Advances in Image-Guided Therapy

John A. Carrino, M.D., M.P.H.
Assistant Professor of Radiology, Harvard Medical School
Clinical Director, Magnetic Resonance Therapy Program
Co-Director, Spine Intervention Service

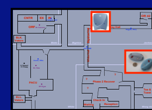
Minimally Invasive Therapies

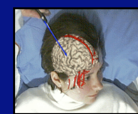
- Smaller operational volume
- Limited access
- Limited visualization
- Tissue damage limited to target volume
- Less complicatio[n]
- Faster recovery

Bringing Advanced Technology to the Operating Room


Laparoscopic Procedures


Integrated OR


Advanced Procedure Room


Real Time Image Guidance

Endo-video, Instruments

PC's,Remote Monitoring, Communications

Wireless, New Devices

Models, Grid Computing

High Technology Base

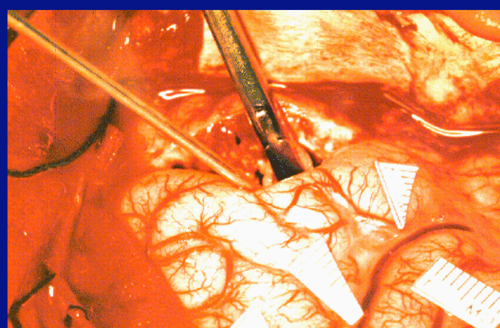
What is surgery ?

Hand – eye coordination

The role of Image-guidance

- Beyond the surface visualization
- Target definition

n



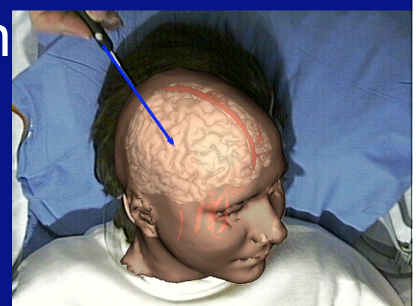


Image-Guided Procedures

- Localization
- Targeting
- Navigation
- Monitoring
- Control

Diagnostic Imaging
Surgical Planning
Interactive Imaging
Dynamic Imaging
Quantitative Imaging

Why use MR for image guidance?

- Flexibility of image contrast
- No ionizing radiation
  - safe for patients & staff
- Cross-sectional technique
- Adjustable imaging plane

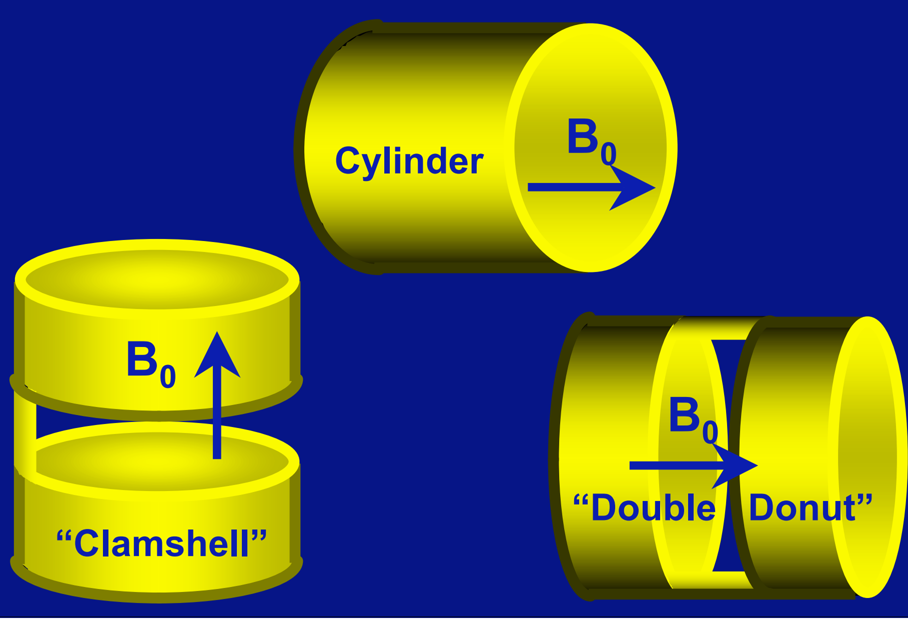
Technical Aspects

- Magnet
- Devices
- Spatial accuracy
- Imaging techniques
- Guidance methods

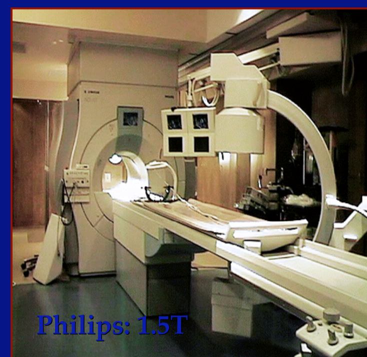
The Magnet

- Configuration
  - access to patient *vs.* field homogeneity
- Field strength
  - safety *vs.* image quality/speed
- Gradient strength
  - spatial resolution *vs.* artifacts

Magnet Configurations



i-MRI Systems: Demand new navigation and monitoring systems



Courtesy of Dr. Roberto Blanco Sequeiros, Oulu University Hospital, Finland


UNIVERSITY OF MINNESOTA
DEPARTMENT OF
RADIOLOGY
CENTER FOR MR-GUIDED THERAPY


VE RI TAS
BRIGHAM AND
WOMEN'S HOSPITAL
Magnetic Resonance Therapy

MRT
Program History

In 1989, BWH Radiology and Harvard Medical School initiated a project to develop MR-guided interventional procedures and intraoperative guidance for surgeries.

MR Safety of Devices

- Safe in magnet room
  - low forces on device
  - device works in magnetic field
- Safe around patient
  - device does not distort or degrade image
  - device does not arc during imaging
  - magnet room safe

MR Safety of Devices

- Safe to use <u>in</u> a patient
  - no local heating from RF deposition
  - device and target visible
  - no significant artifacts
    - position correct?
    - target visible?

Many Objects are *<u>Not</u>* MR Room Safe

- Test all objects with strong magnet prior to entry into room
- Keep all unsafe objects out of MR area entirely
- Train all personnel about magnet safety

RF Deposition - Heating

- Field strength dependent
  - changes as square of field strength
  - e.g. RF deposition at 1.5T > 0.5T by 9X
- Antenna concept
  - needles, wires, etc. act as antennas
  - needles can heat more easily at higher frequency RF (higher Tesla, shorter wavelength)
  - higher frequency RF has greater energy

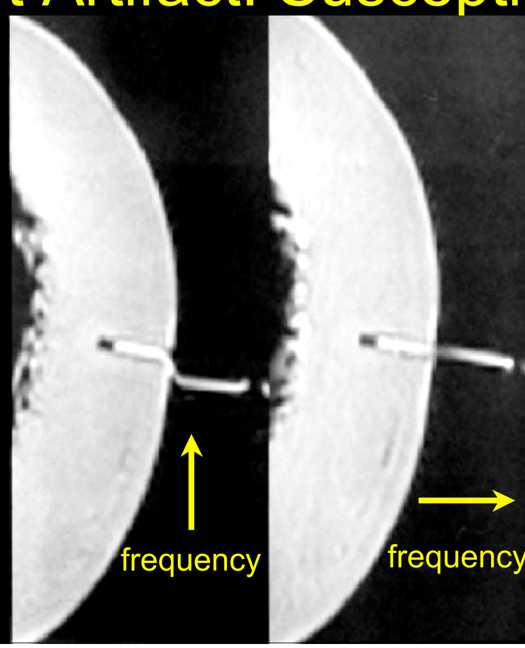
Spatial Accuracy

- Procedures demand <u>exact</u> localization
- Location determined by frequency
  - static magnetic field, B_o
  - switched gradient fields
- Accuracy of localization dependent on:
  - B_o homogeneity
  - gradient field homogeneity

Geometric Distortion: Shift Artifacts

- Imaging assumes uniform B_o
- Local frequency changes cause "shift artifacts" - analogous to chemical shift
- Shift artifacts displace pixels in frequency direction

Shift Artifact: Susceptibility

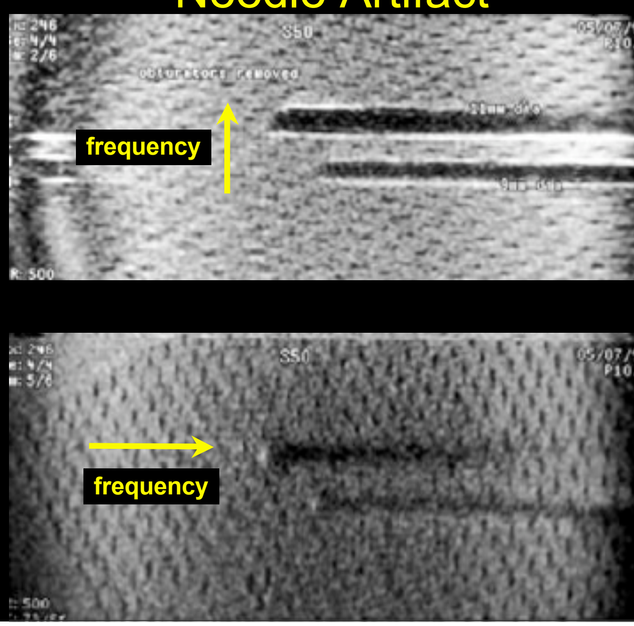


E Schneider, PhD

Minimizing Shift Artifact

- Frequency direction orthogonal to long axis of needle - most accurate tip position
- Spin echo & FSE *not* gradient echo
- Wide bandwidth (more Hz per pixel)
- Low field strength magnet
- Lower spatial resolution

Effect of Frequency Direction on Needle Artifact



Guidance Methods

- Externally referenced - *prone to distortion errors*
  - optical guidance
  - RF guidance
- Self-referenced - *minimizes distortion errors*
  - anatomical landmarks (your finger!!)
  - fiducial markers
- MR tracking - uses MRI hardware - *distortion free*

Optical Tracking

- LED's on device tracked by cameras
- Position update 6 per sec.
- Device must remain in clear view of cameras
- Optics independent of MR image distortion – may cause errors

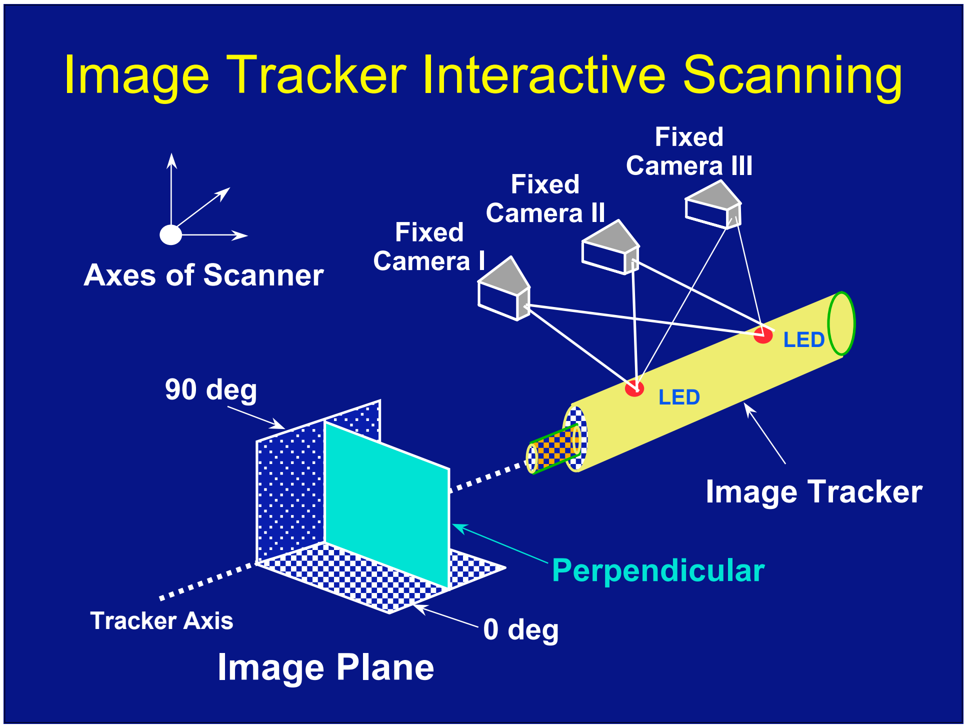


Image Tracker Interactive Scanning
Axes of Scanner
Fixed Camera I
Fixed Camera II
Fixed Camera III
LED
LED
90 deg
Image Tracker
Perpendicular
Tracker Axis
0 deg
Image Plane

