

# Image-guided Spinal Anesthesia

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Research Council of Canada



CIHR IRSC  
Canadian Institutes of Health Research  
Instituts de recherche  
en santé du Canada



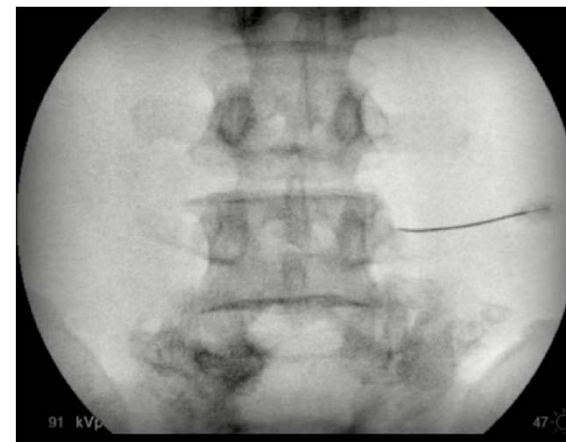
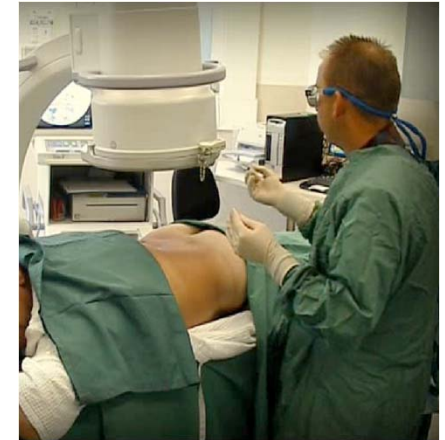
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# Spinal anesthesia

- Epidurals
  - Facet blocks
  - Spinal blocks
  - Spinal taps
- 
- All are done blindly or under fluoroscopic guidance
  - For example, it takes 60 patients for a resident to reach competency of 90% in epidural insertion.



Motivation / Tools / Planning / Guidance

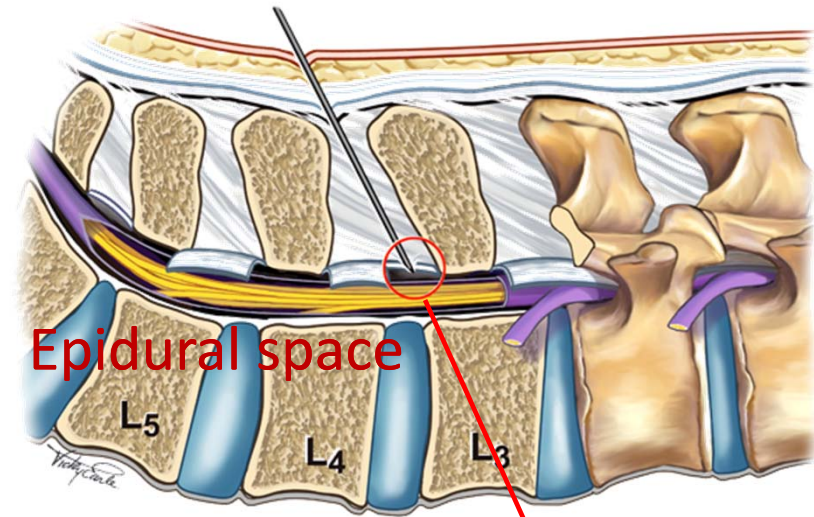


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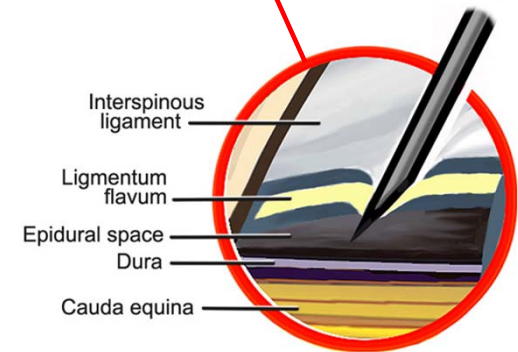


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# Epidural needle insertion



Epidural space



Motivation / Tools / Planning / Guidance



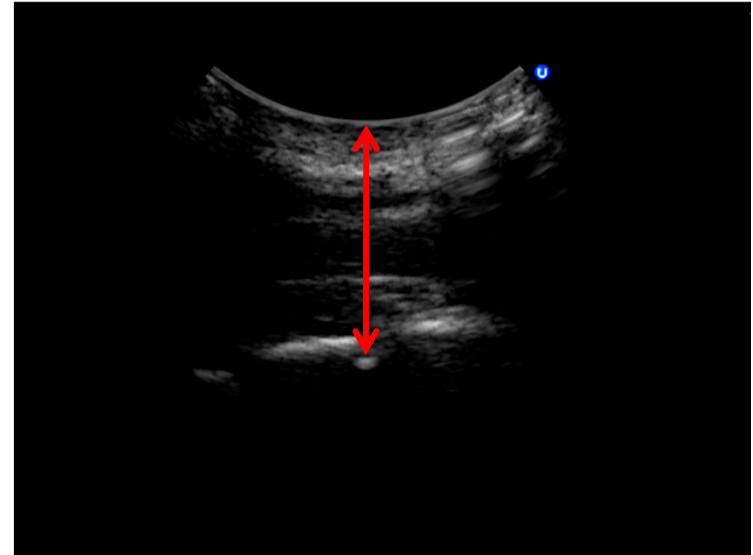
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# Image-based solutions

- Pre-puncture planning
- Real-time guidance
- Some tools may help:
  - Ultrasound: real-time
  - CT: off-line
  - Tracking equipment
  - User interface/software



