Percutaneous Spinal Injections – problem presentation for HW1

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Why Needles?

- Potentially significant impact on medical practice
  - Minimally invasive (compared to open surgery)
    - Faster recovery
    - Less morbidity
    - Fewer complications
    - Lower cost
    - Repeatable in many indications
  - Sharply increasing number of procedures

- Challenging but doable
  - Constrained process – formally describable
  - Major challenges (in addition to open/lap surgery):
    - no visibility
    - no access
    - no room to maneuver
    - no room to recover
Why Spine? Why pain management?

- In US alone 70% of population affected in lifetime
- Single most expensive disease
- Pain management: alleviate pain caused by stressed/pressured/pinched spinal nerve by suppressing sensory input at nerve root
- Numb with lidocaine/novocaine etc.
Key technical issues

- Accuracy
  - Longevity of pain relief
  - Collateral damage
  - Pain during procedure
  - Acceptable ~ 1mm
- Time
  - Volume/throughput = money
  - Good surgeons < 10 min
  - Mediocre/poor surgeons ~ 30-40 min
- Toxic radiation – primarily to physician !!!
  - Good surgeons < total 5.0 sec beam time
  - Mediocre/poor surgeons ~ 30 sec beam time
Current standard 1: CT guidance
Affix IZI Biopsy Strip  Pick Entry and Target
Current workflow for CT-guided procedure

1. Put patient in prone to scanner
2. Palpate vertebra
3. Affix IZI Biopsy Strip fiducials
4. Take thin volume scan
5. Select slice of interest
6. Pick target and entry
7. Determine angle and depth
8. Pull out patient to outer laser plane
9. Identify entry on skin
10. Touch needle to entry point
11. Enter needle manually – 22G beveled
12. Maintain insertion angle by sight
13. Keep needle in laser plane
14. Judge current insertion depth by feeling
15. **Insert contrast (optional)**
16. Push patient back to scan plane
17. Take confirmation CT
18. Pull out patient
19. Inject therapeutic agent
The challenge

- Transfer entry, angle and depth over patient
- Control all 3-DOF simultaneously during insertion
Current standard 2: C-arm Fluoroscopy

- Mobile
- Real-time
- Inexpensive
- Broad coverage

- Limited rotation
- X-ray dose
- Low soft tissue contract
- Need for calibration
- Need for tracking

Courtesy of Siemens
Current workflow for Fluoro-guided procedure

1. Put patient in prone on table
2. Palpate vertebra
3. Set C-arm in anticipated needle direction
4. Turn on beam
5. Adjust C-arm angle to optimal
6. Reach into beam with needle
7. Touch entry with needle tip
8. Keep needle perpendicular to beam
9. Optimize entry location
10. Fulcrum with needle till barrel-view
11. Turn off the beam
12. Rotate C-arm by 90 degrees
13. Turn beam on, keep beam on
15. Monitor insertion depth/deflection in image
16. Stop needle at target position
17. **Insert contrast (optional)**
18. Take confirmation C-arm image
19. Inject therapeutic agent
Handheld Needle Guide
CT-Mounted Laser Guide
CT-Mounted Image Overlay

Goal: Simple and radiation-free X-ray vision during surgery
Approach: Merging data model with physical space through half-mirror
Future work: Cadaver studies in June/July 2003

Industry partner: Siemens
Funded by Siemens, PI: Fichtinger
Robot assistance: 3-DOF RCM-PAKY

Robot: D. Stoianovici

Robot

- 7-DOF passive arm
- Locking arm
- 2-DOF Remote Center of Motion robot
- 1-DOF needle injector w/ mounted stereotactic fiducials
- Joysticks and safety switches
- Table side robot mount
- Amplifier box

Robot assistance: 3-DOF RCM-PAKY

Robot: D. Stoianovici
Robot-CT Registration: Stereotactic Adapter

Robot registered to CT from a single image using stereotactic frame on the end-effector

Credit: D. Stoianovici, L. Kavoussi, A. Patriciu, S. Solomon (JHU Bayview)
CT-Robot Registration: Stereotactic Adapter
Surgical planning...
Robot-CT Registration: Scanner’s Laser

Robot registered to CT using the scanner’s alignment laser

Credit: D. Stoianovici, L. Kavoussi, A. Patriciu, S. Solomon, JHU Bayview and G. Fichtinger, ERC
The URobotics 6-DOF Accubot™ robot

- 7-DOF passive arm
- 2-DOF rotation motion stage
- 1-DOF Needle insertion stage
- 3-DOF Cartesian motion
- Mounting bridge

Robot: D. Stoianovici
Robot-CT Registration: Optical Tracking
Robot-CT Registration: Optical Tracking

Diagram showing the relationship between different coordinate systems, including CT Coordinate System, Phantom Head and Foot, Robot Tracker Coordinate System, RCM coordinate system, Bridge coordinate system, and Passive Arm.
Robot-CT Registration: Fiducial carrier attached to spinous process
Robot-C-arm registration: Simple fiducial-based registration in biplane fluoroscope
Corkscrew fiducials in monoplane fluoroscope
Joystick Controlled Robot Under Fluoroscopy