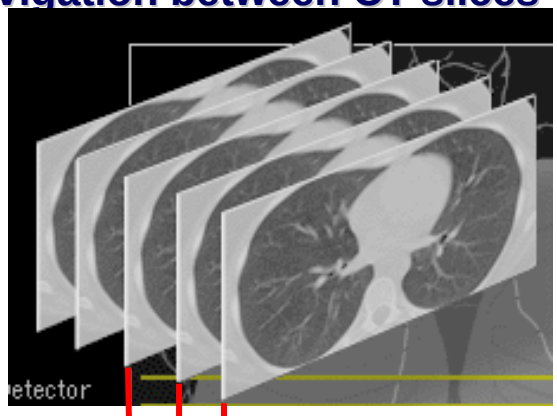
Needle guidance with Computed Tomography (CT)

Computed Tomography

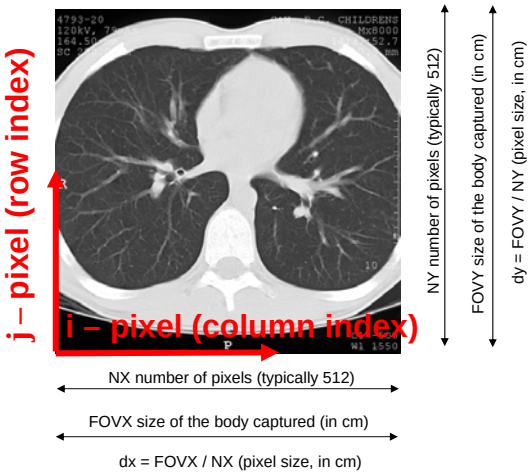
- Widely available
- Reasonable cost
- Broad insurance coverage
- Excellent hard tissue
- Reasonable soft tissue

- 2D by nature
- Limited angles
- X-ray dose
- Access to patient

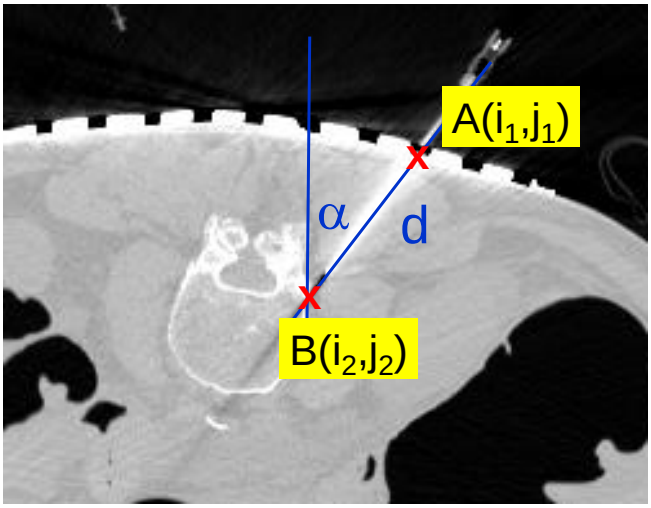
Navigation between CT slices



Navigation in a CT Slice



Calculate needle angle (α) and depth (d)



Conversion between pixel and metric coordinates in CT imaging

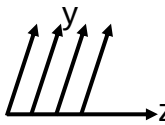
P(xyz) = P(i*dx, j*dy, k*th)

Where:

dx = FOVX / NX
dy = FOVY / NY

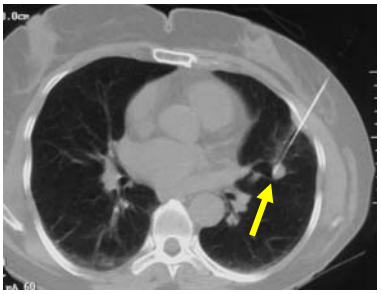
FOVX, FOVY, NX, NY, th are usually printed on the CT image