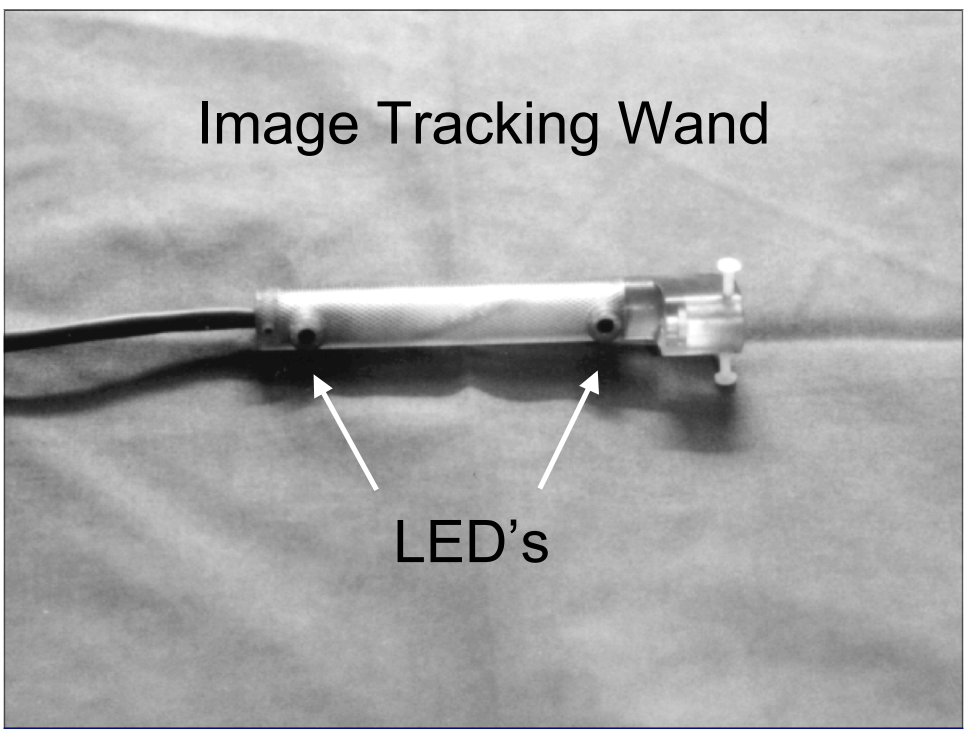
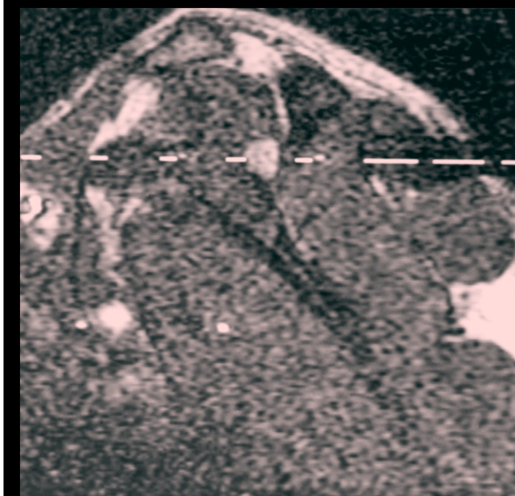
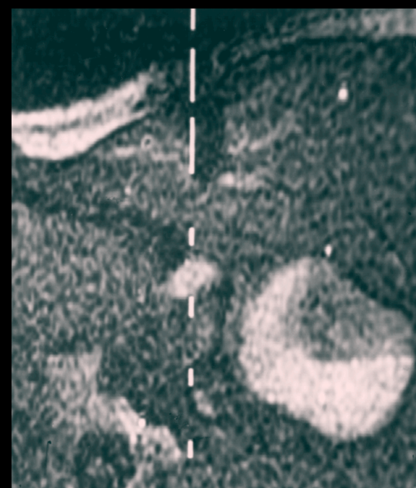


Image Tracking Wand
LED's

Optical Tracking for Needle Placement

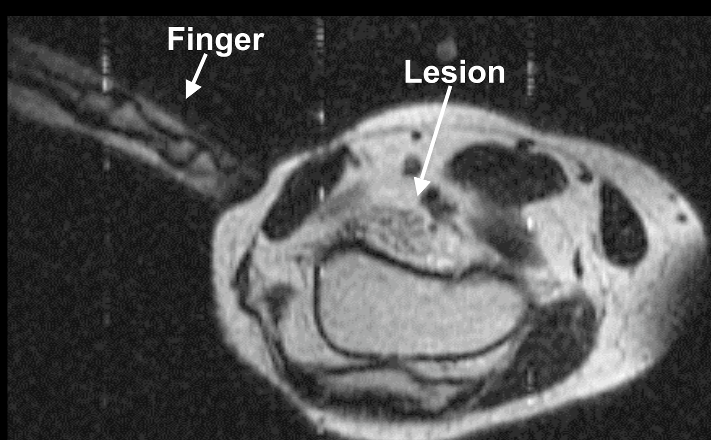


Guided Sagittal FSPGR



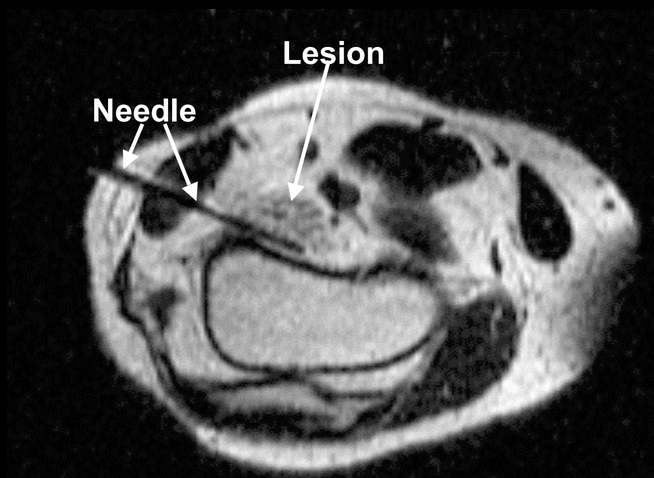
Guided Axial FSPGR

Self-referenced Guidance: anatomical landmarks



Soft-tissue Biopsy: PVNS

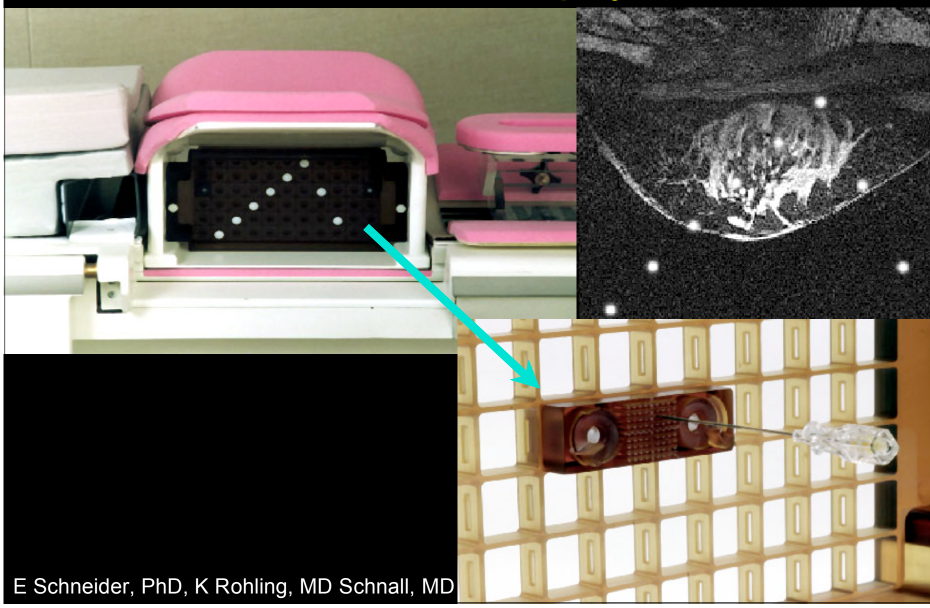
SOFT-TISSUE BIOPSY: PVNS



Fiducial Markers

- MR visible markers close to target
- Trajectory calculated from position of target relative to markers
- Shift & warp artifacts similar for markers and target
- Impact of distortion dependent on distance of markers from target

Guidance by Fiducial Markers: Breast Biopsy



E Schneider, PhD, K Rohling, MD Schnall, MD

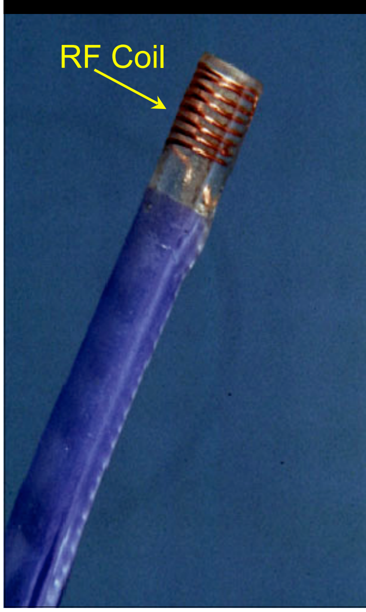
Radiofrequency Tracking

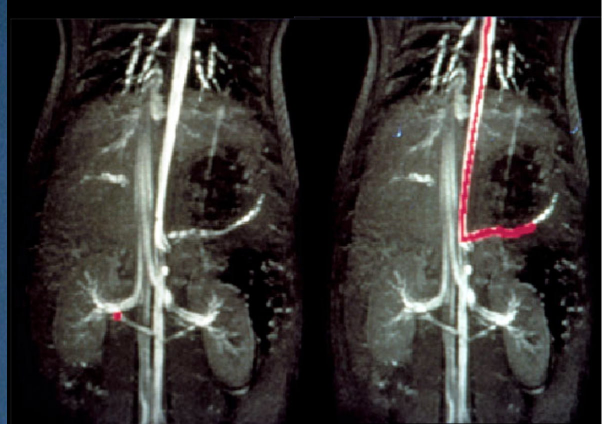
- Device localized by external RF transmitters
- Device may be within or outside of patient
- Objects absorbing RF may interfere with device localization
- RF field & MR image distortion independence potentially causes errors

MR Tracking

- MR receive coils on device track location
- Same imaging parameters localize device & image
  - inherent self-referencing
  - MR image shows true device position
- Localization interleaved with image sequence
  - rapid position updates (80 per sec.)
- Can work with any pulse sequence

Catheter Placement by MR Tracking



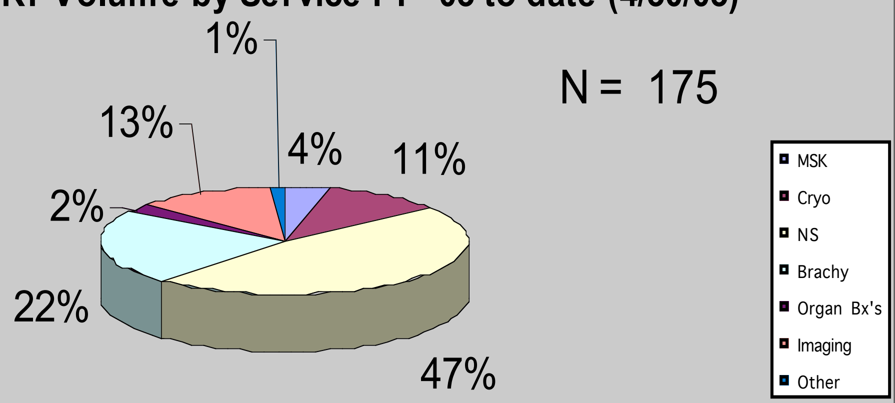


CL Doumilin, PhD; JA Debatin, MD

Clinical Aspects

- Why use MR guidance for procedures?
  - Diagnostic
  - Therapeutic

MRT Volume by Service FY ' 03 to date (4/30/03)



BRIGHAM AND WOMEN'S HOSPITAL

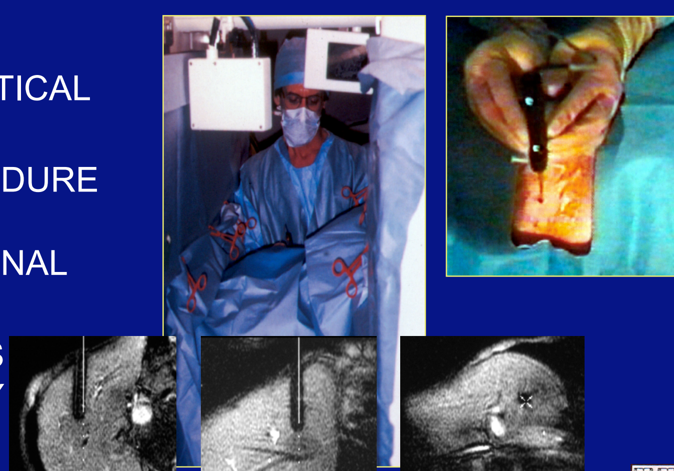
Magnetic Resonance Therapy

Interventional MRI: Broad Categories

- Percutaneous Procedures
- Intraoperative Procedures
- Thermal Ablations
- Vascular Interventions

MRI-guided Biopsy - Techniques

MRI system:
OPEN / VERTICAL
Imaging:
PRE-PROCEDURE /FAST CONVENTIONAL
Targeting:
FRAMELESS STEROTAXY



Silverman et al Radiology 1995

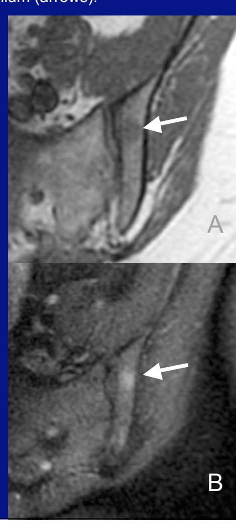
Why use MR guidance for biopsies?

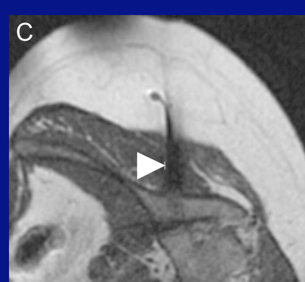
- lesion not visible (or visualized well enough) by other modalities
- Limited access route/complex trajectory
- collections/lesions near hardware
- target a specific portion of lesion
- Pregnancy

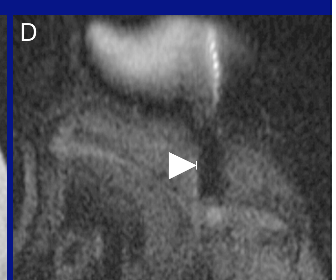
BONE BIOPSY DURING PREGNANCY:

38 y.o. woman 23 weeks gestation with history of breast cancer. A small iliac bone lesion found on an MR imaging study for hip pain.

Pre-procedure T1W (A) and STIR (B) axial images show a small lesion (<1cm) in the left ilium (arrows).







Procedure:

With the patient in the right lateral decubitus position, a 6 mm trephine needle (arrowheads) was positioned at the lesion (C,D). 2 contiguous core biopsies removed all visible lesion. FNA samples were performed through the corticotomy. Post-procedure T1W image (E) shows the biopsy tract (arrows) after removal of the cores. The use of MR-guidance avoided radiation exposure to the fetus.

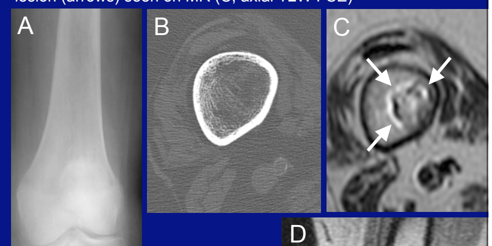
Diagnosis: Metastatic Breast Carcinoma

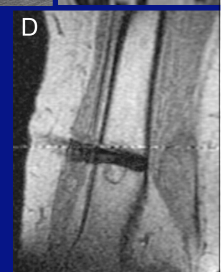
Both the core & FNA samples were diagnostic.