Motivation / **Tools** / Planning / Guidance

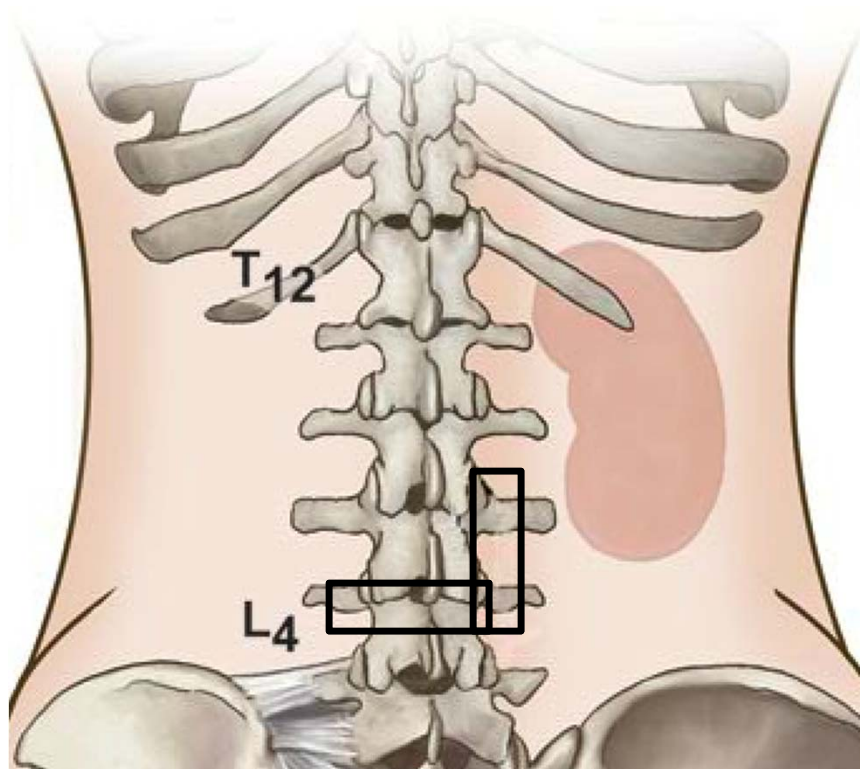


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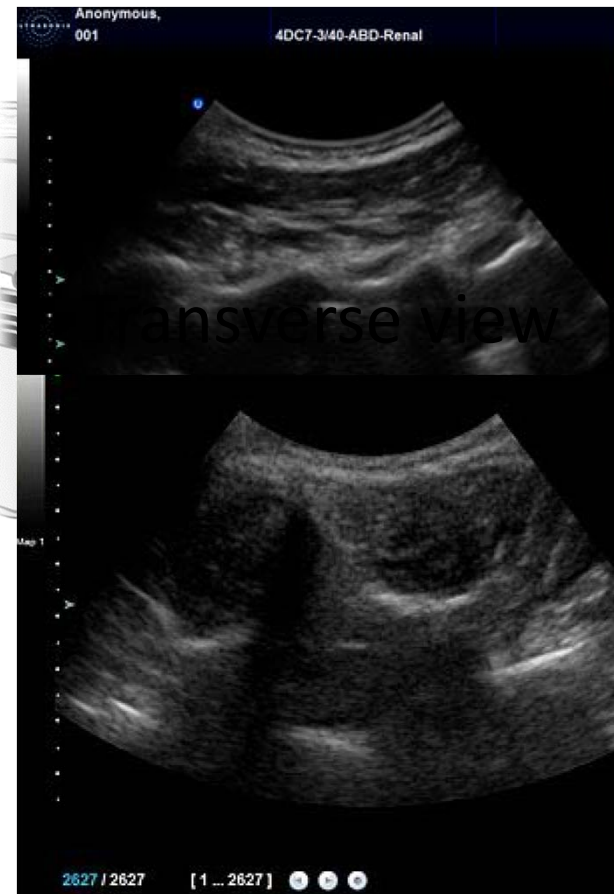


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# Prepuncture 2D ultrasound in epidural



## Para-median view



Motivation / **Tools** / Planning / Guidance

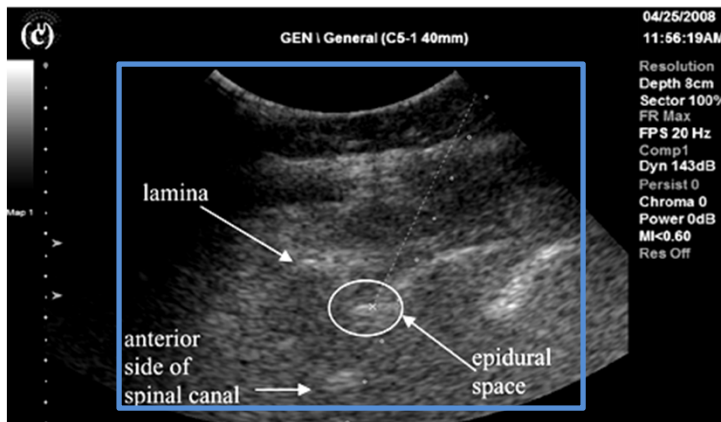
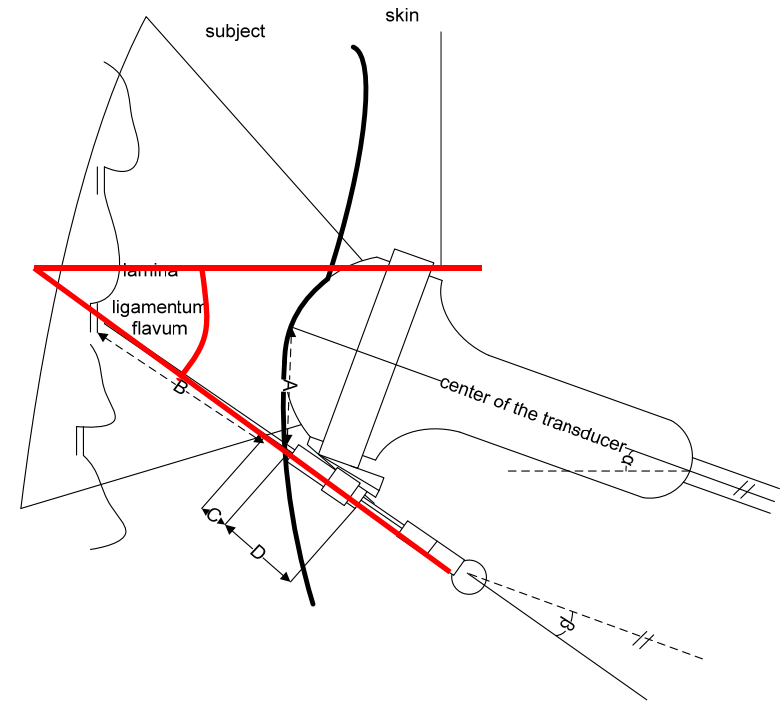
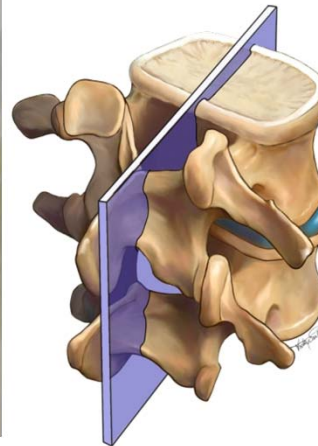


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# Real-time needle guidance using 2D ultrasound



Steep angle: longer needle path  
Paramedian view: painful needle insertion through spinae erector muscle

No context

Motivation / **Tools** / Planning / Guidance

**Tran'10**



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# Needle tracking – commercial tools