Tilted CT gantry



No longer a Cartesian coordinate system

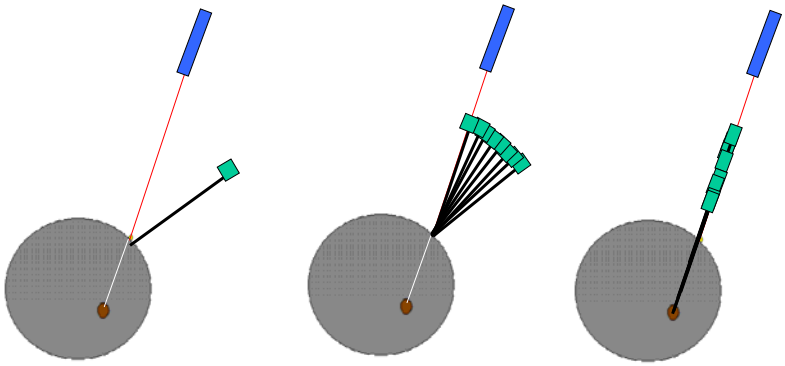
The needle placement challenge



- **To navigate a needle to a certain point within the body that corresponds to the same point in a CT-image**

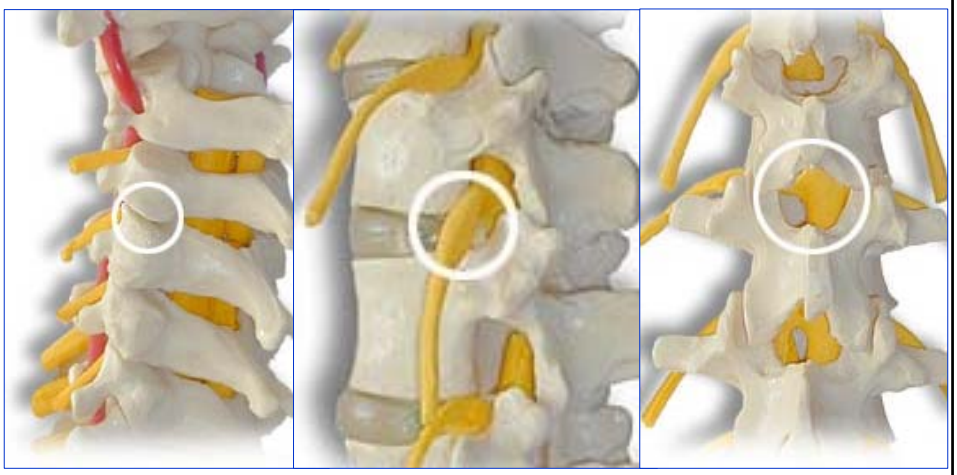
Needle insertion as a 5-DOF problem

Decoupled motion



3-DOF Cartesian	2-DOF pivoting	1-DOF or 2 -DOF insertion
Safe but feasible	**Must be very accurate**	**Assumes no bending and accurate depth**

Example: spinal pain management

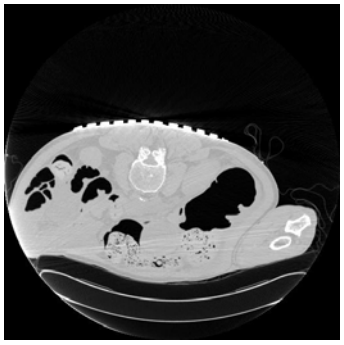


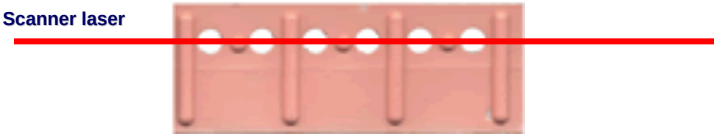
Targeted areas in facet joint injection (left), nerve block (middle), and epidural space injection (right). All figures show the lumbar spine. Facet joint injections and nerve blocks are also frequently performed on the thoracic and cervical spine.

Key Clinical Issues

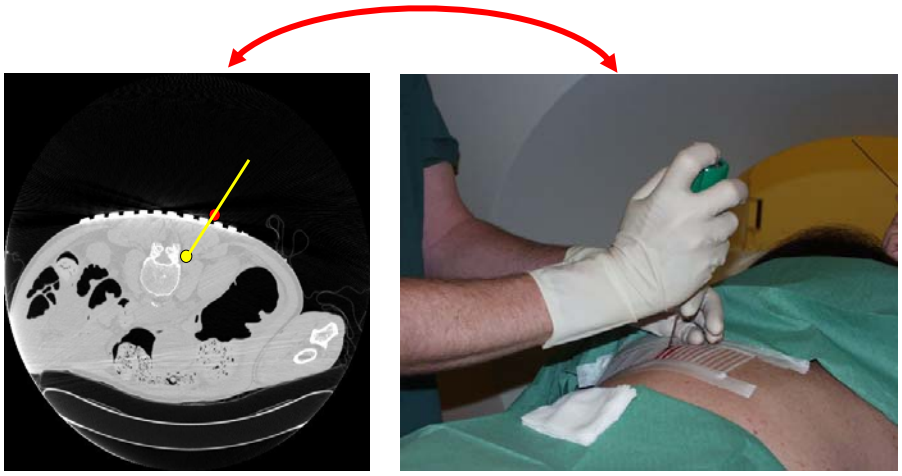
- **Accuracy**
  - Longevity of pain relief
  - Collateral damage
  - Pain during procedure
  - Acceptable ~1mm
  - Access/accuracy challenges in 10% of cases for good surgeons
- **Time**
  - Time = Money
  - High volume / high throughput procedure
  - Good surgeons ~10 min, others may be 45 min
- **Toxic radiation**
  - Primarily concern is physician & staff
  - Typical fluoro times:
    - Good surgeons ~5 sec total beam time
    - Others may be 30+ sec total beam time

