Periscopic Spine Surgery
Technology Developments in Minimally Invasive Procedures

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Washington, DC

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Overview of Presentation

Background
ISIS Center / mobile CT
Medical robotics
  – Review
  – Spinal nerve blocks at Georgetown
Image-guided surgery (magnetic localization)

Summary
Background
Georgetown University

Located in Washington, DC
Large, private university
– Medical school
– Law school
– International studies
Ranked in top 25 hospitals in U.S.
No engineering school
Radiology Equipment

2 MRI
- Research MRI: 7T
3 fixed CT
- Siemens SOMATOM Volume Zoom (CT fluoro)
Mobile CT scanner
2 angiography labs (+1 soon)
3 fluoroscopy units
- Siemens MultiStar
- Siemens NeuroStar biplane system
  • 3D Virtuoso software (accelerator board)
3 general radiology rooms
7 ultrasound machines
5 portable C-arms (3 angio capable)
1 PET scanner
ISIS Center

Imaging Science and Information Systems (ISIS)

Part of Radiology Department

Collaborations with many departments

30 people (faculty, staff, and support)

Completely externally funded

Director: Seong Ki Mun, PhD
ISIS Center Research Areas

Image processing
- Digital mammography
- Computer aided diagnosis

Telemedicine

Chronic disease: web-based monitoring

Computer aided surgery (image-guided surgery, medical robotics, etc.)
Mobile CT Scanner

Operational April 1998
117 cases to date (Feb 2000)

– Interventional Radiology
  • Spinal interventions
  • Drainage procedures

– Operating Room
  • Complex Spinal Tumor Resections
  • Head and Neck surgery
  • Craniotomies
Mobile CT Components

Gantry and Table

Workstation
Interventional Suite Layout
Volume Rendered Image
(Cement in Green)
Volume Rendered Image (Cement Green)
Tumor Resection in OR with mobile CT for visualization

Spine tumor resection & stabilization
Medical Robotics Review
Medical Robotics

• Tremendous potential for improving the precision and capability of physicians to perform minimally invasive procedures

• At the beginning of the application of robotics to medicine

• Many questions remain as to effectiveness, safety, and cost
Medical Robotics (continued)

• Several commercial companies selling medical robots
  – Total installed base is extremely small
  – Market will most likely continue to grow slowly

• While factory robotics grew rapidly during the 1970s and 1980s, medical robotics has not yet reached a critical mass

• Believed the benefits of medical robotics will become increasingly clear and this will lead to a continued rise in their use in medicine.
Clinical Applications

- Neurosurgery
- Orthopaedic
- Urology
- Maxillofacial
- Ophthalmology
- Radiosurgery
- Cardiology
Neurosurgery

- First recorded medical use of a robot
  - Kwoh 1985
- Simple positioning device to orient a brain biopsy needle
- Robot held a needle guide and surgeon inserted needle
- Not continued due to safety concerns
Neurosurgery: Minerva

Diagram showing a robotic system with components labeled as follows:
- Scanner
- BRW reference system
- Patient
- Robot control unit
- BRW - robot linkage arm
- Scanner table - robot linkage arm
- PC
- Main computer
- Table
MR Compatibile Robot

Courtesy, Nobuhiko Hata, Ron Kikinis SPL, Boston
Orthopaedics: RoboDoc Courtesy Integrated Surgical Systems
Radiosurgery

Accuray
(Stanford)

Cranial, spine, lung, pancreas, tracking of respiratory motion
Cardiology: Intuitive Surgical Telesurgery System

(www.intusurg.com)

Source: (Fox news archive)
Intuitive Surgical Components
Intuitive Surgical Console
Questions

Is there a large base of installed medical robots?
Are there niche markets?
Will robots replace surgeons?
Is there a robot in your future?
Spine Robotics at Georgetown

Robot

Mobile CT gantry
Robot designed and constructed by Dan Stoianovici, PhD, Hopkins URobotics Laboratory; Georgetown

Mechanical arm

Touch screen and joystick controls

Mounting base
Robot in Interventional Suite
Robotically Assisted Nerve and Facet Blocks: Purpose of Clinical Study

To demonstrate that a physician controlled robotic needle driver is equivalent in safety and effectiveness to the standard manual technique for needle placement in nerve and facet blocks in the perispinal region.
Nerve and Facet Blocks