IMPROVED VISUALIZATION OVER CT

74 y.o. woman with lung cancer. Femoral lesion by PET scan. Is there metastasis?

AP radiograph (A) & CT scan (B) fail to show the distal femoral lesion (arrows) seen on MR (C, axial T2W FSE)



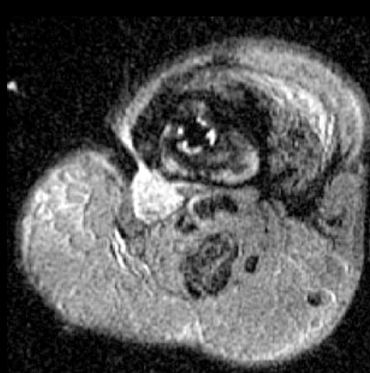


Sagittal image (D) shows placement of a 3 mm trephine needle in the superior portion of the lesion with a single core obtained. Using a 16G vacuum needle, 2 marrow aspirates were also performed.

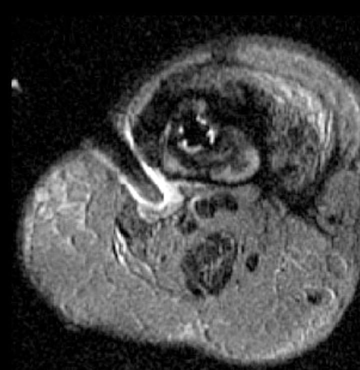
<u>Results</u>: No Metastasis

Core biopsy specimen showed lamellar bone but no tumor. Aspirate was insufficient. No clinical progression of lesion at 20 months.

Biopsy Near Hardware – Recurrent Sarcoma



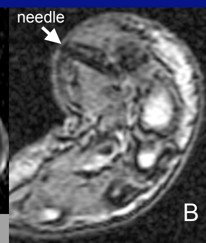
Axial STIR FSE

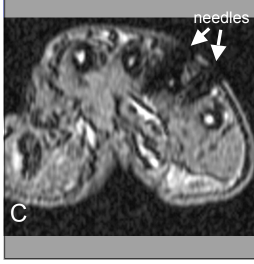


Axial STIR FSE

PRE-SURGERY STAGING OF SARCOMAS

Pre-procedure axial T2W FSE image (A) shows abnormal signal in the thenar eminence & first 3 web spaces that is worrisome for tumor. If 3rd or 4th web space were involved, resection of the ring finger ray would be required & hand amputation would have been performed.





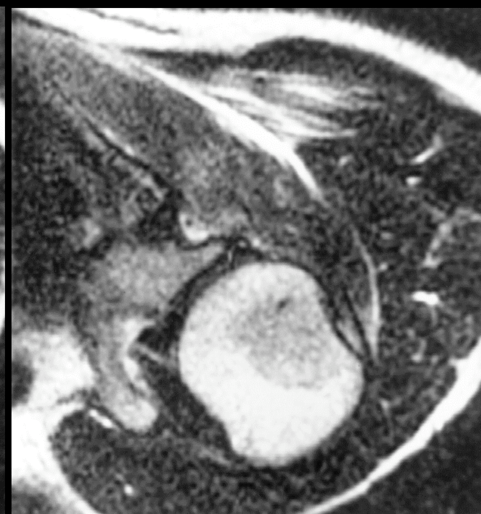
<u>Results</u>:
FNA & core biopsies of the thenar eminence (B), 3rd & 4th web spaces (C), properly staged the tumor showing involvement of the thenar eminence, but not either web space. Resection of 1st 3 rays was performed with thumb reconstruction. Surgical pathology confirmed biopsy staging.

34 y.o. man with recurrent epithelioid sarcoma of the hand pre-op for resection.

- MR compatible needles:
  - Core - Biopsy gun: (16 or 18G, MRI Biogun™ E-Z-EM, Inc., Westbury, NY)
  - Trephine 3, 4, or 6 mm: (Bone Biopsy™, MRI Devices Daum GmbH, Schwerin, Germany)
  - Vacuum needle 16G: (MD Tech, Manan™ MRI Techna-cut, Karlsruhe, Germany)
  - FNA - 20G or 22G: (MRI Histology™, E-Z-EM, Inc., Westbury, NY)

Aspiration & Steroid Injection

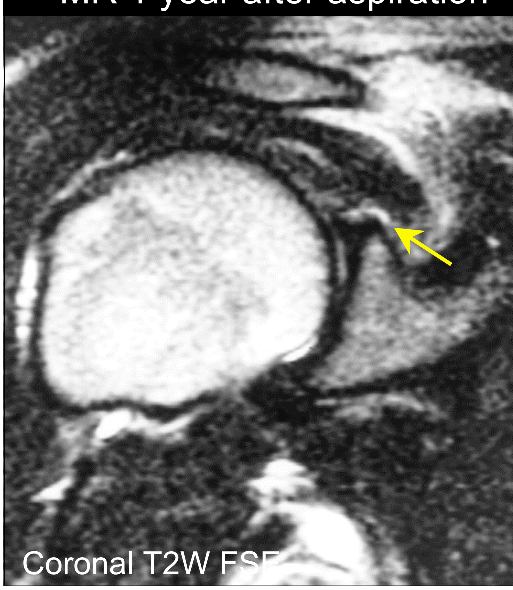
Axial T2W FSE



Axial T2W FSE

Clinical Course

MR 1 year after aspiration

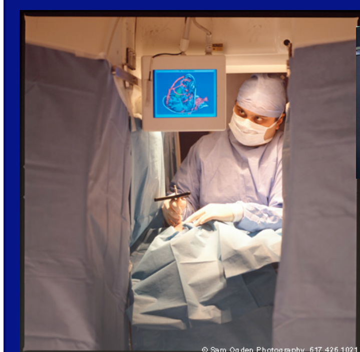


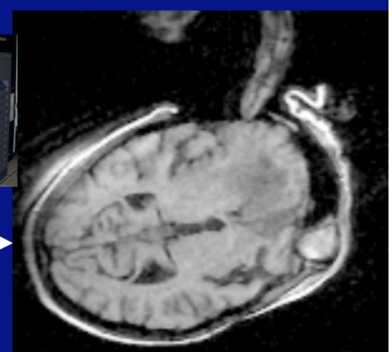
- Symptoms resolved within days
- Muscle weakness & atrophy resolved
- 3.6 years after therapy shoulder remained asymptomatic

Winalski CS, Robbins MI, Silverman SG, Davies JAK. Intraoperative Magnetic Resonance Image-guided Aspiration Therapy of a Glenoid Labral Cyst. JBJS [Am] 2001 8:1237-42

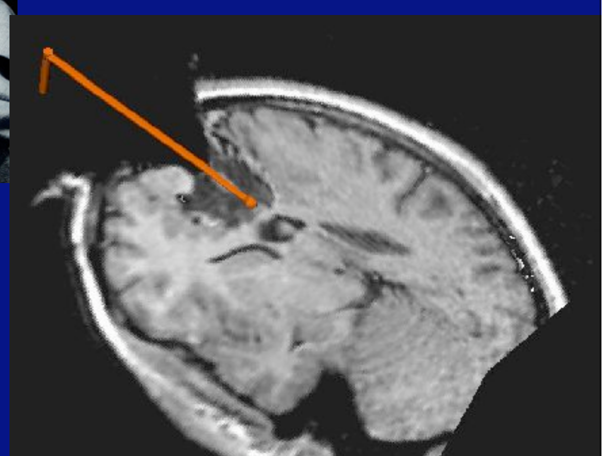
Computer-Integrated Surgery

Integration with imaging



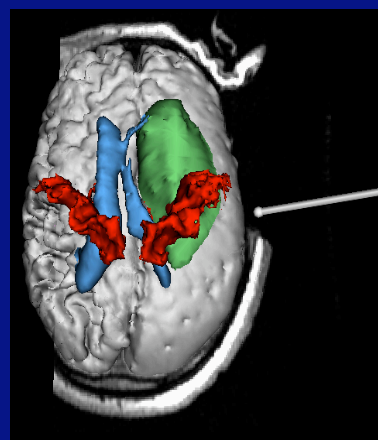


Integrated Navigation System

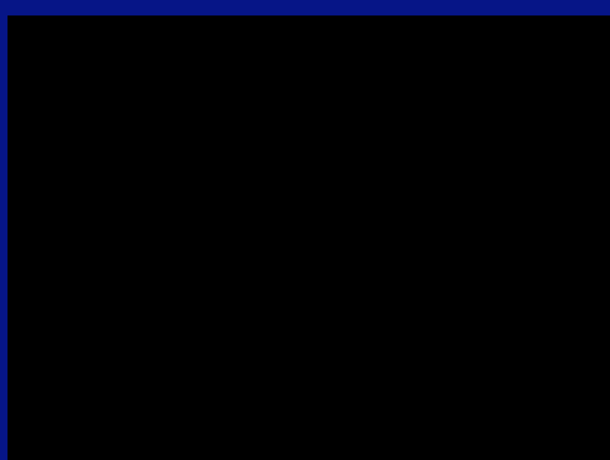


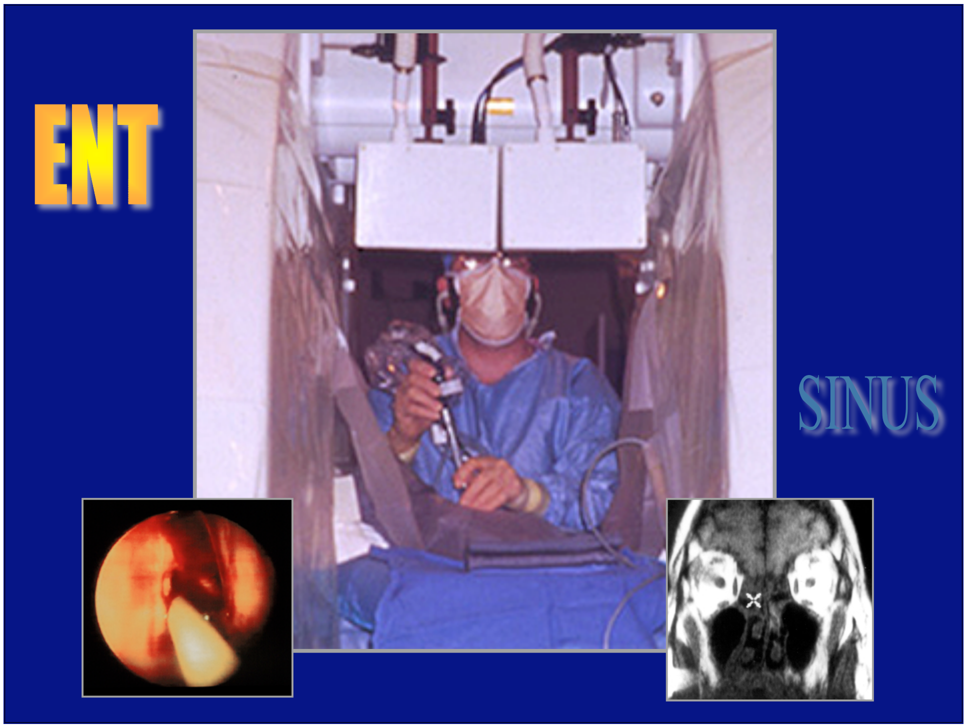
Provided by D. Gering

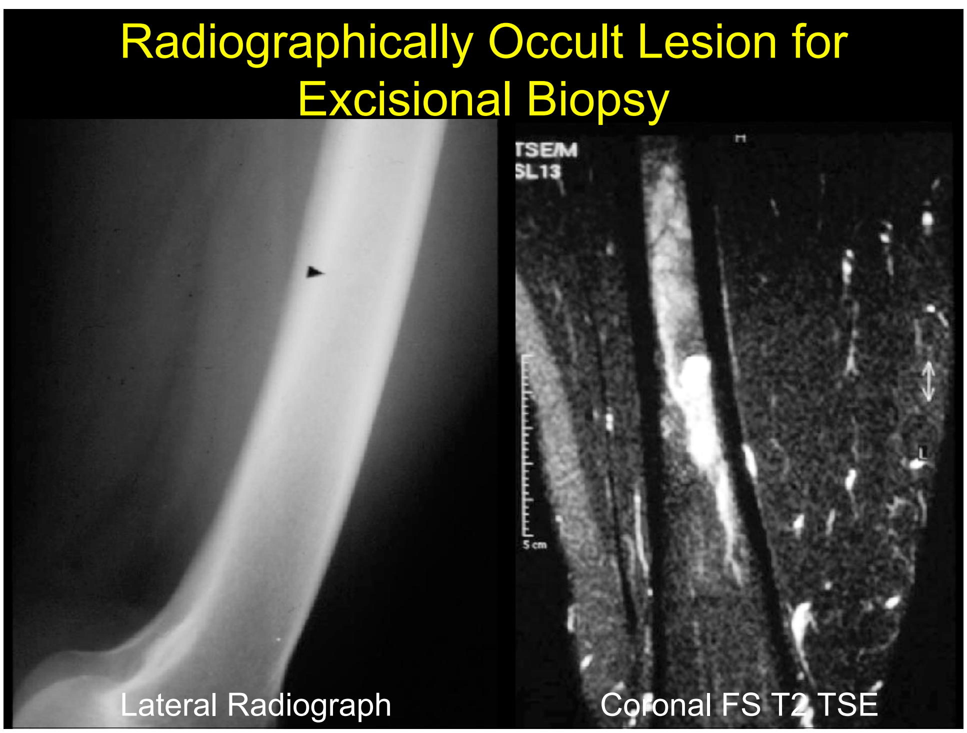
INTERACTIVITY NAVIGATION



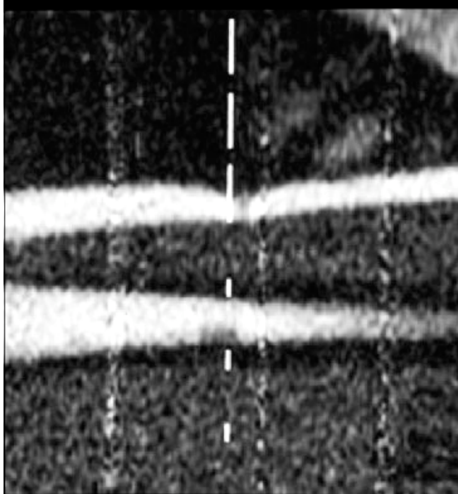
Brain Tumor Resection




ENT
SINUS


Radiographically Occult Lesion for Excisional Biopsy
TSE/M
SL13
5 cm
Lateral Radiograph
Coronal FS T2 TSE