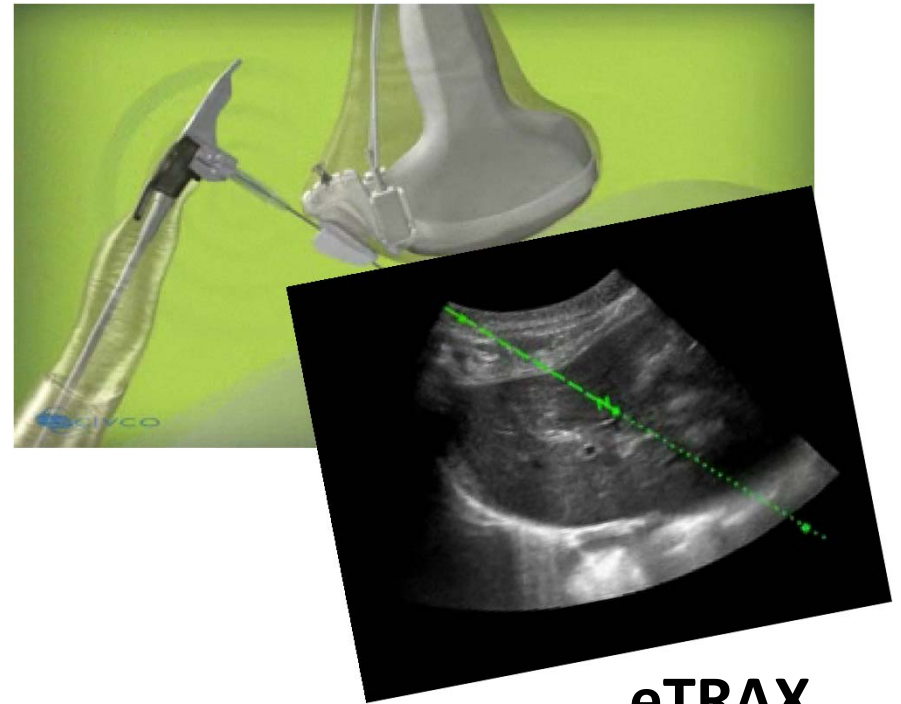
## Examples

### SonixGPS

Ultrasonix, Richmond, BC,  
Canada



Sensor-based tracking



### eTRAX

Civco Inc., Kalona, Iowa,  
US

Motivation / **Tools** / Planning / Guidance

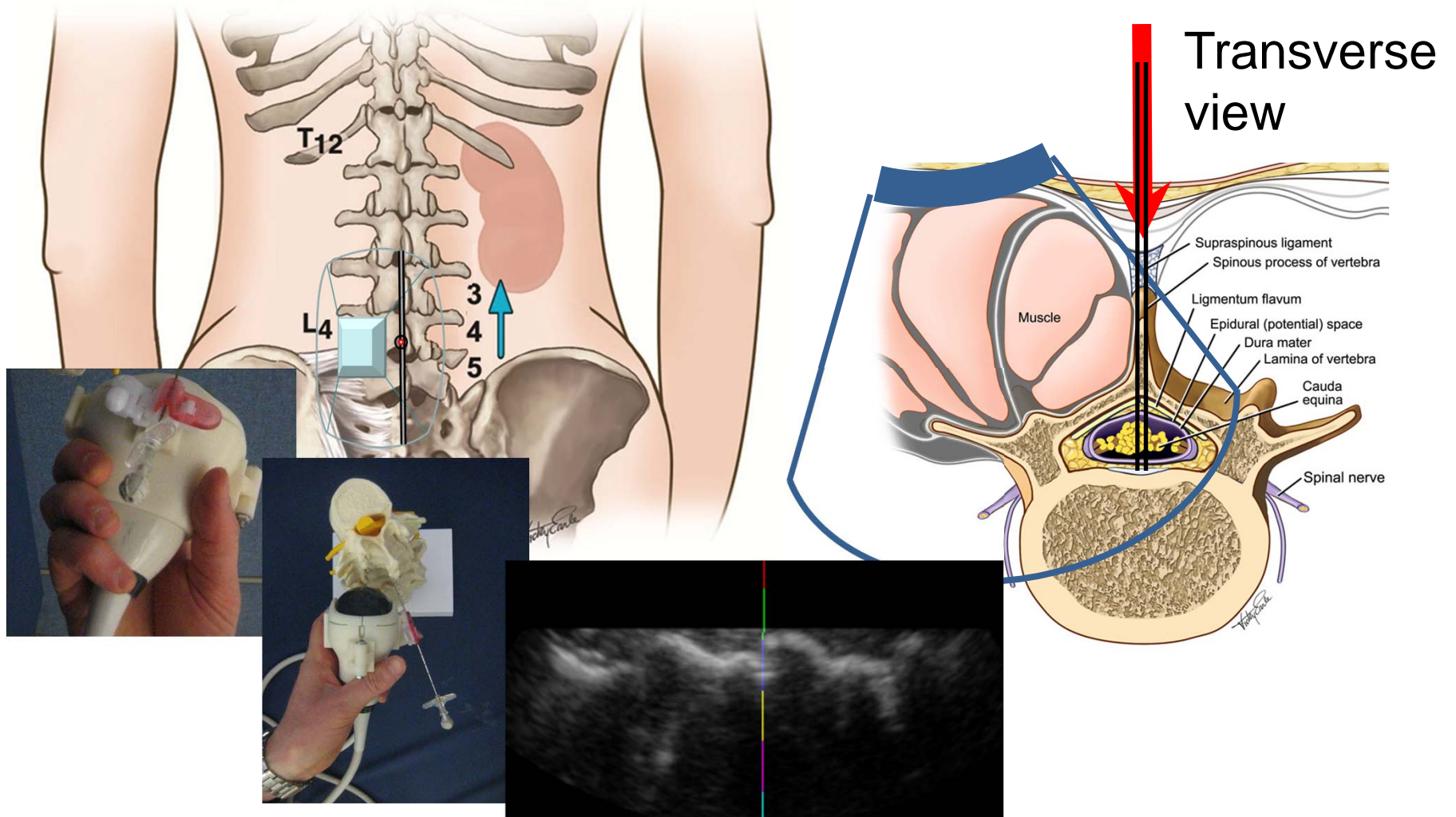


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# 3D reslice ultrasound imaging



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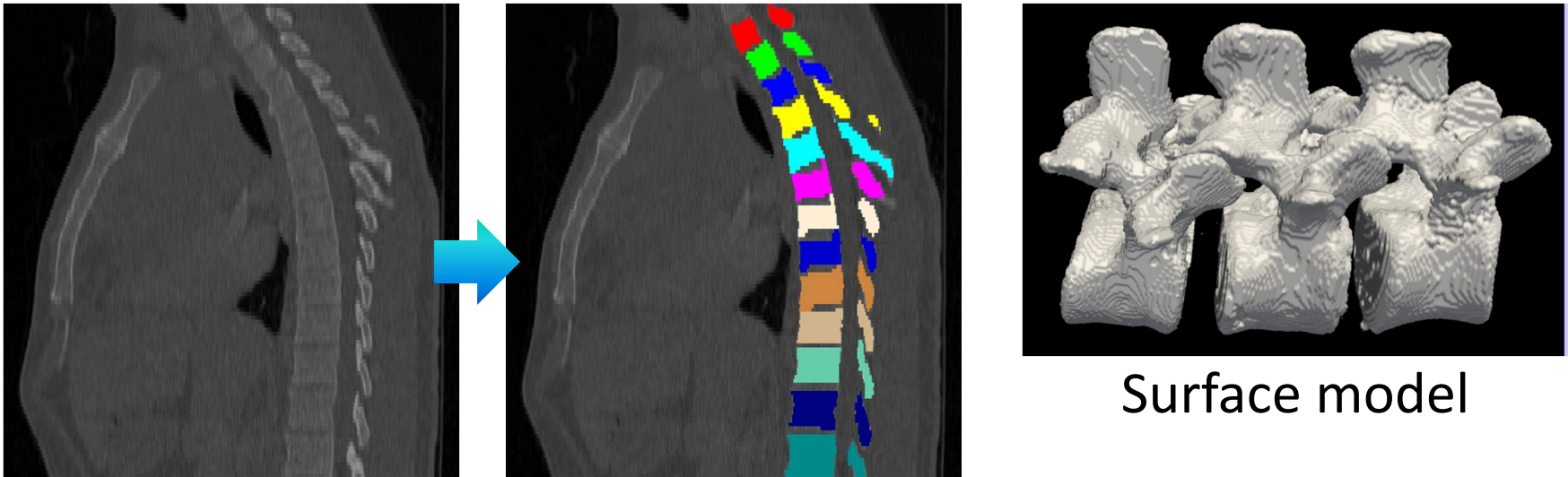


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# CT images

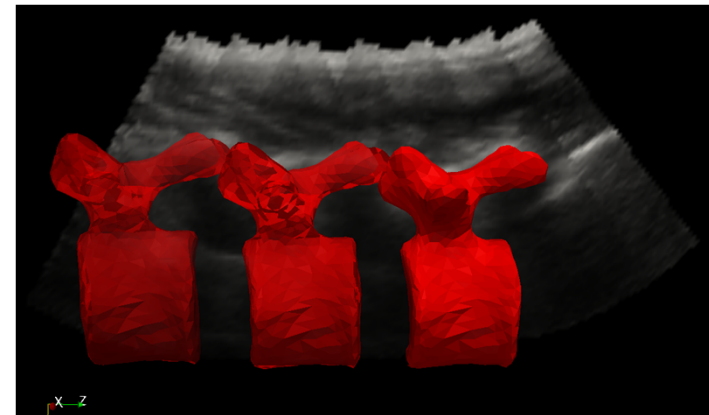
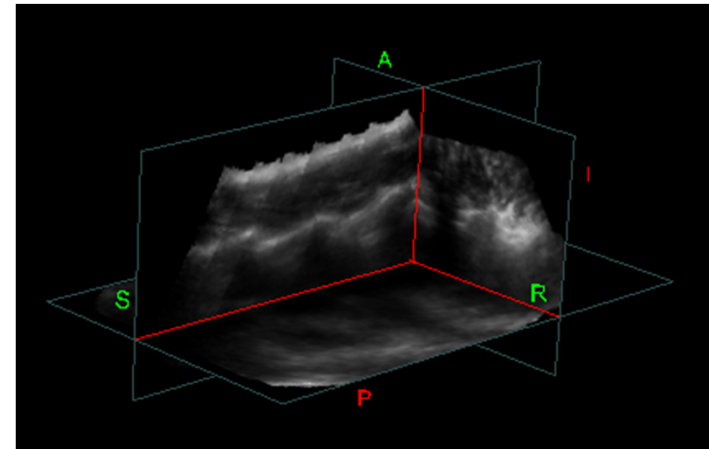
- Spine can be segmented manually or automatically



