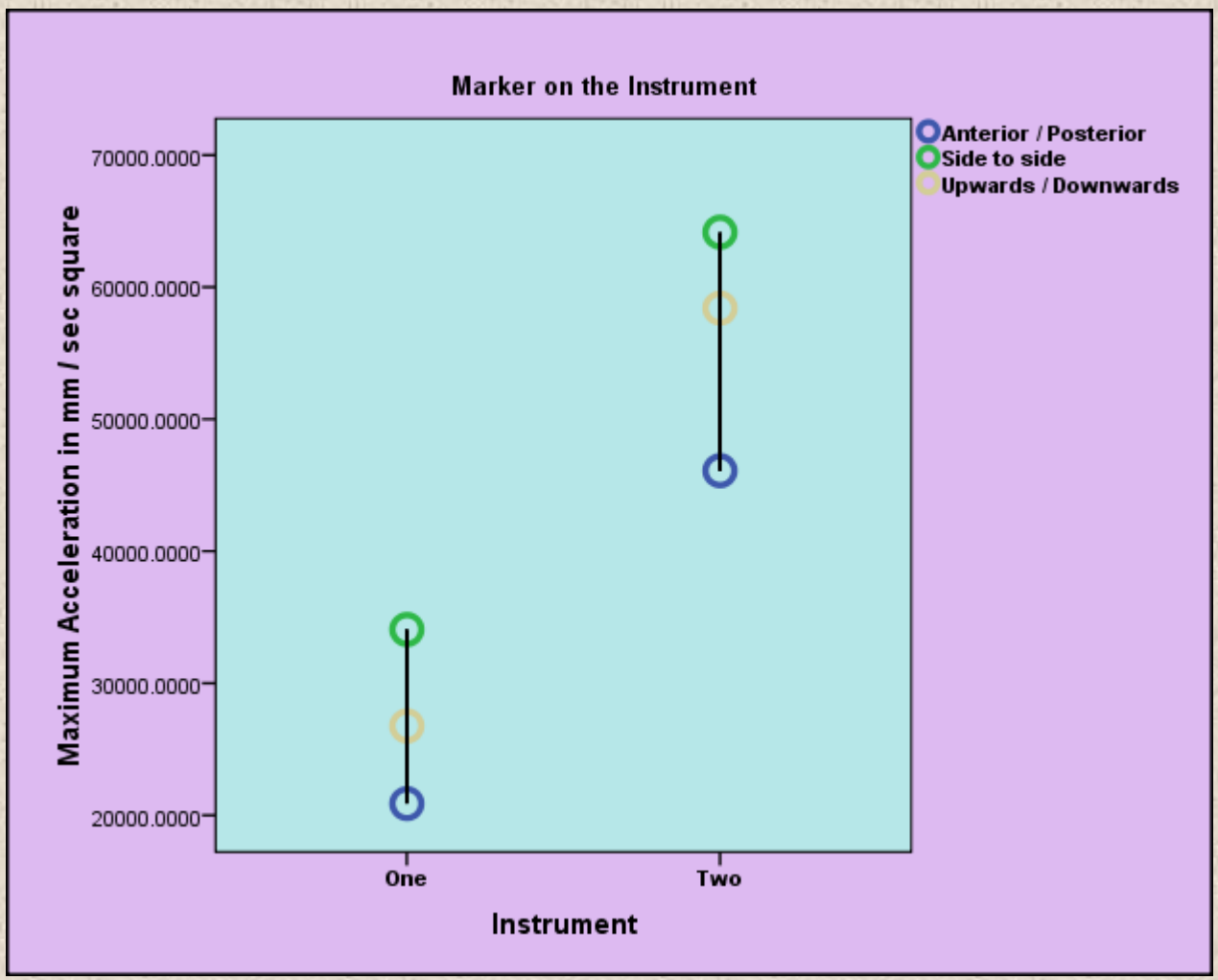
Instrument 1 = joystick

Vicon analysis: wrist palmar flexion and ulnar deviation with the two manipulators