Optical Guidance for Needle Localization

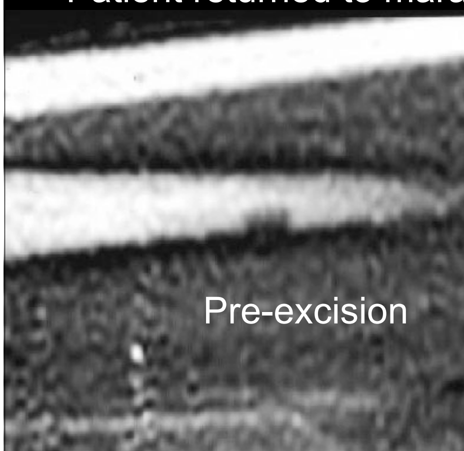


Guided Sagittal T1W FSE

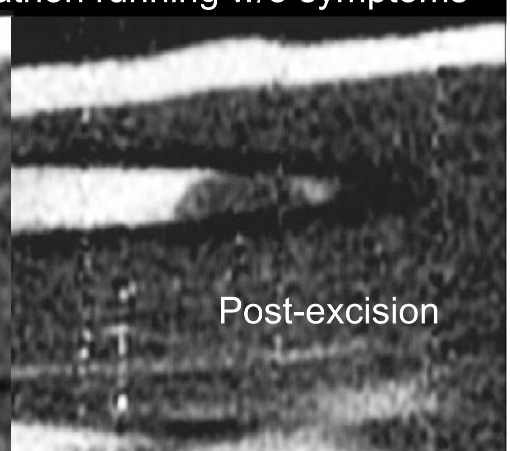
Guided Sagittal T1W FSE

Open Excision Through Drill Hole

- Small drill hole rather than 1 cm cortical window
- Enchondroma
- Patient returned to marathon running w/o symptoms

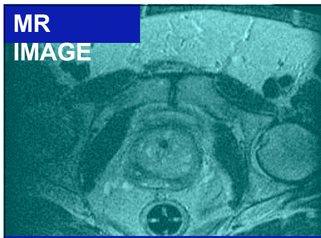


Sagittal T1W



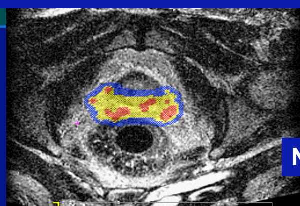
Sagittal T1W

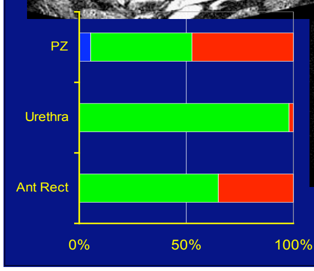
MR IMAGE



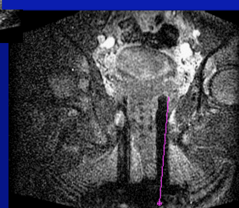
Prostate cancer imaging and Brachytherapy program-Today

TREATMENT PLANNING





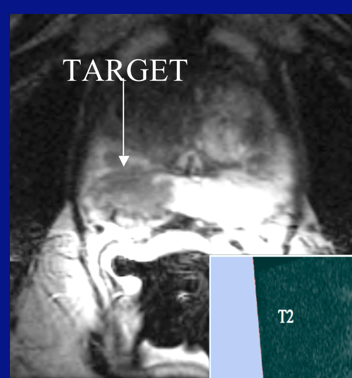
NEEDLE PLACEMENT

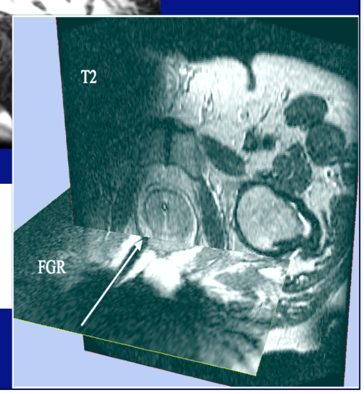


- Pre clinical testing, feasibility testing and Clinical trial, designed and established by Drs D'Amico & Tempany
- 1997 First patient treated in MRT *(GE Signa SP 0.5T)*
- Pt selection criteria-T1C, PSA<10, GG< 3+4
- Ecoil- no extra-glandular disease

MR-guided prostate biopsy program

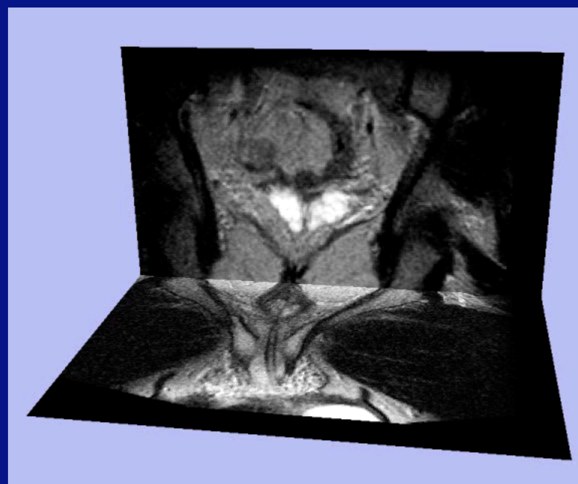
- Rising PSA after negative TRUS
- S/P APR
- Need target validation method
- Need 'free-hand' aspiration > Robot



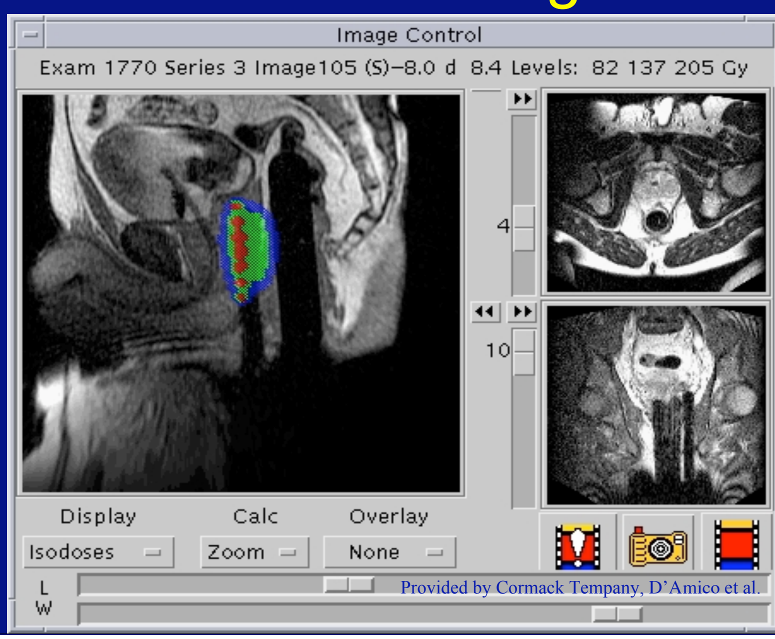


3D-Slicer adapted for prostate procedures and target definition, trajectory planning and guidance

MR guided biopsy-3D slicer

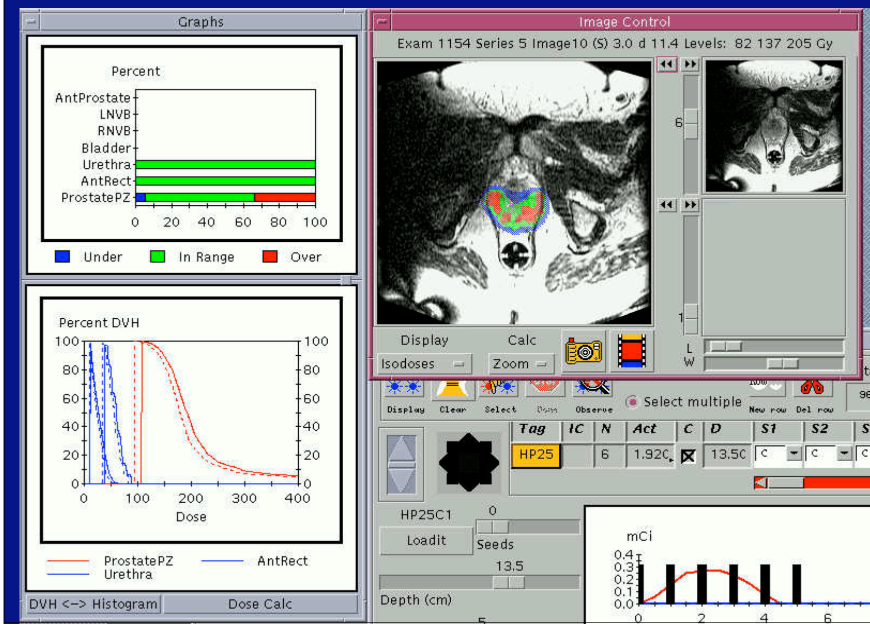


Treatment monitoring/needle

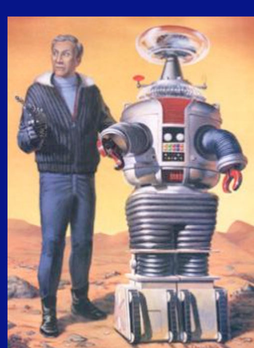


Provided by Cormack Tempany, D'Amico et al.

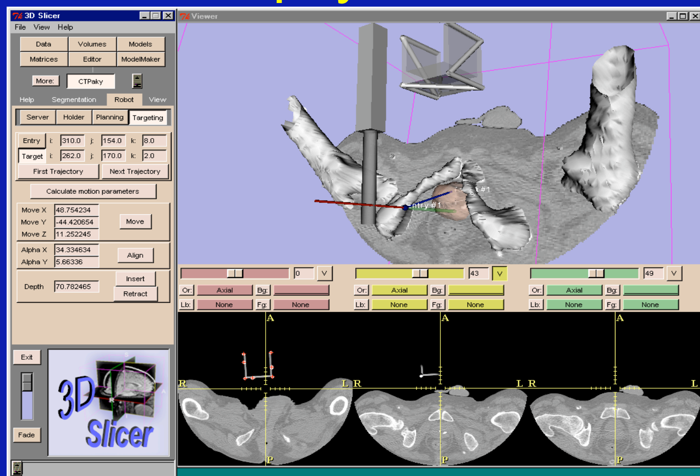
Brachytherapy planning



Robot Assisted Procedures



CISST 1: CT-guided Prostate Biopsy Robot



Intra-operative Plan – with Slicer © G. Fichtinger, D. Stoianovici, et.al. (CISST@ JHU)

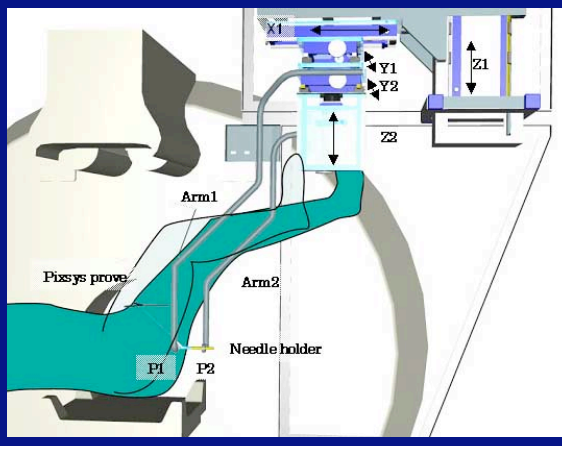
MRT Robot 1999-2001

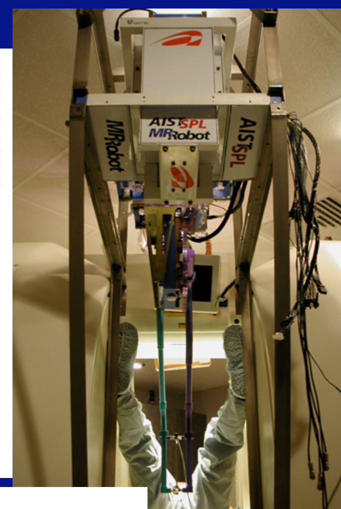
Mechanical Configuration

32 sec

Robotic Assist for MR-guided Prostate Brachytherapy

Pre-clinical evaluations





© SPL and AIST

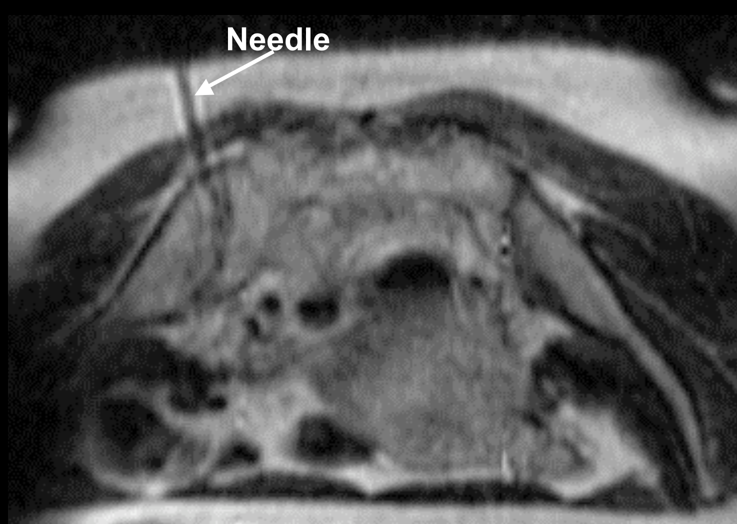
Chinzei et al., MICCAI-2003 (accepted)

Chinzei et al. Med Sci Monit, vol. 7, No. 1, pp. 153-63, 2001.