Surface model

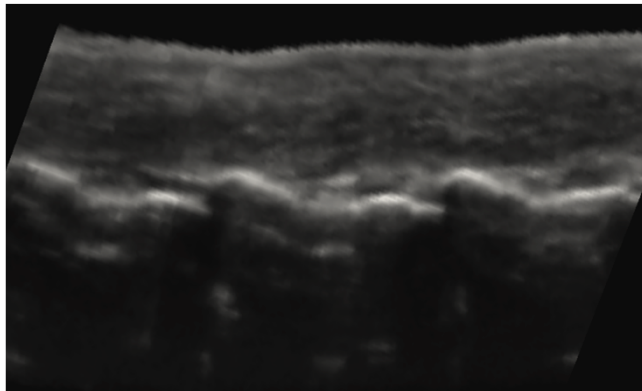
# Solution for both planning and guidance

- Acquire images
- Augment images
  - Why augment images:
    - Provide context
    - Improve accuracy

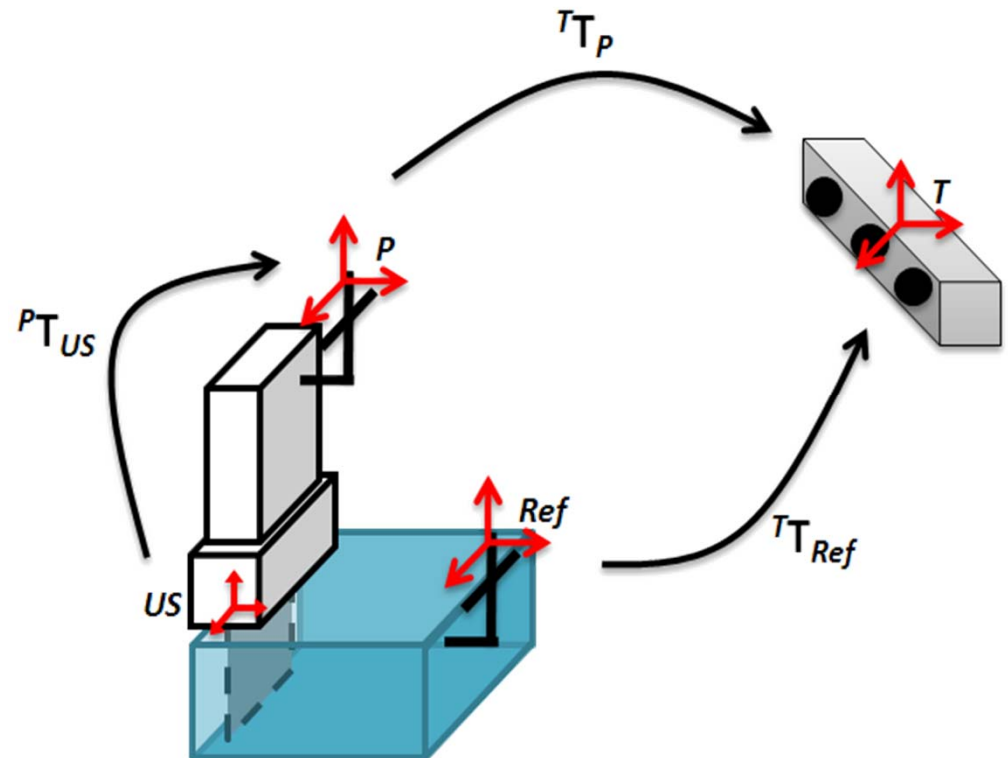


# 3D Ultrasound reconstruction of spine: with tracker

- Ultrasound probe calibration and tracking



Paramedian view of the ultrasound volume of Lamb fixed in a container



Requires patient tracking

Motivation / Tools / **Planning** / Guidance



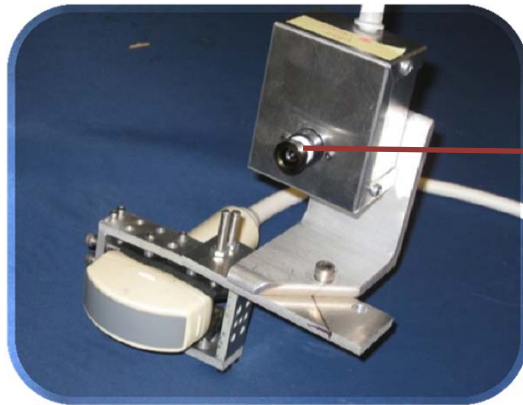
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Gill'10

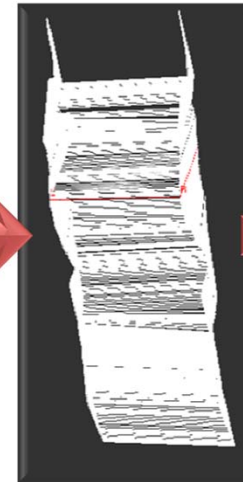
# 3D Ultrasound reconstruction of spine: with camera on probe



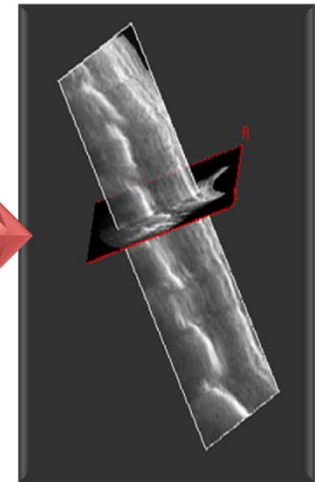
Single  
camera



marker strip  
with unique  
features



Ultrasound frame  
pose estimation



Ultrasound  
panorama  
construction

Motivation / Tools / **Planning** / Guidance

**Rafii-Tari'11**

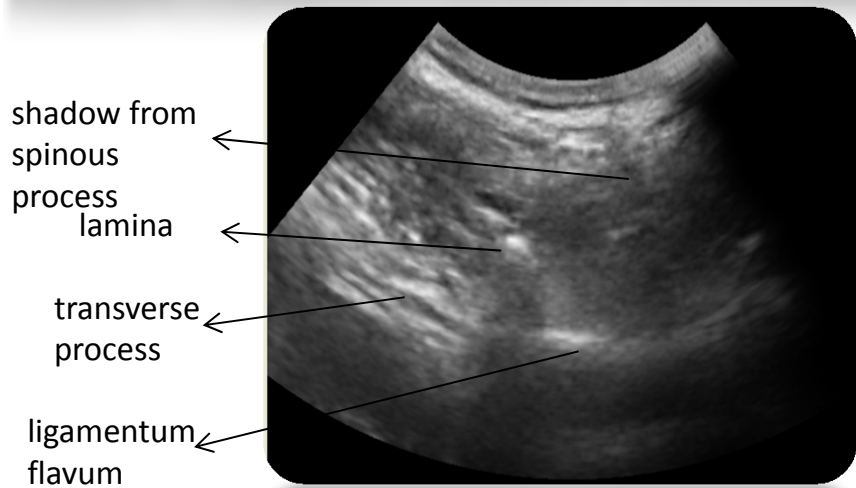
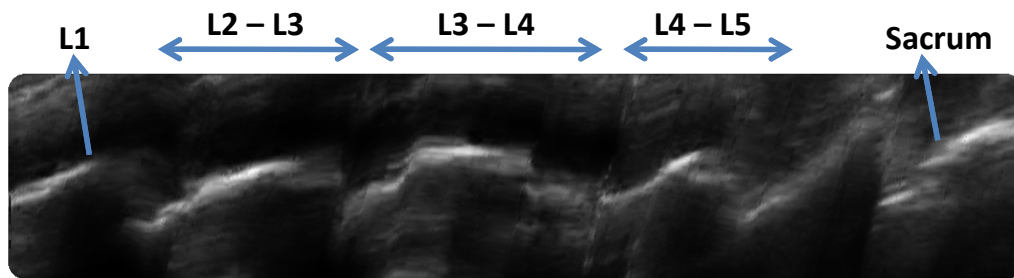