Mark the plane of interest with fiducial strip



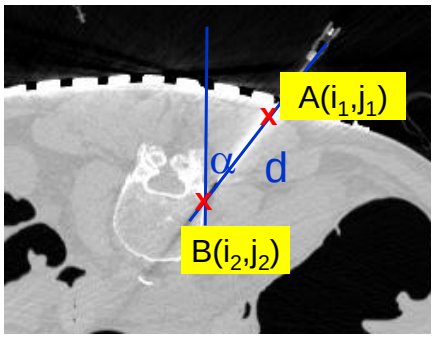


Entry point based on fiducial



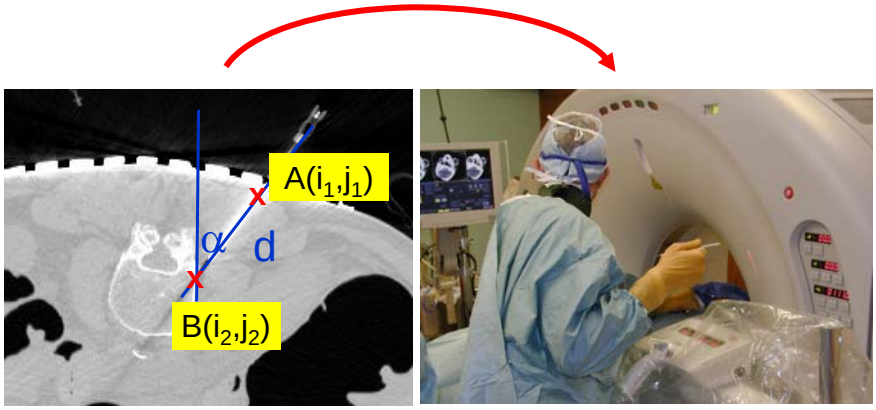
NeoRad.com

Workflow for CT-guided injection



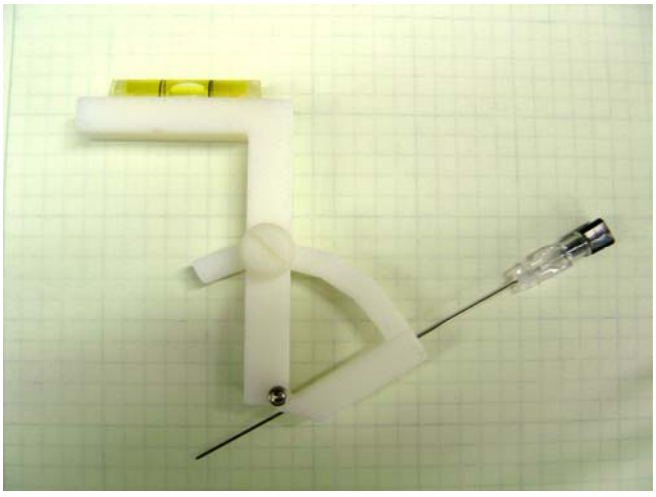
1. Put patient in the scanner
2. Palpate vertebra
3. Take thin volume scan
4. Select slice of interest
5. Affix fiducial strip
6. Take single slice
7. Pick target and entry
8. Determine angle and depth
9. Identify entry on skin
10. Touch needle to entry point
11. Maintain insertion angle
12. Keep needle in laser plane
13. Judge current insertion depth
14. *Insert contrast (if need to)*
15. Push patient back to scan plane
16. Take confirmation CT
17. Pull out patient
18. Inject therapeutic agent

The challenge



- **Transfer entry, angle and depth onto the patient**
- **Control all 3-DOF simultaneously during insertion**

Handheld Needle Guide



Bubble level + protractor

Fichtinger, et al.