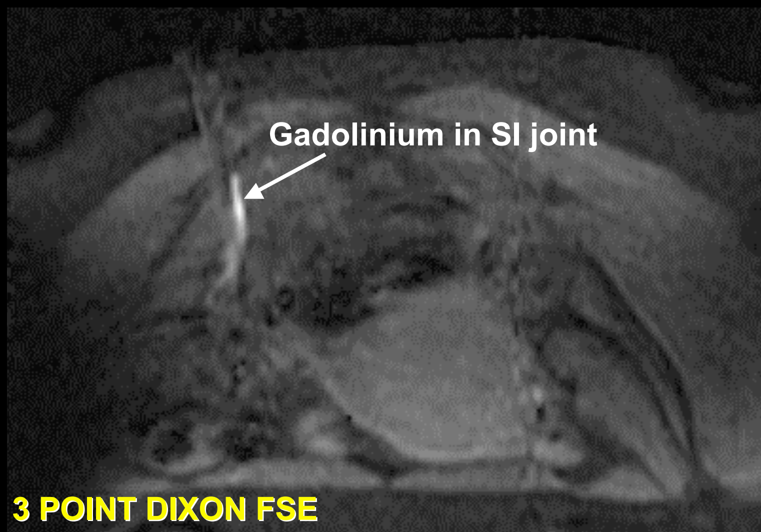
Spine Procedures

- Biopsies
- Injections
- Disc procedures
- Cryotherapy of facets
- Vertebral augmentation

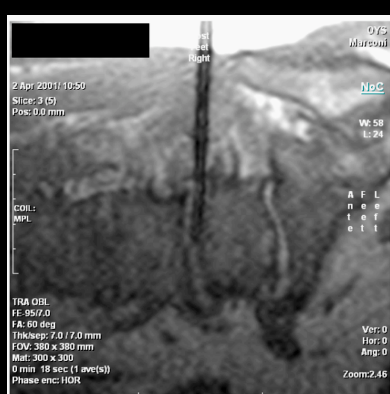
SACROILIAC JOINT ASPIRATION



SACROILIAC JOINT ASPIRATION

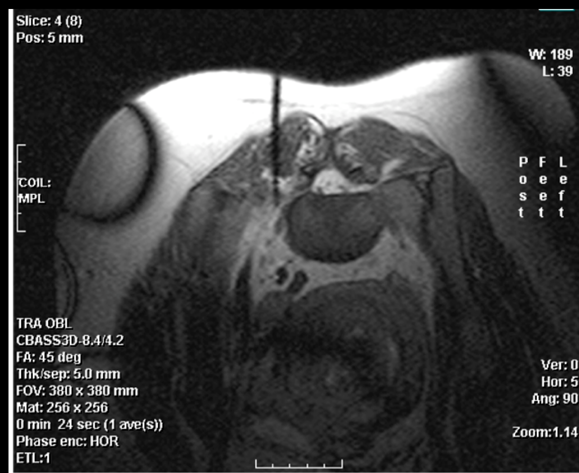


Discography



Courtesy of Dr. Roberto Blanco Sequeiros, Oulu University Hospital, Finland

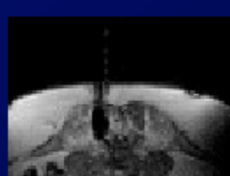
Periradicular Injection



Courtesy of Dr. Roberto Blanco Sequeiros, Oulu University Hospital, Finland

Facet Syndrome Cryoablation Neurotomy

Technique



freezing cycles

ice ball diameter control by MRI visualisation

du Centre Hospitalier Universitaire de Québec (CHUQ)

CHUQ CENTRE HOSPITALIER UNIVERSITAIRE DE QUÉBEC

Tumor Ablation

MR is temperature sensitive & can monitor treatment

- Cryotherapy
- Radiofrequency (RF)
- Laser Interstitial Treatment (LIT)
- Focused UltraSound (FUS)

ELEMENTS OF THERMAL ABLATION

- Planning
- Targeting
- Monitoring
- Controlling
- Assessment

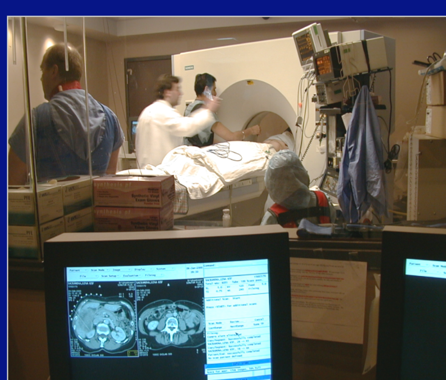
Imaging plays a key role in each

193 Percutaneous Ablations

	CT/US-Guided		MRI-Guided
Organ/Agent	RFA	ETOH	CRYO
Liver	67	8	34
Kidney	6	-	15
Adrenal Gland	5	-	1
MSK/Soft Tissue	9	1	27
Breast	1	-	-
Pancreas	-	2	-
Lung	17	-	-
Totals	105	11	77

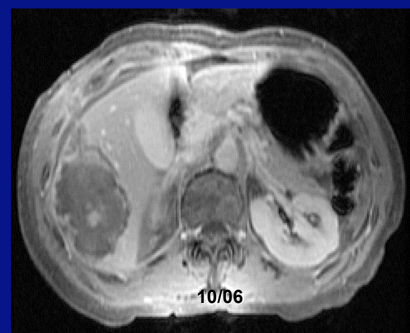
per 7/31/03

CT-GUIDED RF ABLATION



Standard CT scanners can provide guidance for interventional procedures including thermal ablation. While thermal monitoring is sub-optimal, targeting tumors with radiofrequency (RF) electrodes benefits from quick scan times and CT-fluoroscopy.

CT-GUIDED RFA - LIVER



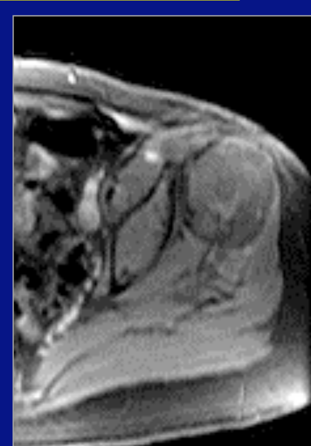
Intraprocedural CT @ 12 min RFA

Post-RFA MRI

CT-GUIDED RFA - MSK

CT PRE

CT INTRA



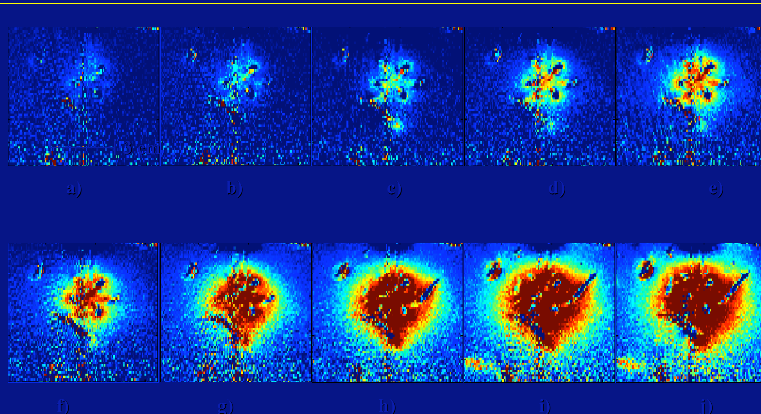
MRI POST

CT-GUIDED RFA - LUNG

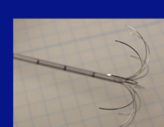
RFA

Post-RFA MRI Coronal

MRI THERMAL MAP of RFA

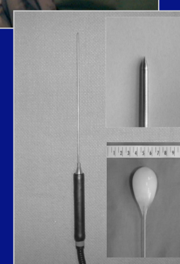


Radiofrequency ablation in liver in vitro at 1.5T
Image plane perpendicular to long axis of Boston Scientific array-style electrode (shown at right).
Above images acquired with RF “off” at progressively longer exposures.

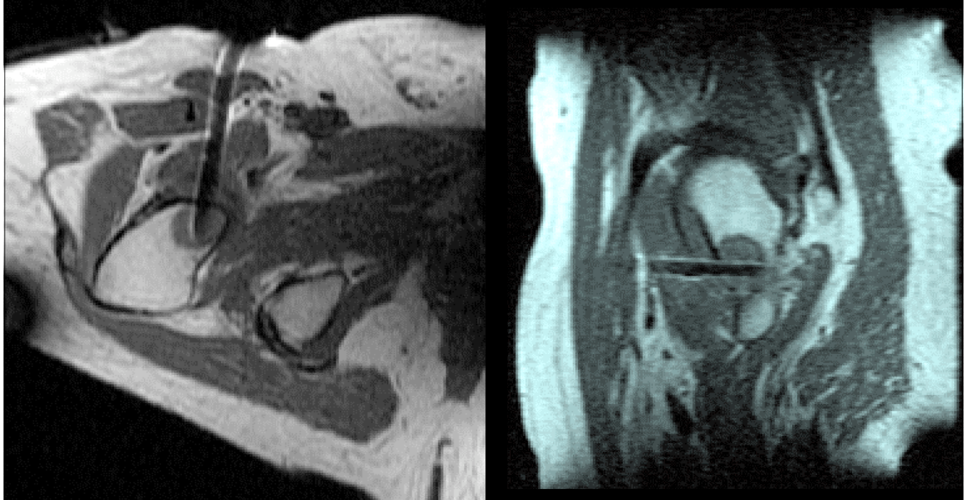


MRI-GUIDED CRYOTHERAPY

Vertically open 0.5T MRI scanner provides access to patient for percutaneous thermal ablation; gas-based cryo technology allows for multiple, small diameter cryo-needles to freeze tumors.

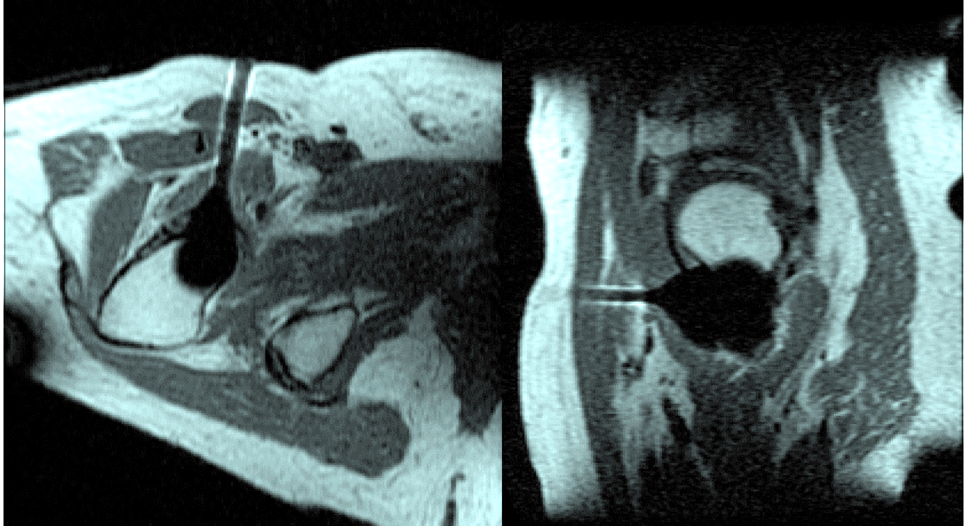


Cryotherapy Needle Placement



Axial T1W Sagittal T1W

Monitoring of Ice Ball

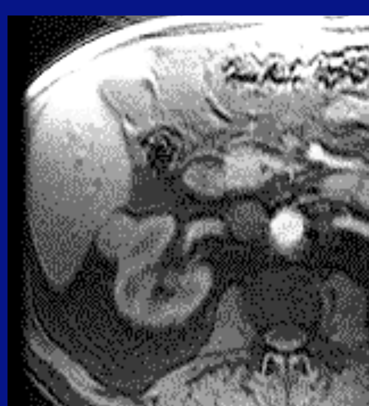


Axial T1W Sagittal T1W

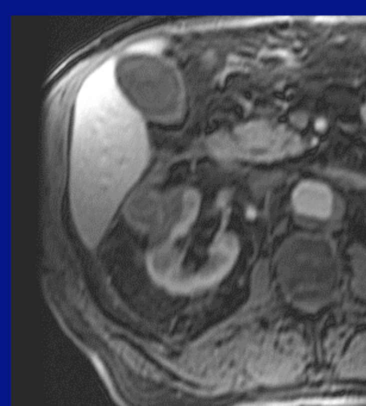
MR Following Cryotherapy

Axial STIR FSE

MRI-GUIDED CRYO - KIDNEY



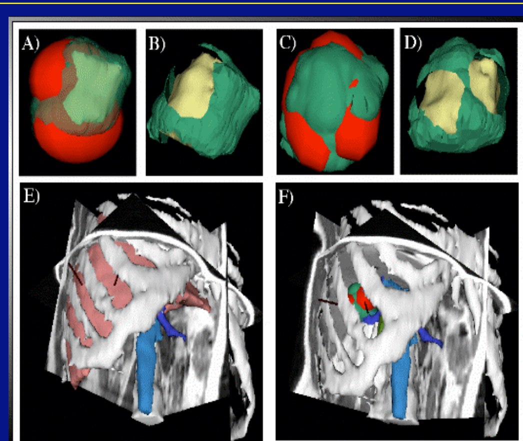
Pre-Procedure



Post-Procedure

MRT CRYO Proc#104

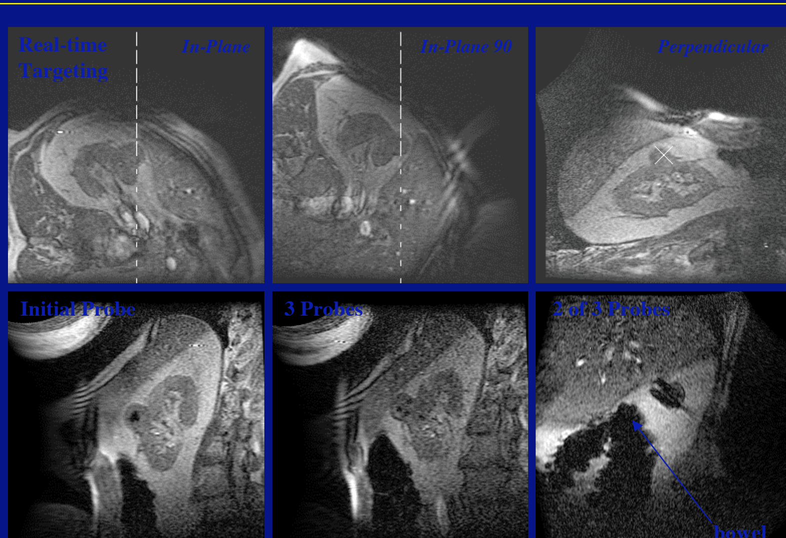
PLANNING



Computer-assisted planning of cryotherapy can assist in the optimization of probe placement. Multiple elliptical volumes are used to approximate coverage of a tumor (green), *A and C*. For research, such idealized plans can be compared retrospectively against actual ice formation (yellow), *A, B and D*. A global view of the anatomy provides visualization of possible probe trajectories (liver, pink; vessels, blue), *E and F*.