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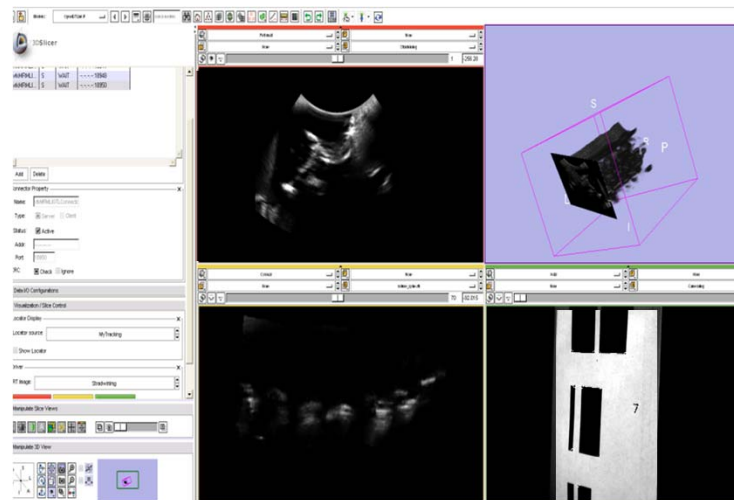


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# 3D Ultrasound reconstruction of spine: with camera on probe cont'd



3D Slicer

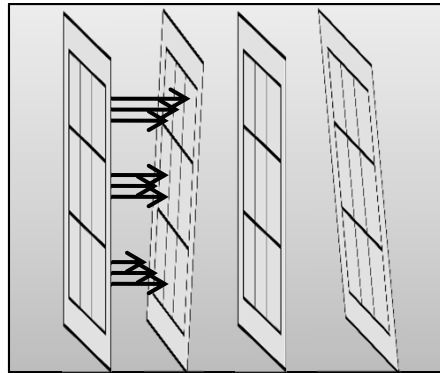
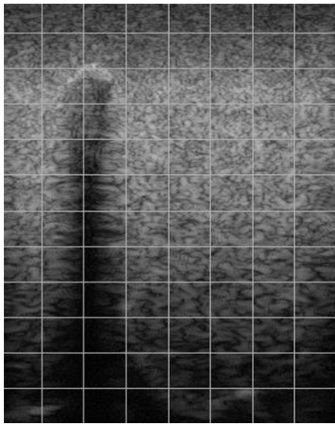


- Online Tracking
- Interactive Interface

Motivation / Tools / **Planning** / Guidance

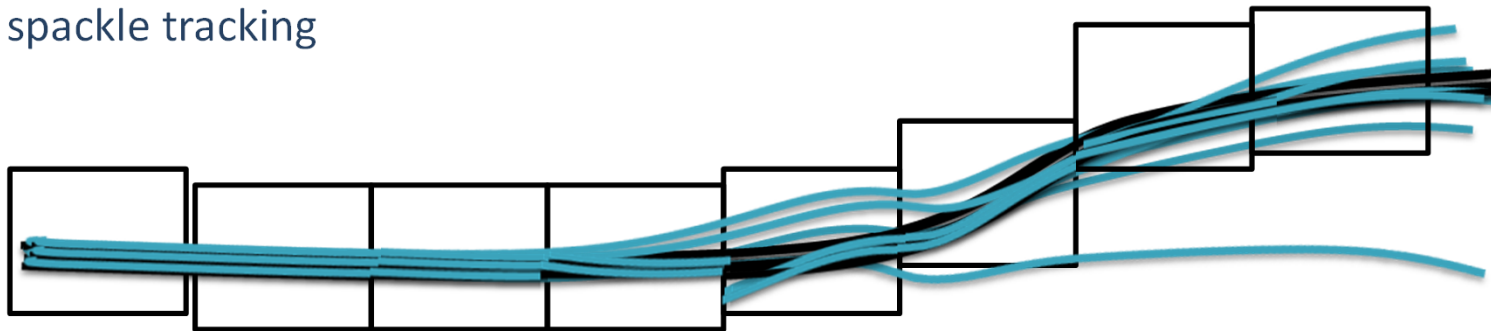
# 3D Ultrasound reconstruction of spine: no tracker

- Speckle tracking

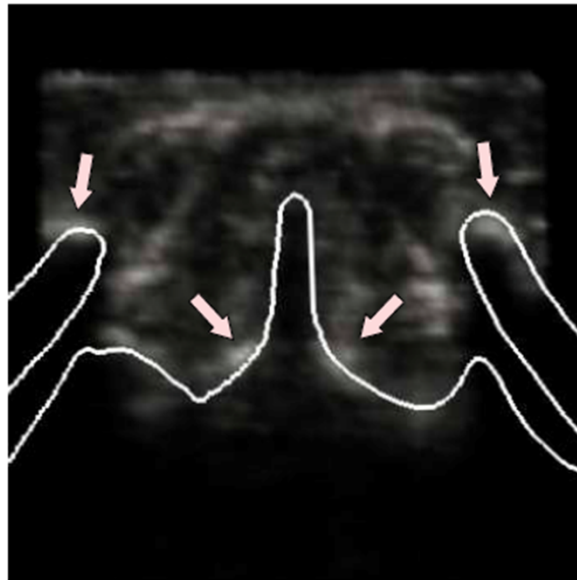


In-plane and out-of-plane motion estimation using speckle tracking

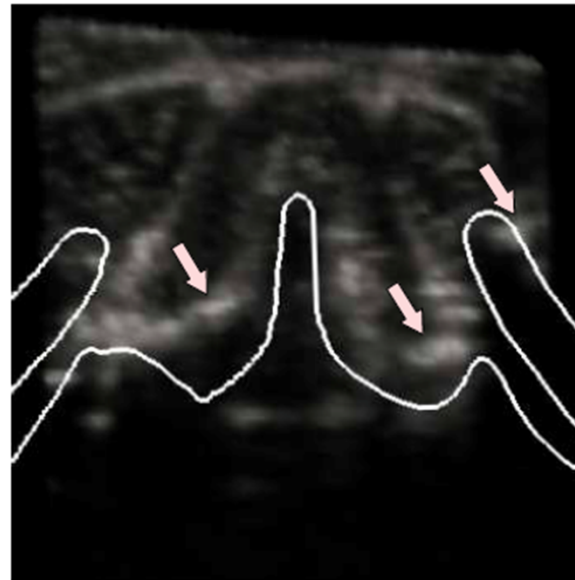
**Correct the estimation by registration with CT**