Instrument 1 = wheel, instrument 2 = joystick

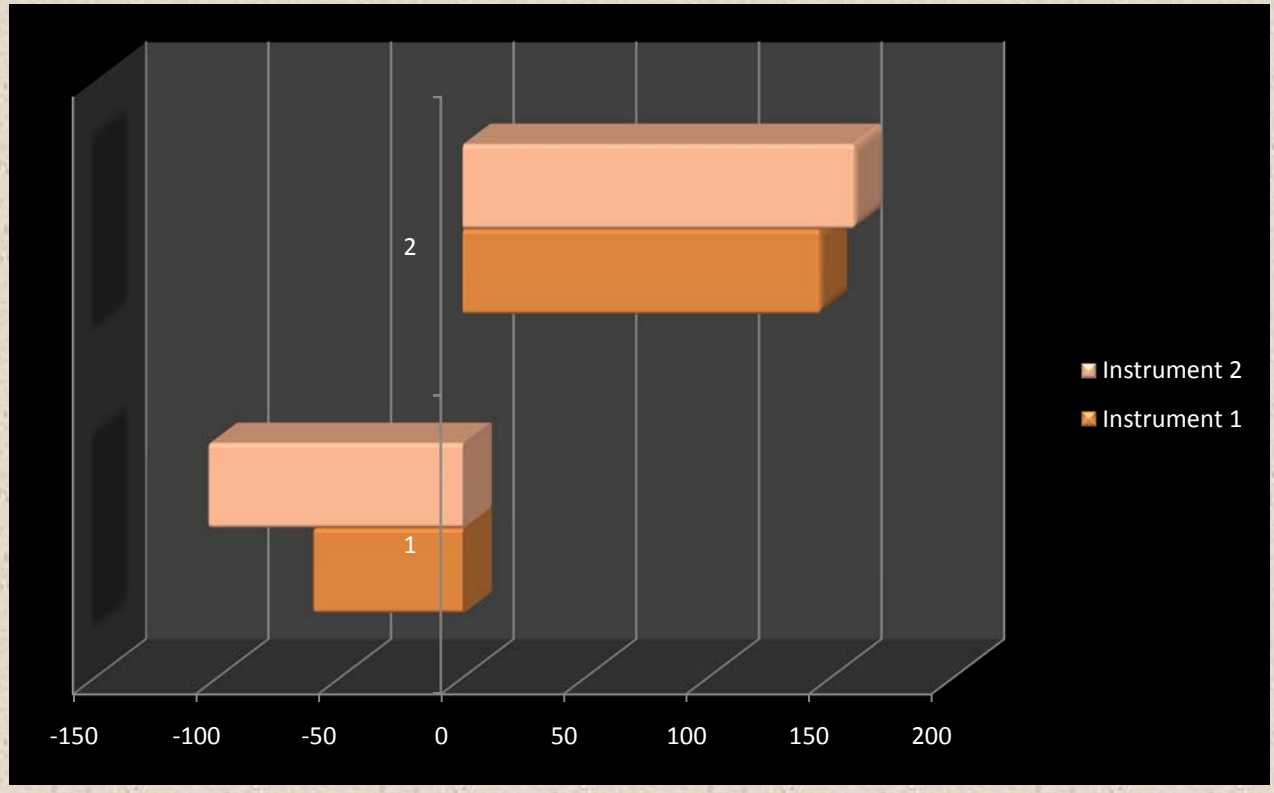
Vicon analysis: maximum acceleration with the two manipulators