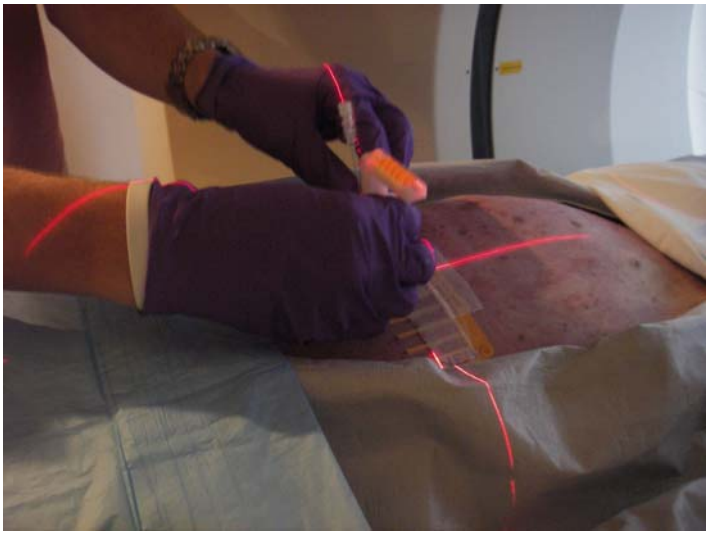
Handheld Needle Guide

Bubble level + protractor

Fichtinger, et al.

The Perk Labs – Laboratories for Percutaneous Surgical Interventions

Handheld Needle Guide



Bubble level + protractor

Fichtinger, et al.

The Perk Labs – Laboratories for Percutaneous Surgical Interventions

CT-Mounted Laser Overlay

Fichtinger, et al.

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CT-Mounted Laser Overlay

Fichtinger, et al.

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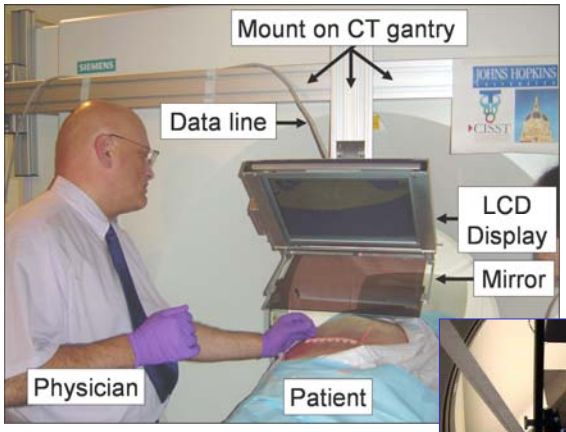
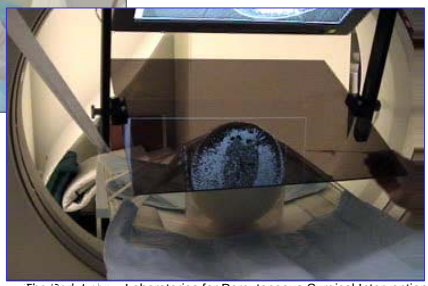
SimpliCT device by NeoRad

NeoRad.com

Image overlay





Fichtinger, et al.

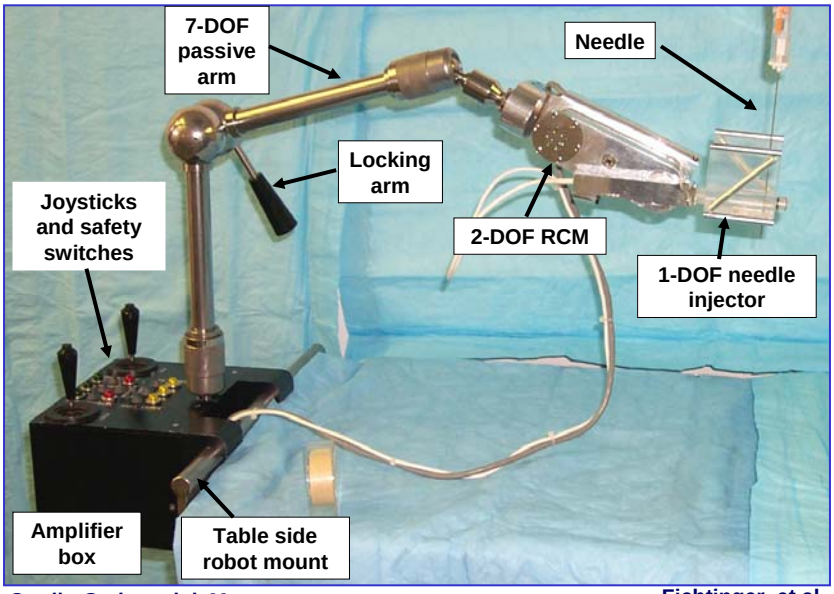
The Picker/Marconi/Philips/Immersion "Pinpoint" device