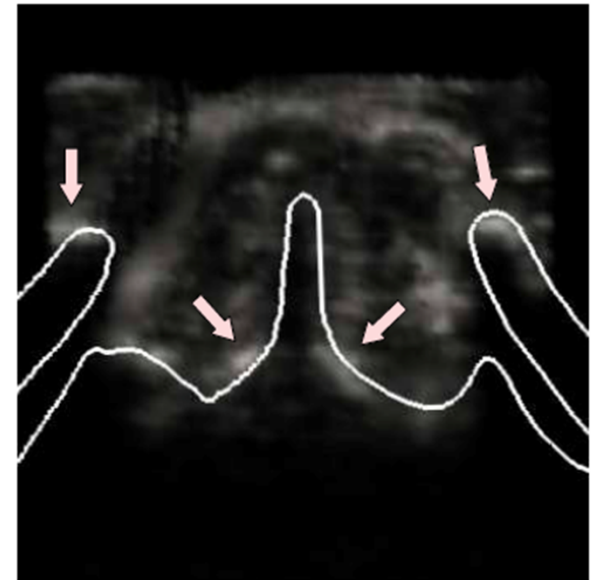
# 3D Ultrasound reconstruction of spine: no tracker



**Ground truth**



**Speckle tracking**



**Correction with  
the CT**

**Lang'11**



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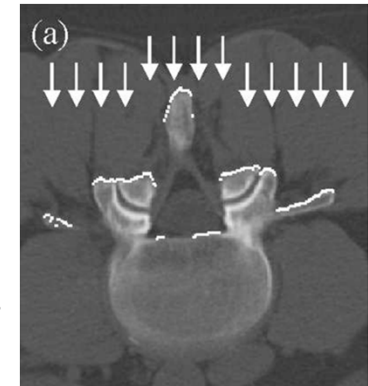


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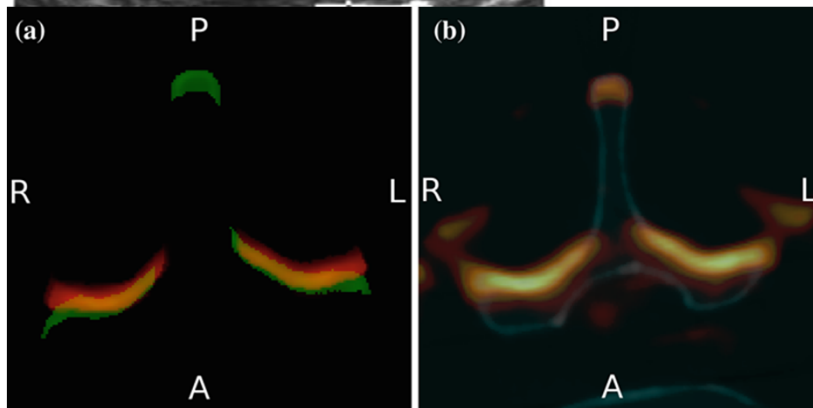
# Ultrasound augmentation with CT: single vertebra



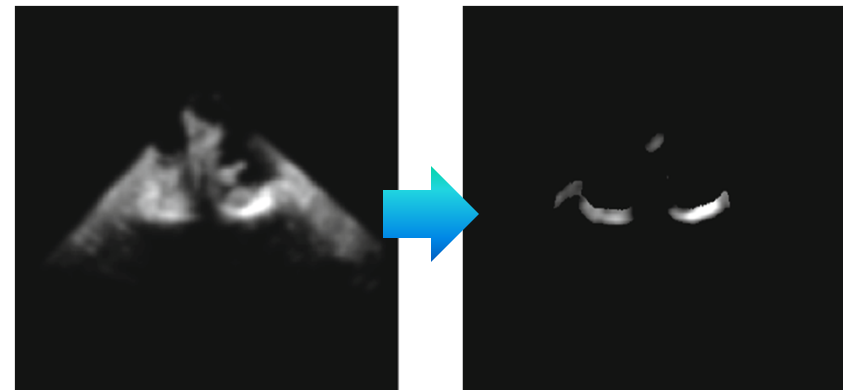
**Winter'08** – surface-  
volume registration



Extract relevant  
points from CT



**Yan'11** – volume-volume  
registration



Enhance bone surface in  
ultrasound images

**Winter'08, Yan'11**

Motivation / Tools / **Planning** / Guidance



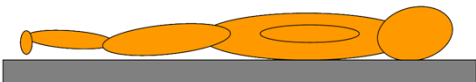
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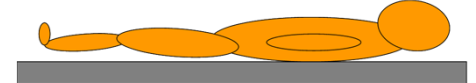
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# Ultrasound augmentation with CT: multi-vertebrae



Ultrasound acquisition



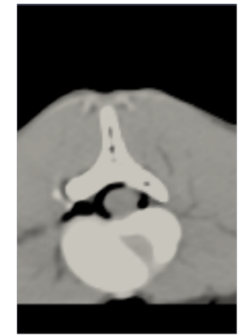
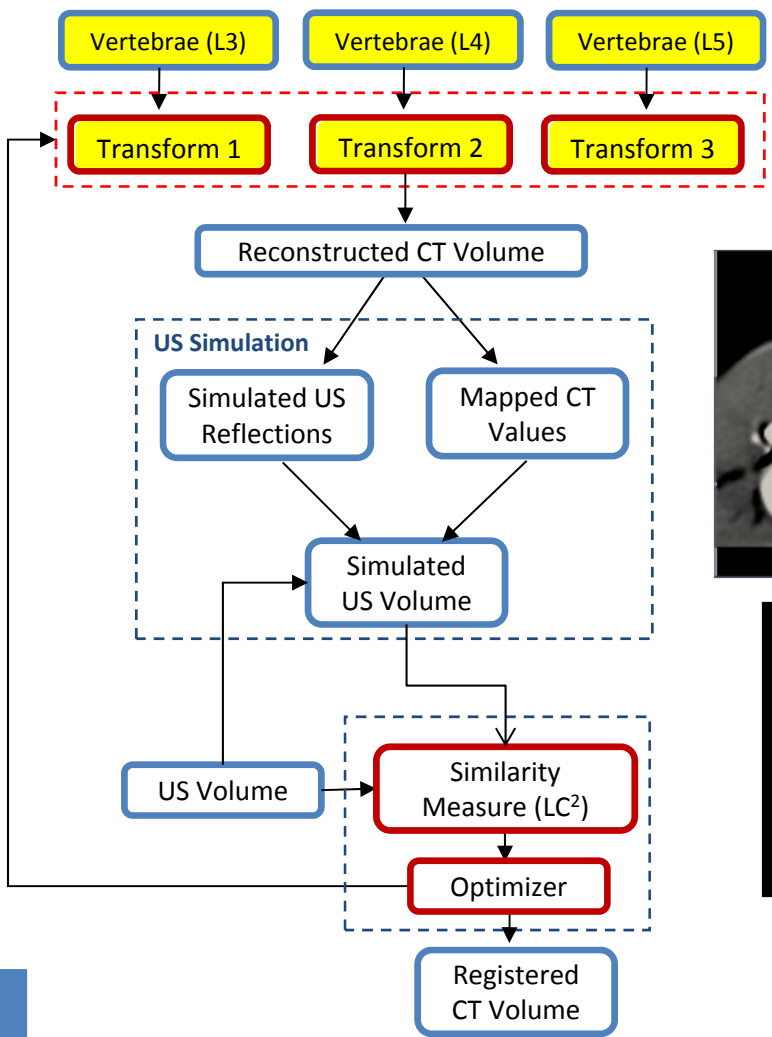
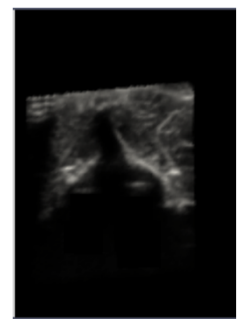
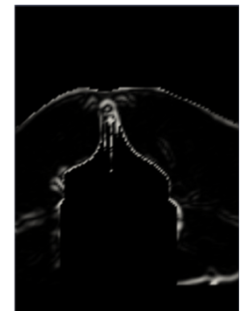
CT acquisition