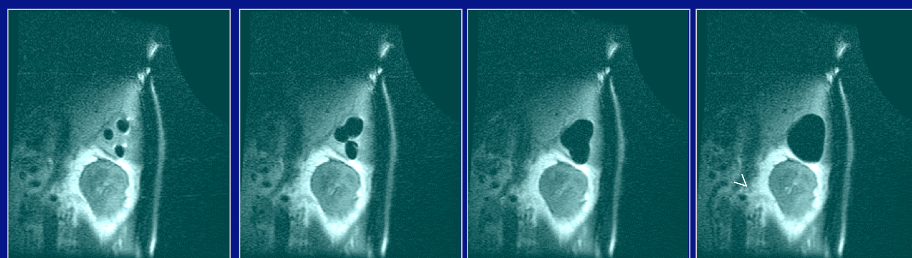
www.spl.harvard.edu

TARGETING



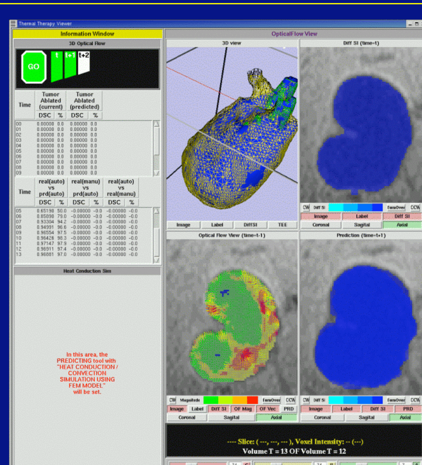
MRI-GUIDED CRYO RENAL

MONITORING



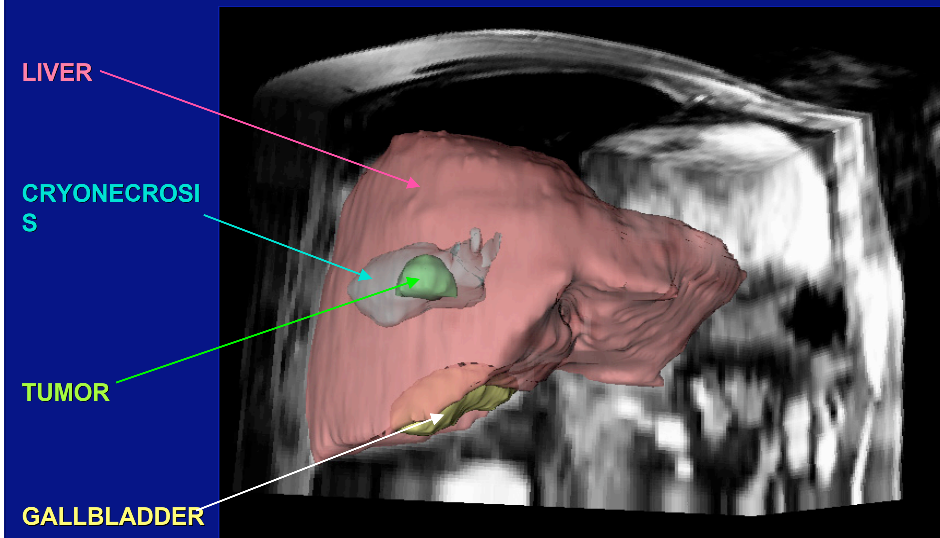
MRI-GUIDED CRYO LIVER
3 CRYONEEDLES AT 4 TIME-POINTS DURING A 15 MINUTE FREEZE ADJACENT TO KIDNEY

CONTROL

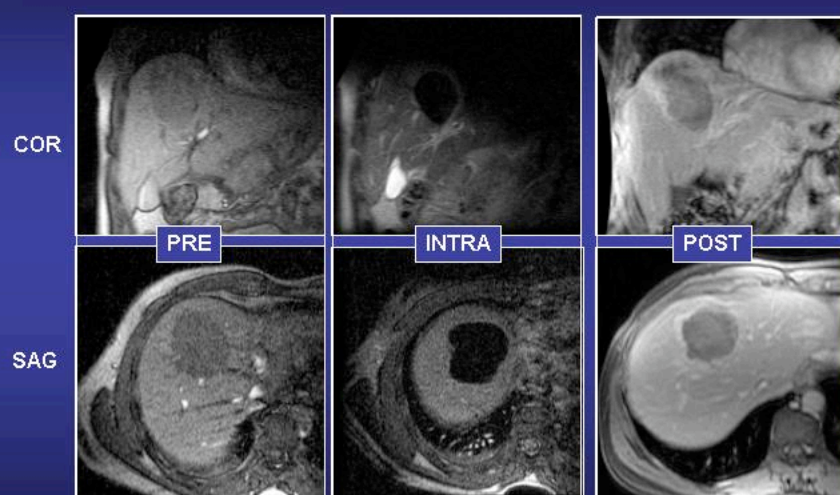


Computer-assisted control can be achieved by techniques such as optical flow (OF) which can both monitor and predict. The 3D computation augments the physicians visualization. 10 min freeze, MRI-guided cryo experimental liver.
Top left: 3D view; *top right*: in plane view of actual iceball;
bottom left: OF vectors identify growth; *bottom right*: predicted iceball.

ASSESSMENT

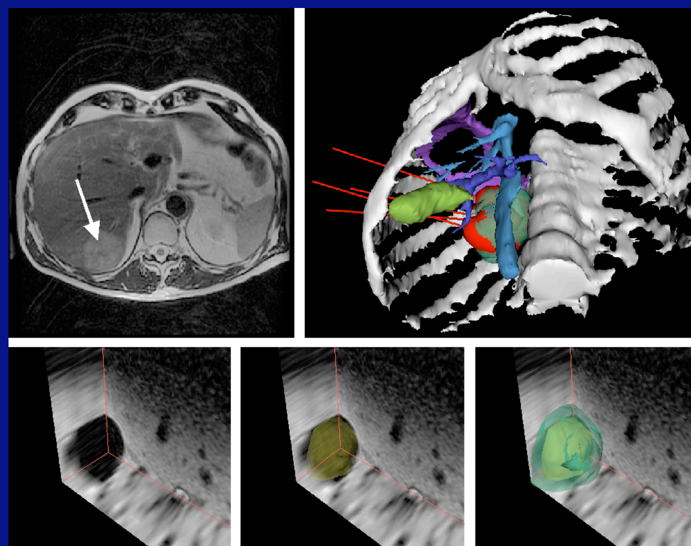


MRI-GUIDED CRYO - LIVER



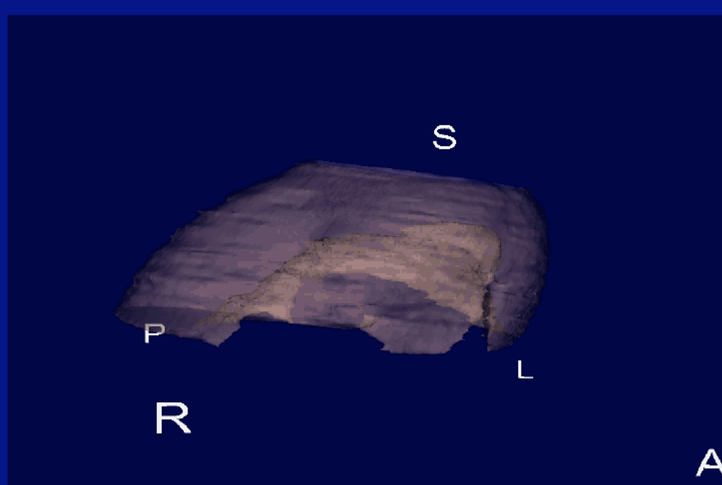
MRT CRYO Proc#077

Liver Cryotherapy



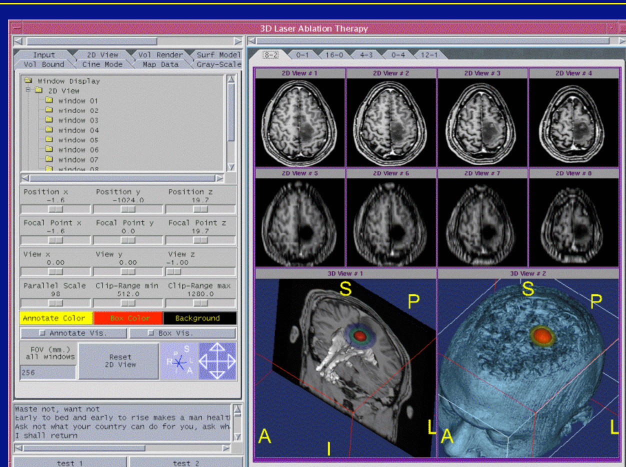
Provided by Silverman, Butz et al.

Ice Ball 3D



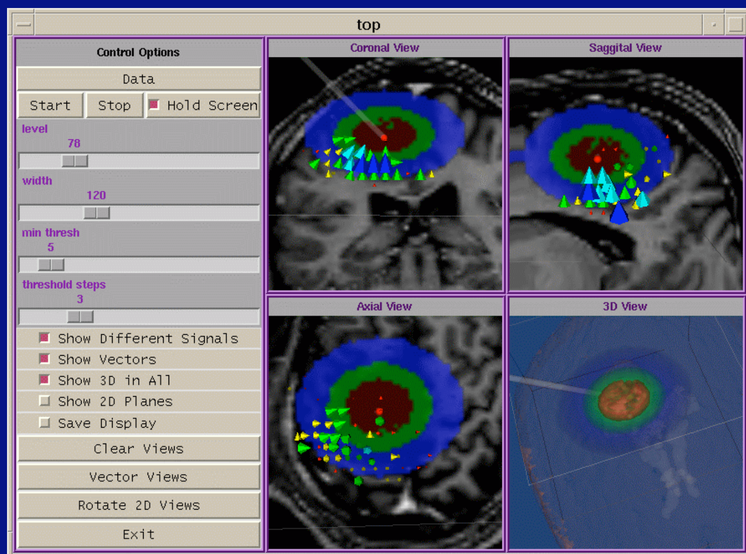
MRI-Guided
Interstitial Laser Ablation

3D THERMAL MAP for ILT

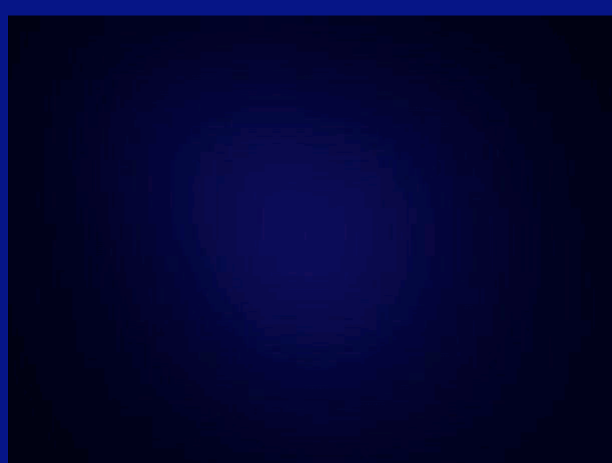


3D Interstitial Laser Therapy (ILT) Surgical Guidance System.
System is interactive with scanner to control image plane and range.
Display allows various combinations of data display: multiple planes, multi-planar reformatted images, volume rendered data, image-derived data as overlays (I.e. temperature mapping)

Laser workstation



Laser 3D

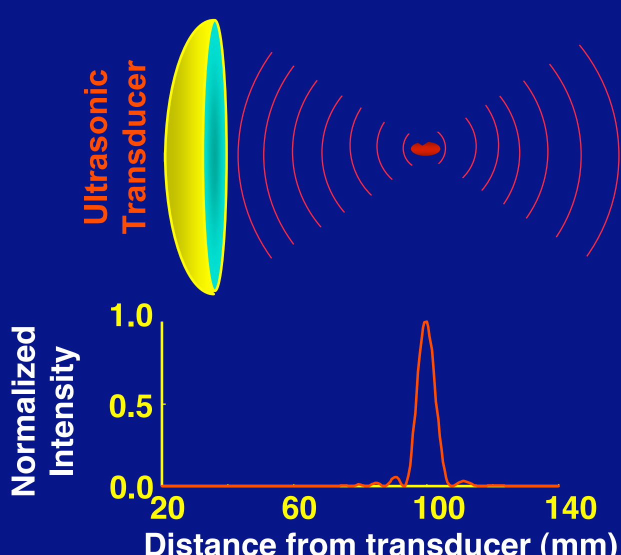


MRI Guided FUS

The “ideal” Surgery:

- Tissue destruction only within targeted area
- No tissue damage outside the targeted area