Instrument 1 = wheel

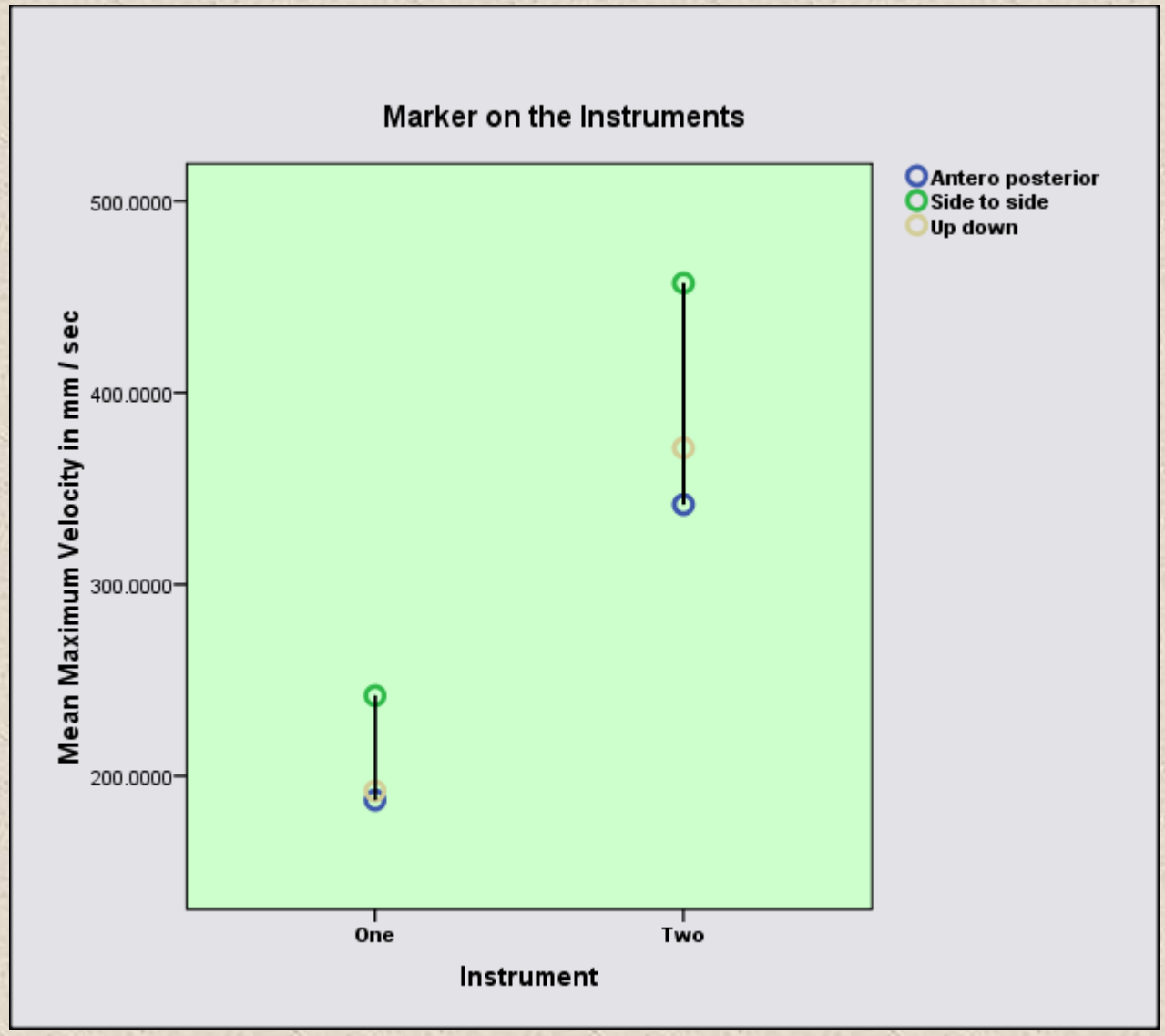
Instrument 1 = joystick

Vicon analysis: trunk movements with the two manipulators