Change in the curvature of the spine

Multi-vertebrae registration

Intensity-based registration



Motivation / Tools / Planning / Guidance

Gill'10

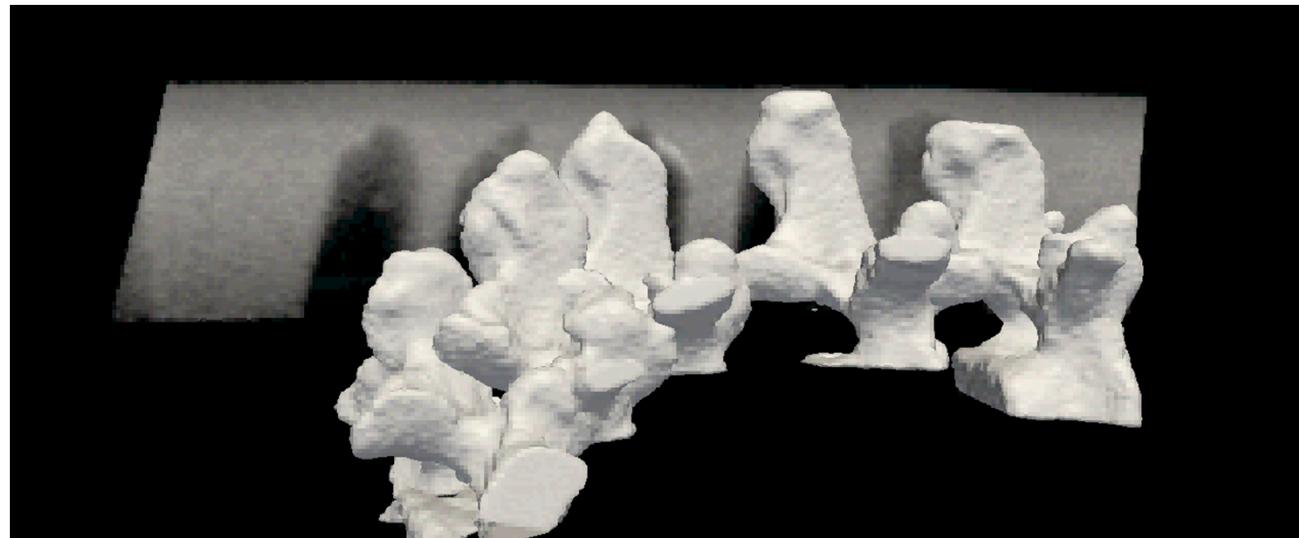
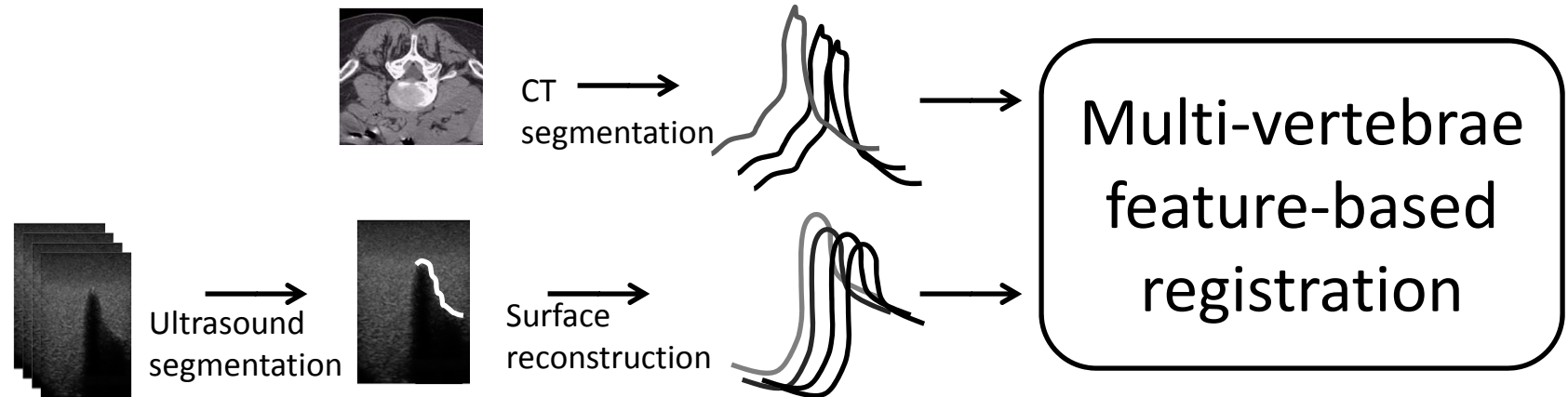


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# Ultrasound augmentation with CT: multi-vertebra



**feature-based  
registration**

Motivation / Tools / **Planning** / Guidance

**Rasouliaan'09**

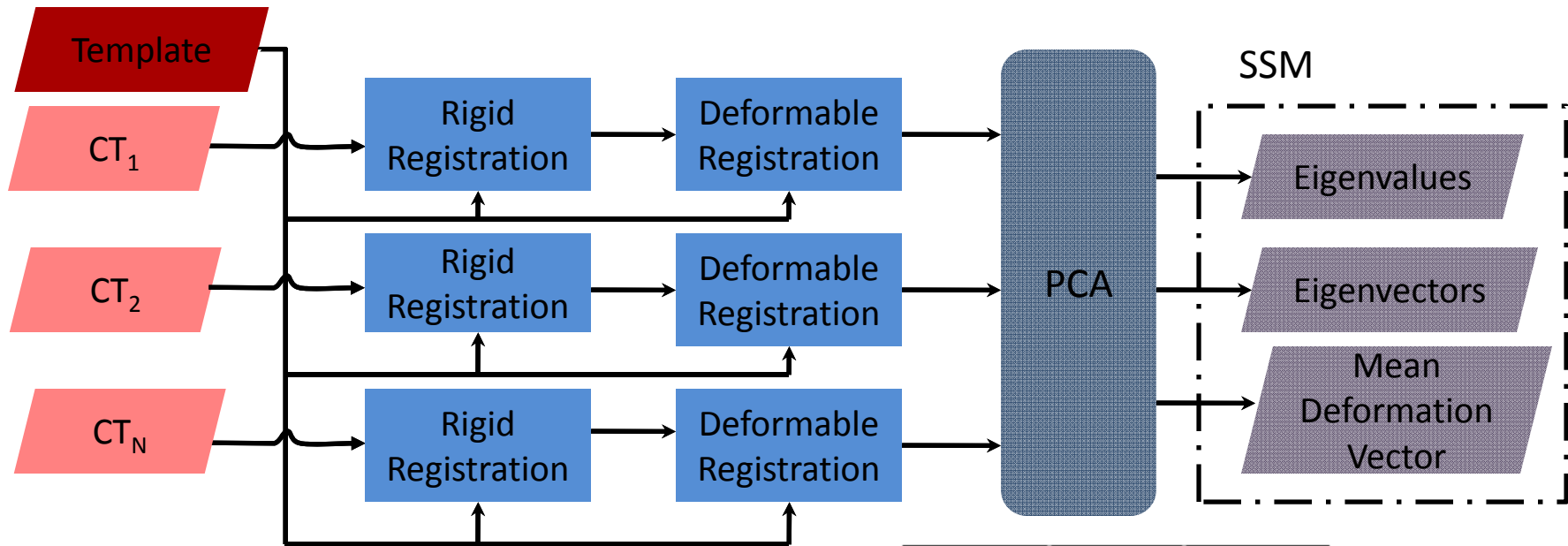


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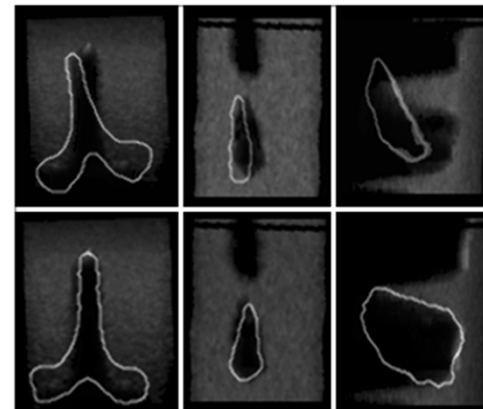
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# Ultrasound augmentation with Atlas