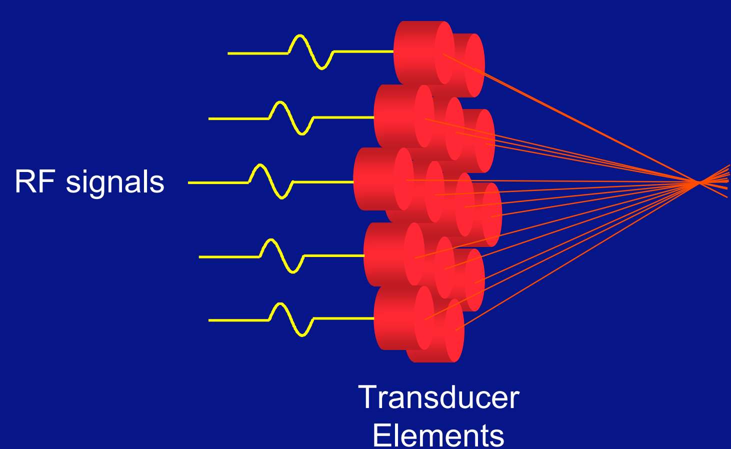
Single Focus Transducer



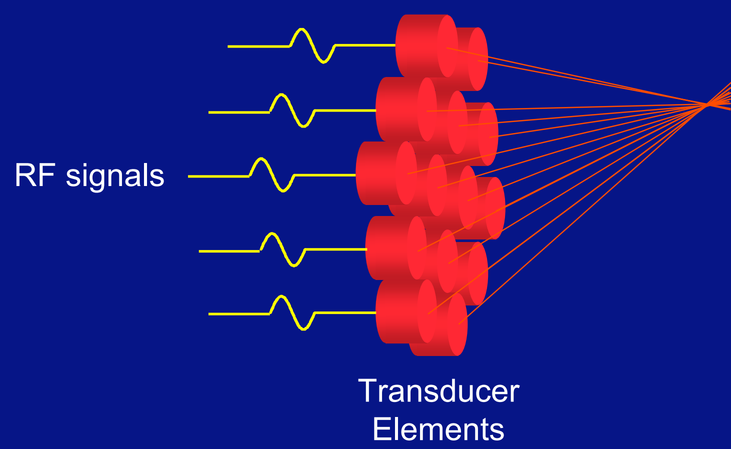
Hynynen -99

Two goals,
Two technologies

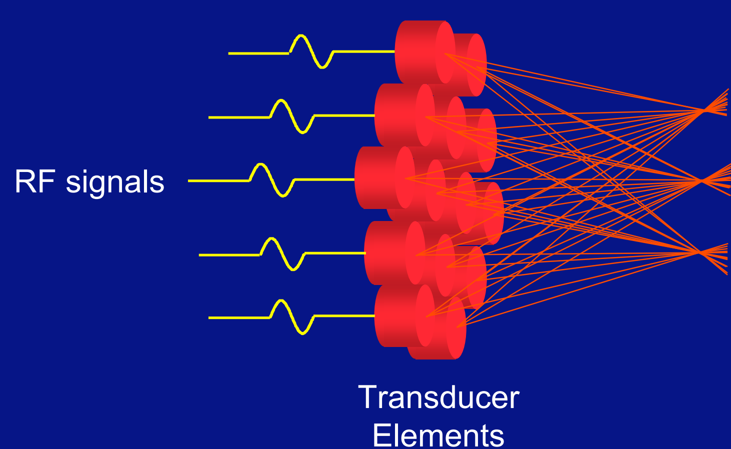
- **Target Definition** **Imaging**
- **Energy Deposition** **Acoustics**



Ultrasound Phased Arrays

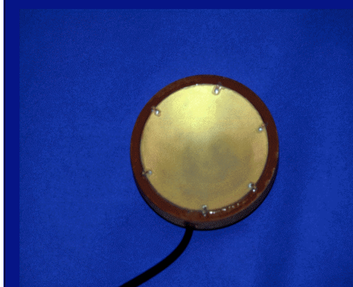


Ultrasound Phased Arrays

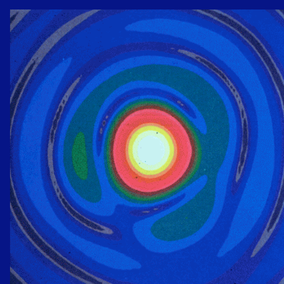


Ultrasound Phased Arrays

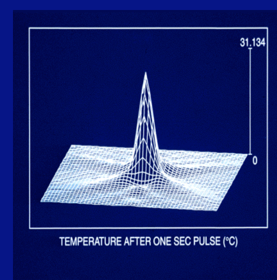
Ultrasound as a Heat Source



Transducer

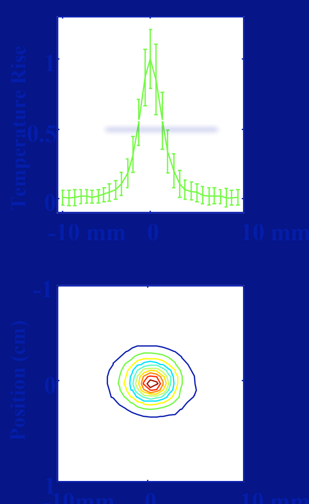


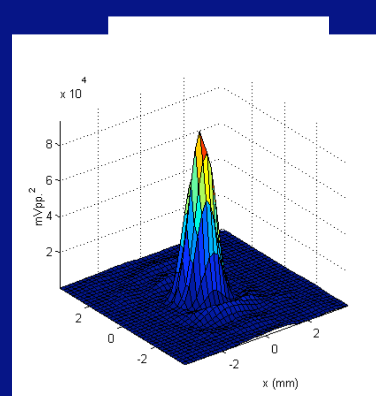
Cross-Section Of Acoustic Energy



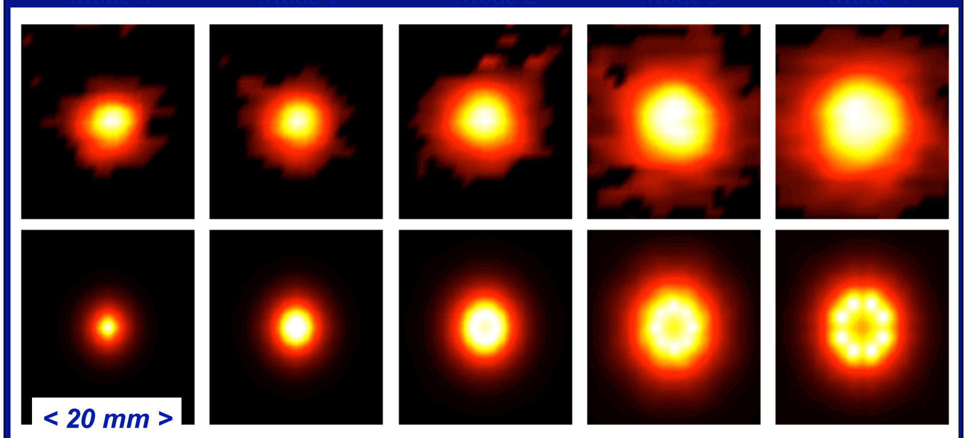
Thermal Map

Temperature Profile





Control of Sonication Volume

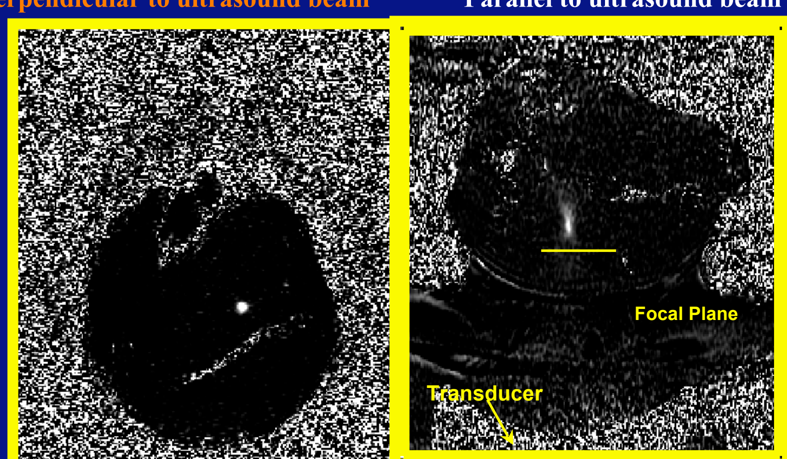


Phased Array Transducer =
Dynamic Electronic Control of Spot Size

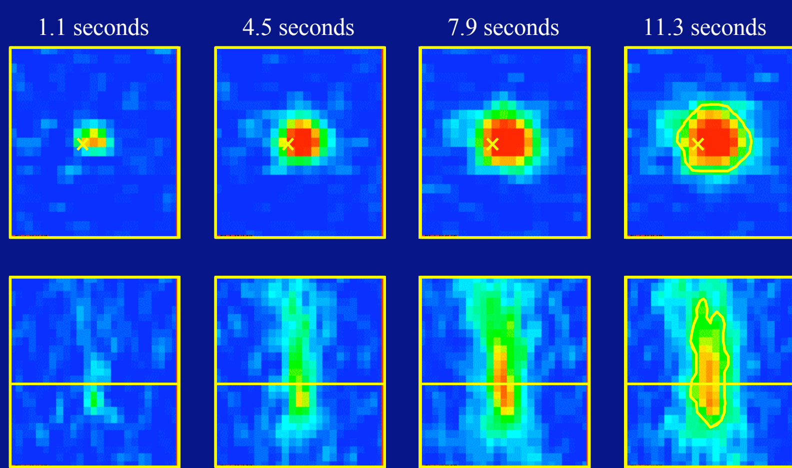
Temperature Images

Proton Resonance Frequency (PRF)

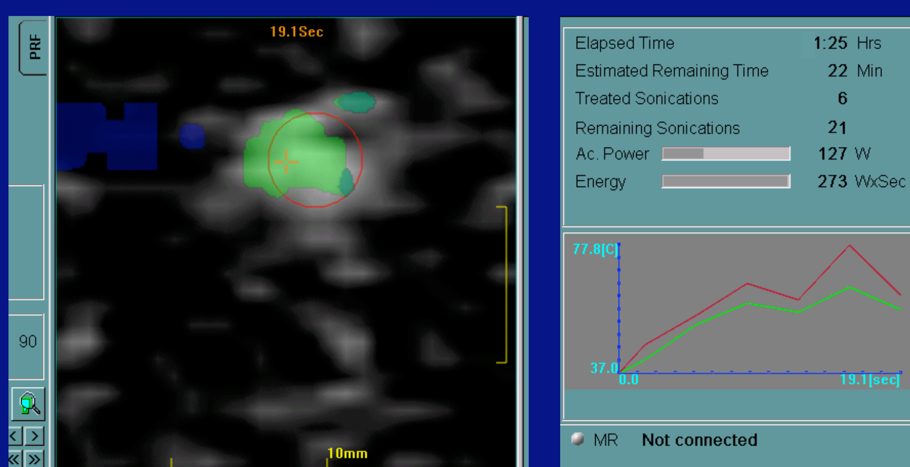
Perpendicular to ultrasound beam **Parallel to ultrasound beam**



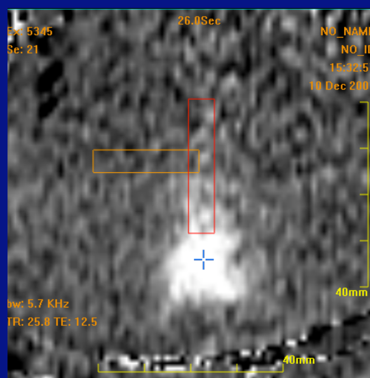
Thermal Development of a 10 Second Sonication

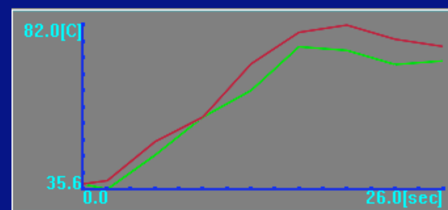


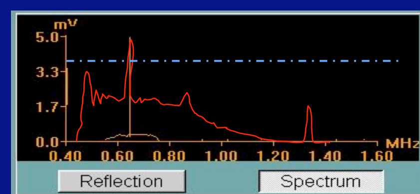
Temperature Graph



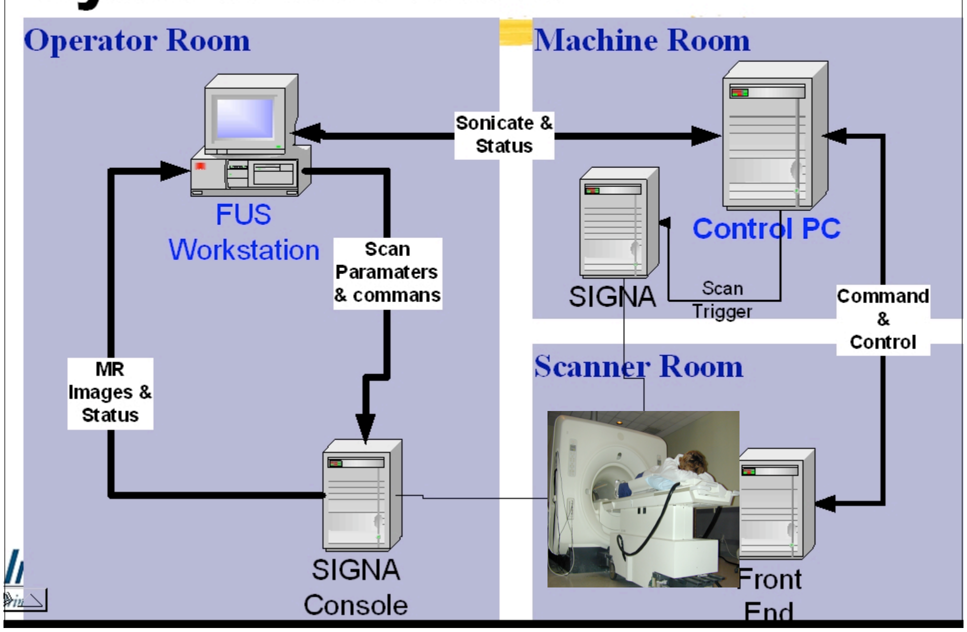
Sonication Monitoring (temperature,dose)