Instrument 1 = wheel, instrument 2 = joystick

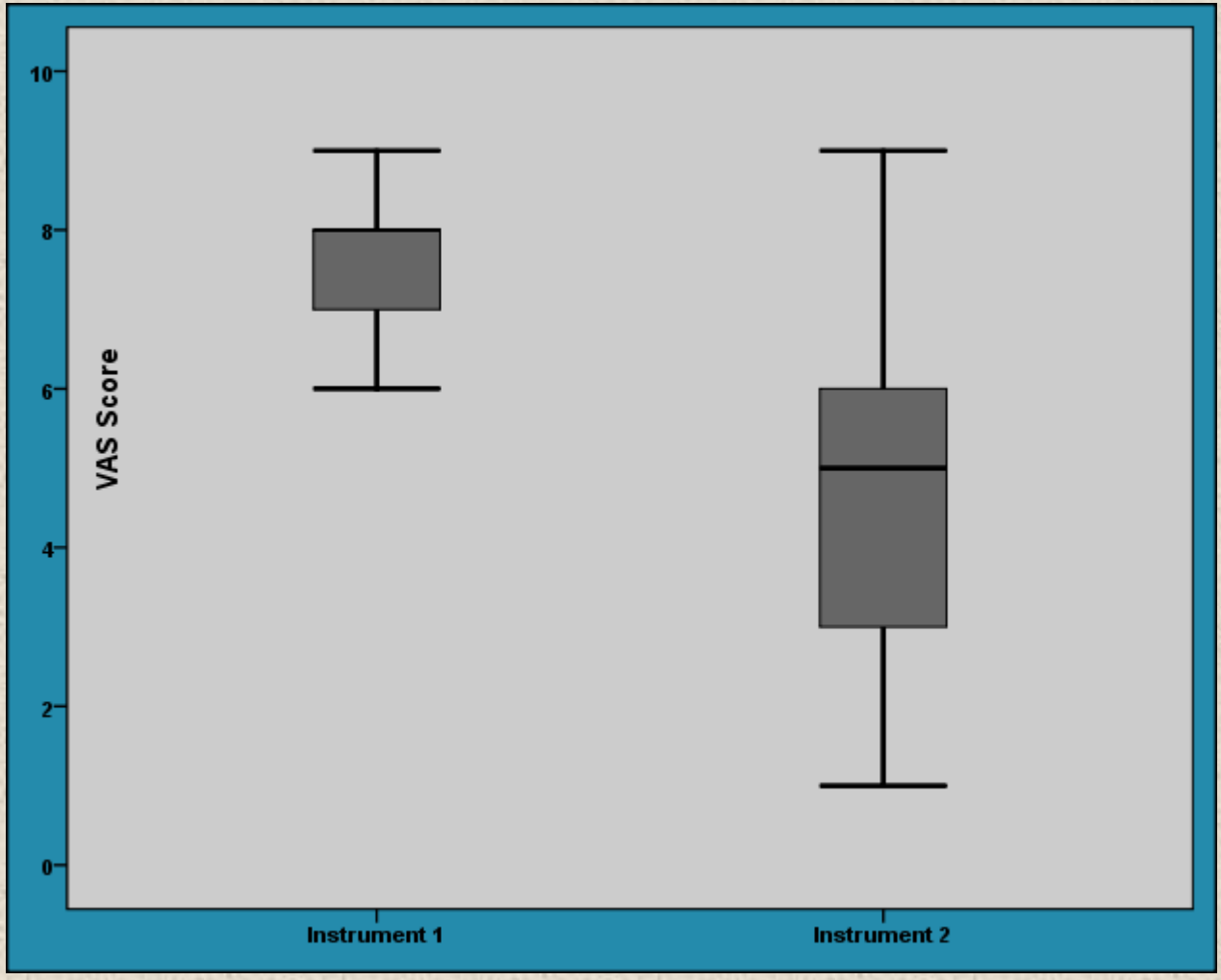
Vicon analysis: maximum velocity with the two manipulators