Immersion

Robot-assisted prostate biopsy

Fichtinger, et al.

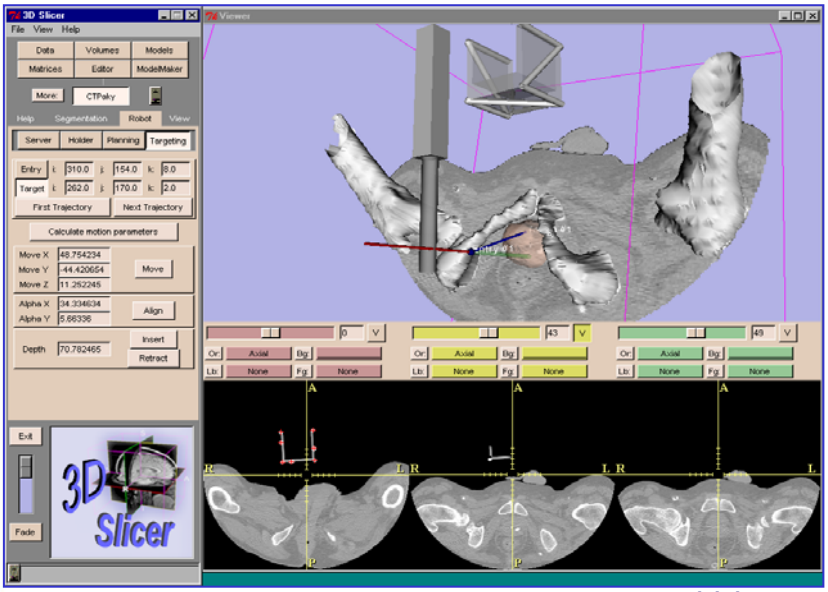
3-DOF decoupled robot



Credit: Stoianovici, Masamune

Fichtinger, et al.

Target & entry planning



Fichtinger, et al.

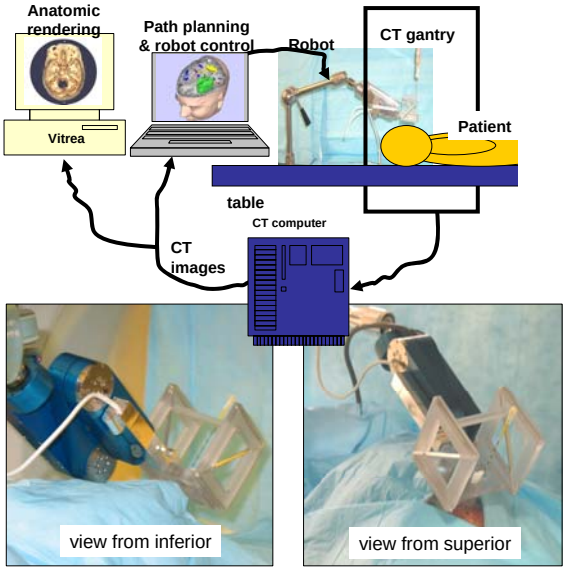
Robotic kidney biopsy

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

MOVIE

Credit: D. Stoianovici, L. Kavoussi, A. Patriciu, S. Solomon (JHU Bayview)

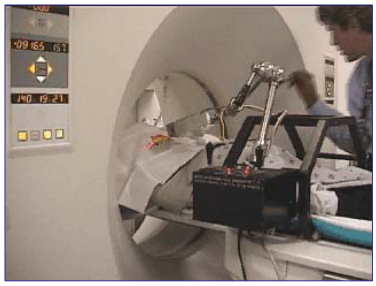
Robot assisted ICH removal

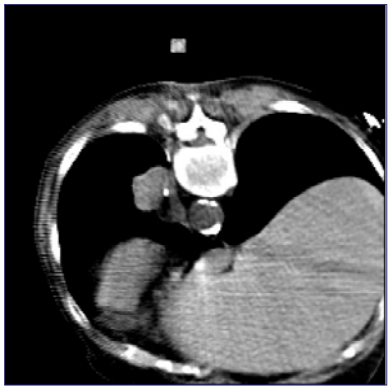


Fichtinger, et al.