**Intensity-based registration of the multi-vertebrae atlas to the ultrasound volume**

**Run-time on GPU: 9 min**



Initialization

Aligned

**Khallaghi'11**

Motivation / Tools / **Planning** / Guidance

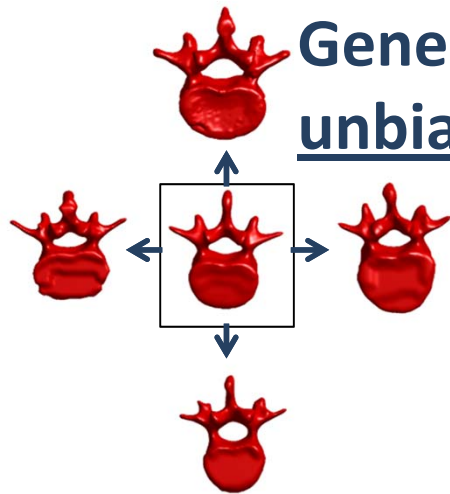


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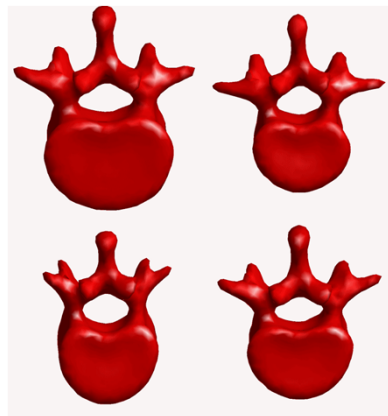
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# Ultrasound augmentation with Atlas



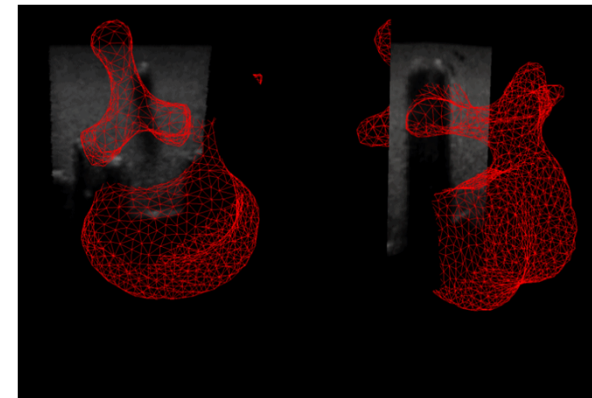
Generation of an unbiased atlas

Feature-based alignment of the single vertebra atlas and ultrasound images

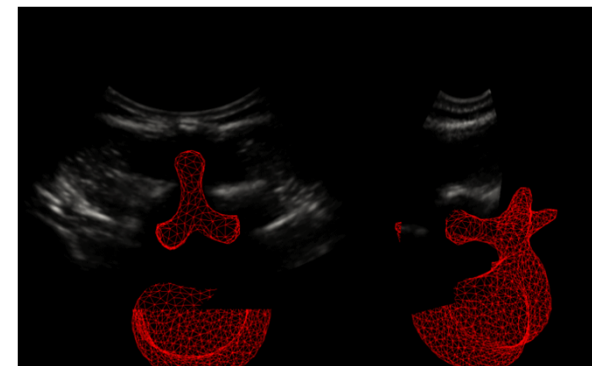


First four modes of the atlas

Run-time on Matlab: 5 sec



Phantom data



*in vivo* human data

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**Rasoulia**n'11



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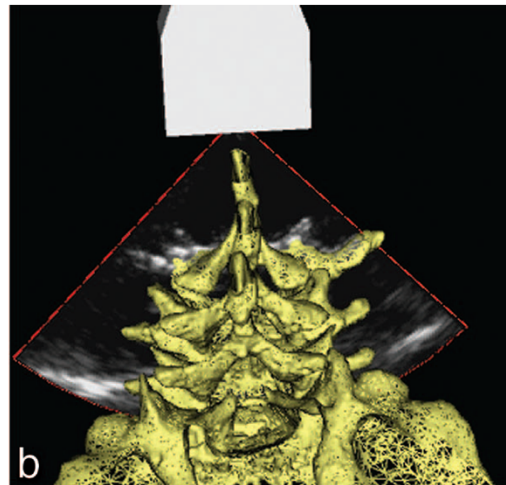
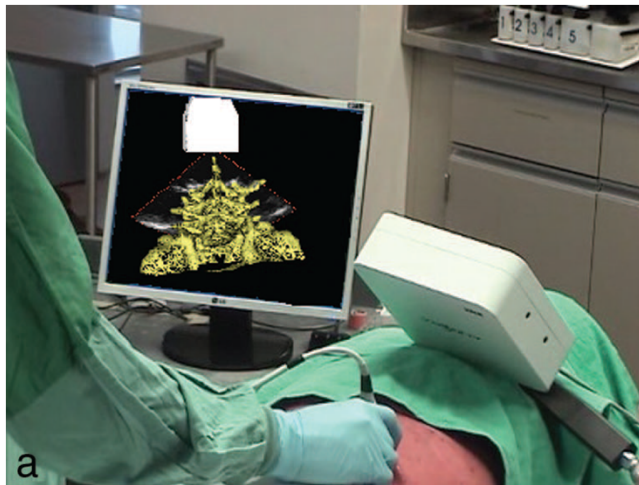
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# Ultrasound real-time augmentation with CT

- Tracked needle tool, ultrasound transducer and tracker field generator
- Phantom and cadaver study

## Accuracy in needle insertion

No guidance	5.77
Guidance using ultrasound image only	4.87
Guidance using ultrasound+CT model	0.57



Motivation / Tools / Planning / **Guidance**

**Moore'09, Chen 2010**



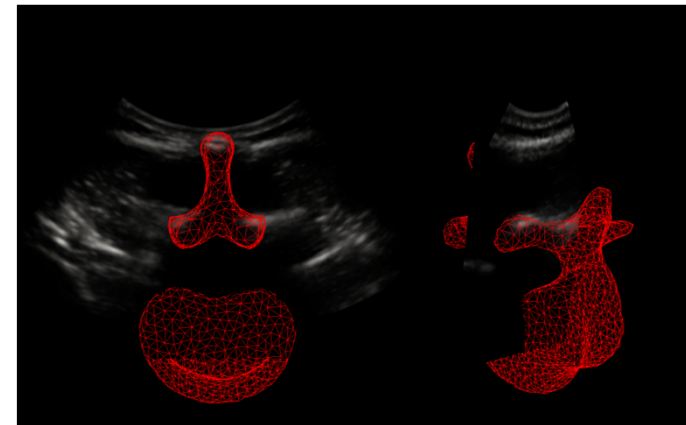
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# Open problems

- Real-time guidance with ultrasound augmented by atlas
- Reduce use of tracking tools
- More patient studies



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**THANK YOU  
QUESTION?**



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- [Rafii-Tari'11] Panorama ultrasound for guiding epidural anesthesia: a feasibility study, IPCAI 2011.
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- [Rasoulia**n**'11] Atlas-augmented ultrasound guidance of lumbar epidural needle insertions, SOAP 2011.
- [Tran'**10**] Single-operator real-time ultrasound-guidance to aim and insert a lumbar epidural needle, CJA 2011.
- [Winter'**08**] Registration of CT and intraoperative 3-D ultrasound images of the spine using evolutionary and gradient-based methods. IEEE Transactions on Evolutionary Computation, 2008.
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