Instrument 1 = wheel

Instrument 1 = joystick

VAS Scores by participating surgeons (n = 20) for the two manipulators

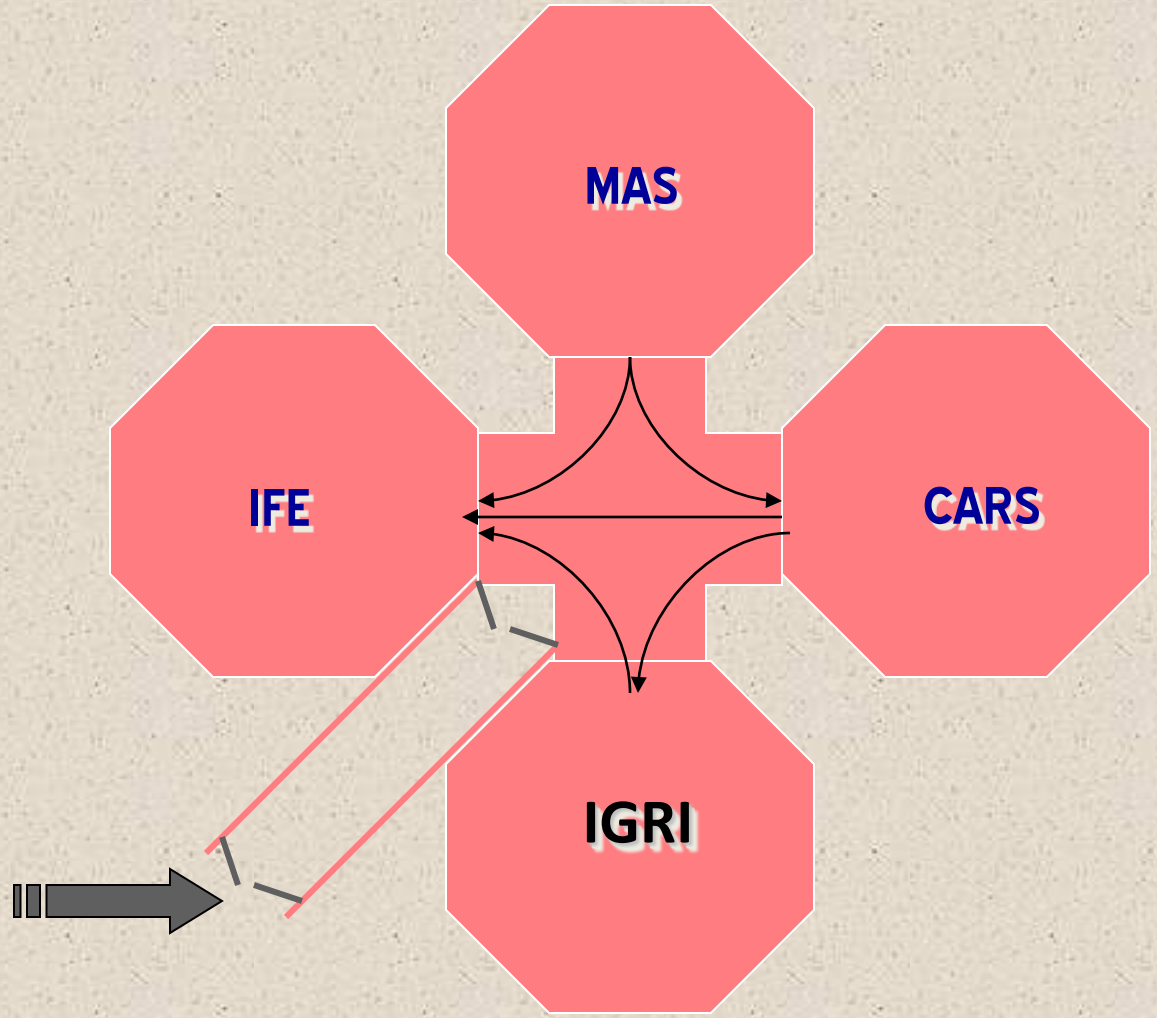


Problems with hand-held manipulators

- 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 indvidualised
- Excision will be replaced by ablation or vaporisation
- Operating rooms replaced by interventional therapy clusters



Pink area
sterile

Concept of Interventional OR Cluster

Medical Robots

- Should not occupy large volumes of space
- Should improve on and not just equal quality of medical care
- Place of humanid 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*