Robotic lung biopsy

Robot registered to CT using the scanner's alignment laser

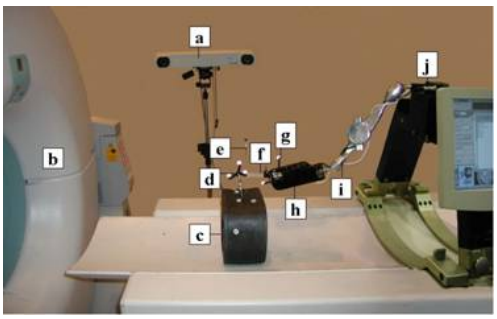


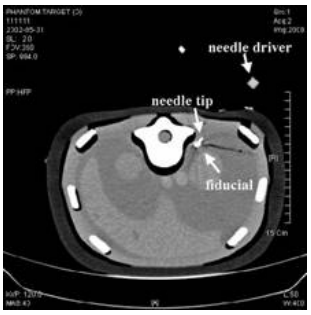


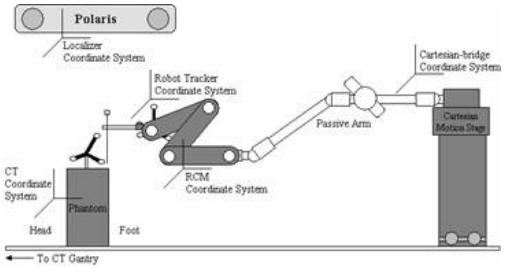
MOVIE

Credit: D. Stoianovici, L. Kavoussi, A. Patriciu, S. Solomon, JHU Bayview and G. Fichtinger, ERC

Robotic spine biopsy

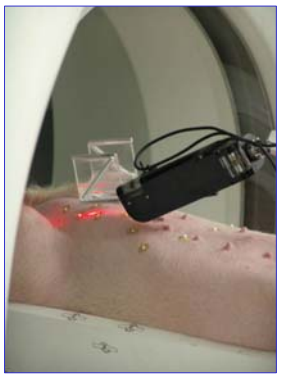


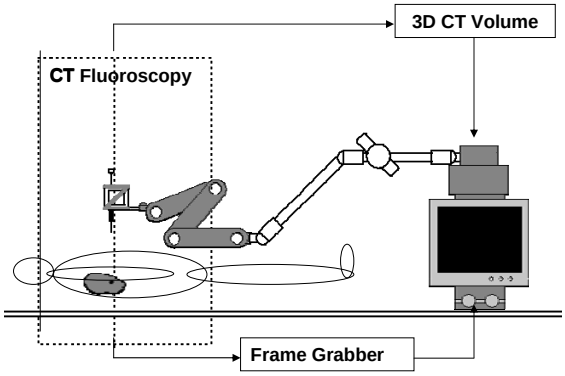


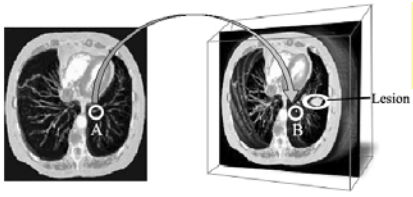


Fichtinger, et al.

Robotic lung biopsy w/ motion compensation







CT Fluoroscopy Image Pre-operative 3D CT Volume

Register real-time CTF to CT
Then compensate with robot

Fichtinger, et al.

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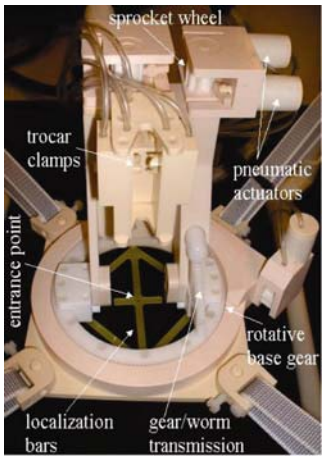
Patient mounted robot for biopsies



- CT/MR compatible
- No trajectory limitation
- Embedded localization
- Pneumatic actuation
- Accuracy <1.5mm

Troccaz, et al.

The Perk Labs – Laboratories for Percutaneous Surgical Interventions