Typically done by interventional neuroradiologists
For both diagnosis and therapy
Requires accurately placing a thin needle (usually 22 gauge) under fluoroscopic guidance
Typical procedure time: 30 minutes
High volume procedure
Not technically demanding
Cadaver Study

Purpose: evaluate feasibility of using robot to place needle for perispinal nerve and facet blocks

Date: 1 September 2001
Materials and Methods

Small metal BB targets placed in lumbar spine at 3 levels
6 nerve block targets and 6 facet block targets
Physician attempts to drive needle to target using joystick to control robot
Accuracy of placement evaluated on x-ray images (goal: within 3 mm)
BBs Used as Targets
Placement of Target BB’s
Scout CT Showing BB Targets
Physician Operating Robot
Robot and Needle Holder
Anterior/Posterior Fluoro Image
Lateral Fluoroscopic Image of BB Needle
Axial CT Image of BB & Needle Tip
Results & Conclusion

All 12 needles were placed within 3 mm of the target BB

A joystick controlled robotic needle driver can be used by the interventionalist to accurately place needles in the nerve and facet regions.

Clinical studies are required to investigate the advantages and disadvantages of this system for interventional needle procedures.
FDA Approval Received

20 patients in initial study
100 patients next
March 2002
IRB approvals
– Georgetown
– Army
Periscopic Spine Surgery

FDA IDE clinical trial study outline

Pre-Procedural Baseline Screening
- Meets Inclusion/Exclusion Criteria
  - Yes: Obtain Informed Consent
  - No: Do Not Enroll

Pre-Procedural Consultation

Randomize to Robotic Assistance or NO Robotic Assistance

Perform Procedure

Post Procedural Consultation

END
Benefits of Robotic Guidance

- Improved path planning
- More precision control of needle trajectory
- Allows operator to advance needle and view trajectory in real-time without exposure to x-ray field
And now to the video...
Localization (non-line-of-sight tracking)
Liver Respiratory Motion Simulator

Goal: demonstrate magnetic tracking technology for interventional procedures
Initial target: liver
Collaboration with Northern Digital & Traxtal Technologies

AURORA™ magnetic tracking system Left to right: control unit, sensor interface device, and magnetic field generator
(Courtesy of Northern Digital Inc.)
AURORA Tracking System

1. Tetrahedron shaped field generator
2. The position sensor is made of an induction coil with a diameter of 0.9 mm
Liver Respiratory Motion Simulator Components

Figure 1: System Components

- (a) Motor Control Box
- (b) Catheter
- (c)Torso With Liver Assembly
- (d) Magnetic Field Generator
- (e) AURORA Control Box
- (f) Probe
- (g) Graphical User Interface Monitor
- (h) Catheter
- Control Computer
Demonstration: Berlin June 2001
Clinical Scenario

Pre-procedure CT

Registration step
– Fiducials in CT space
– Fiducials in magnetic space

Provide image overlay and respiratory tracking during procedure

Confirming image upon completion
Interventional Suite Testing
Results: Biopsy Experiments

<table>
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<tr>
<th></th>
<th>Mean Planning Time (s) ± SD</th>
<th>Needle Manipulation Biopsy Time (s) ± SD</th>
<th>Total Procedure Time (s) ± SD</th>
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<tbody>
<tr>
<td>User 1</td>
<td>72 ± 35</td>
<td>79 ± 40</td>
<td>151 ± 59</td>
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<tr>
<td>User 2</td>
<td>61 ± 31</td>
<td>111 ± 41</td>
<td>172 ± 43</td>
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<tr>
<td>Overall</td>
<td>71 ± 36</td>
<td>93 ± 43</td>
<td>163 ± 57</td>
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# Results: Vessel Puncture

<table>
<thead>
<tr>
<th></th>
<th>Successful Attempts</th>
<th>Unsuccessful Attempts</th>
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<tr>
<td>Mean Duration of Attempts (sec)</td>
<td>21.2</td>
<td>22</td>
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<tr>
<td>Standard Deviation</td>
<td>4.6</td>
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<tr>
<td>Mean Error (mm)</td>
<td>4.8</td>
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<tr>
<td>Standard Deviation</td>
<td>2.2</td>
<td>2.6</td>
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Cadaver Study: Introducing Catheter
Cadaver Study: Field Generator
Liver Simulator Demo Video
Summary

Focus on precision minimally invasive procedures
Clinical relevance is key
Collaboration between engineer and physician
Prospects for future are bright
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