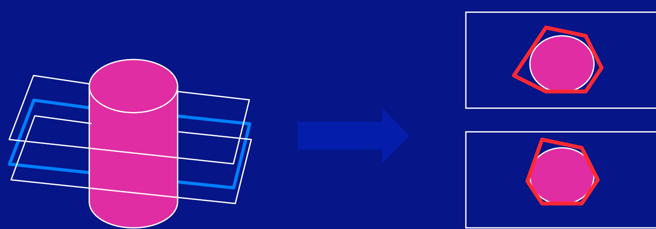


System Overview

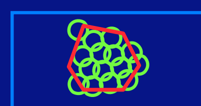


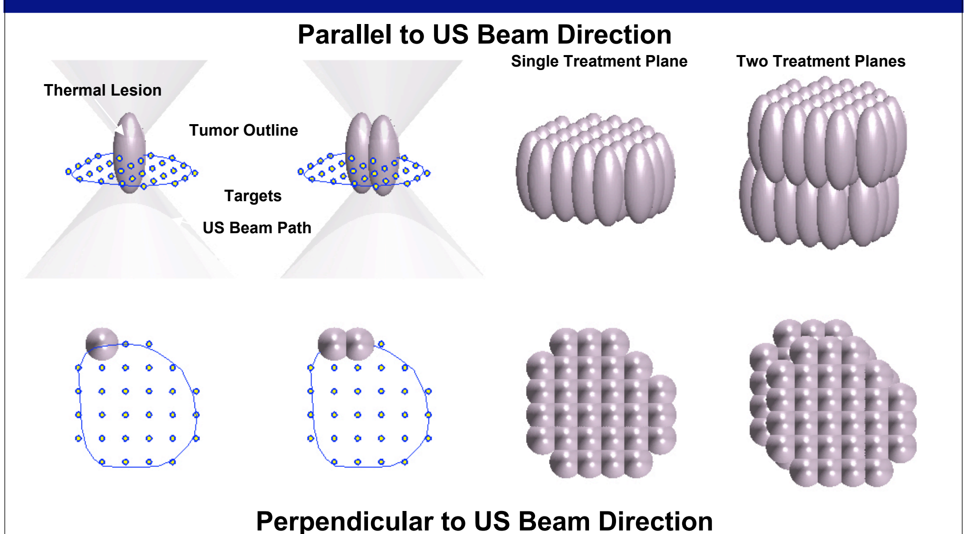
FUS Treatment Plan

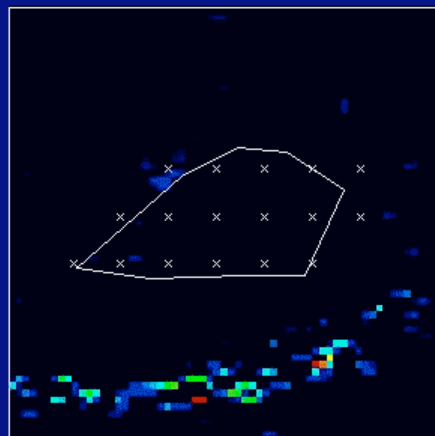
- Draw Treatment Region on 1 or More Slices



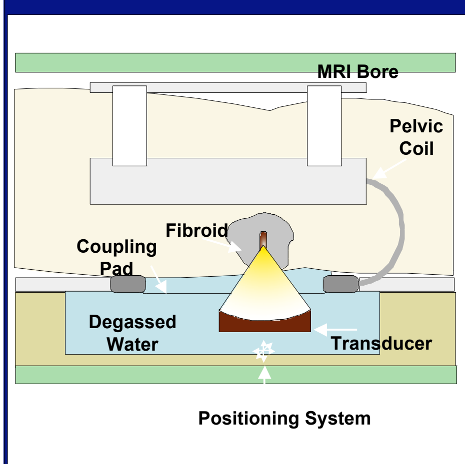
- Computer Fills All Layers With Sonications

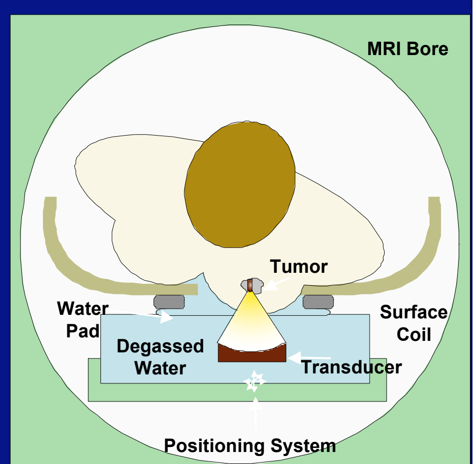






Clinical Applications of MRgFUS

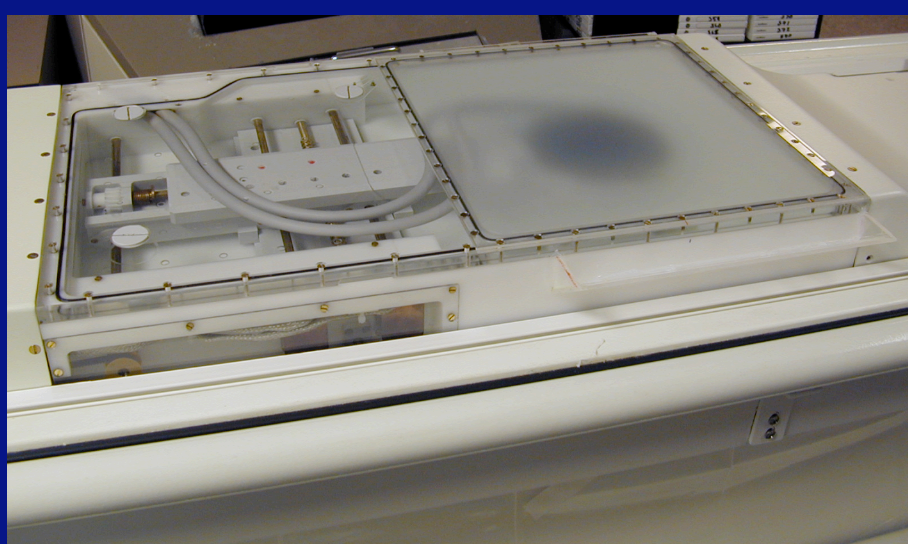




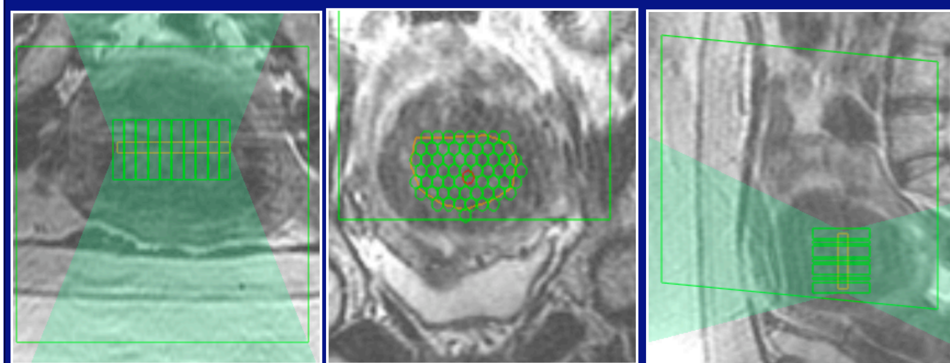
P
e

Pelvis **Breast**

MRI-Guided Focused Ultrasound System

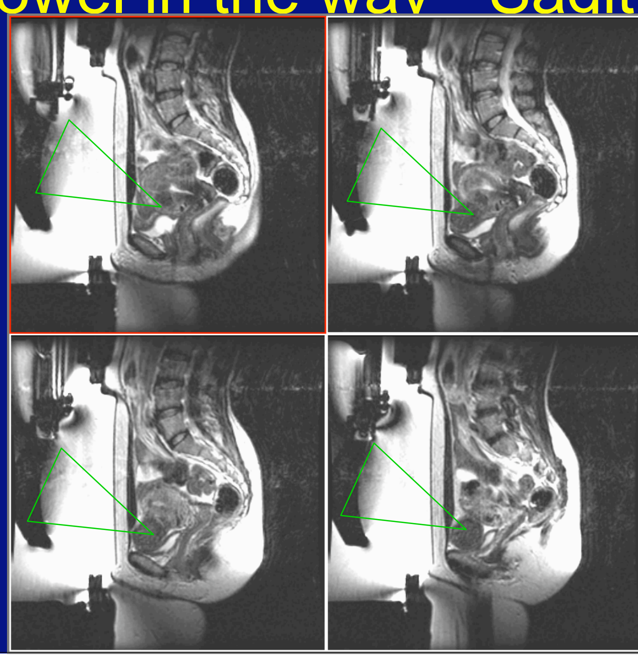


Treatment Planning

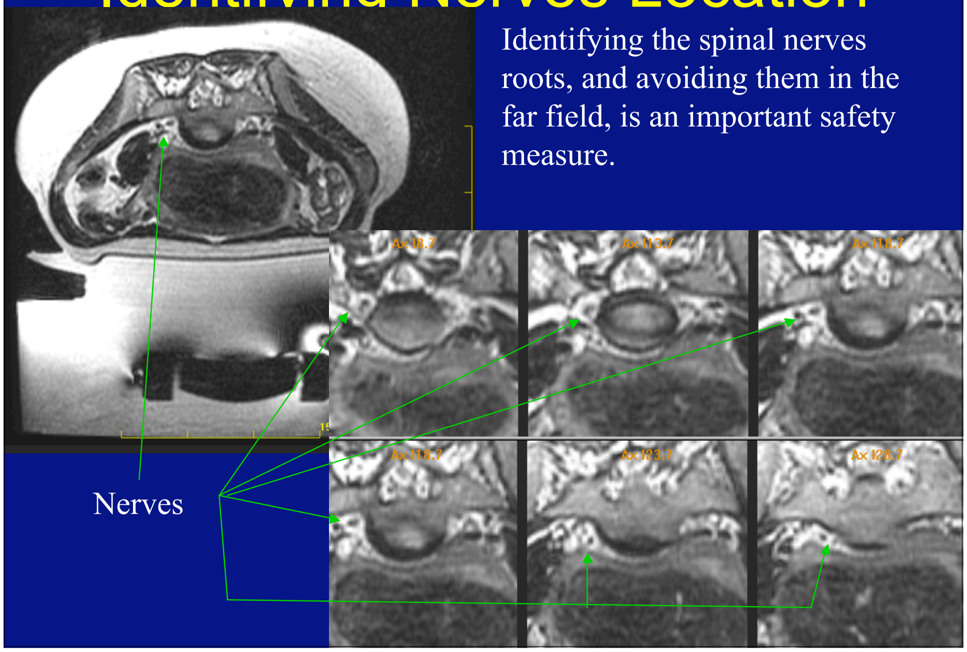


Axial Coronal Sagittal

Bowel in the way - Sagittal

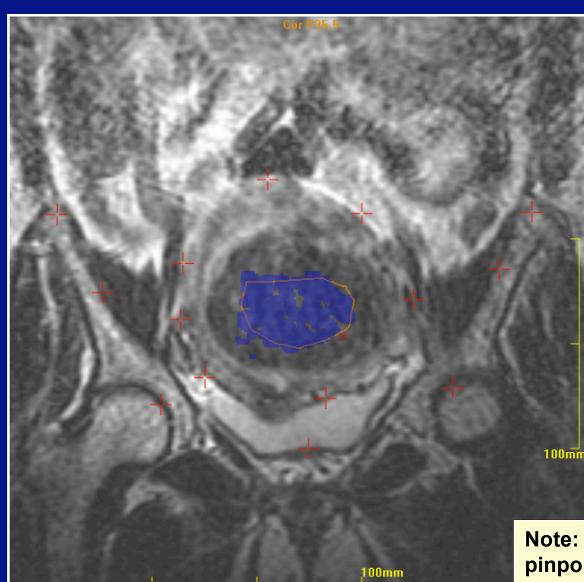


Identifying Nerves Location



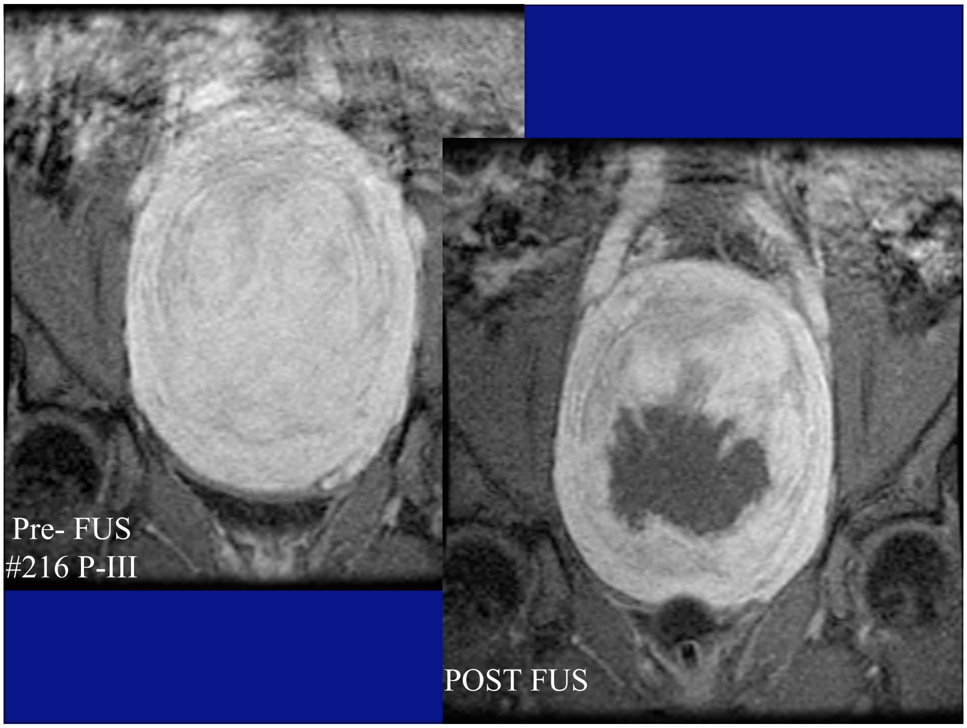
Identifying the spinal nerves roots, and avoiding them in the far field, is an important safety measure.

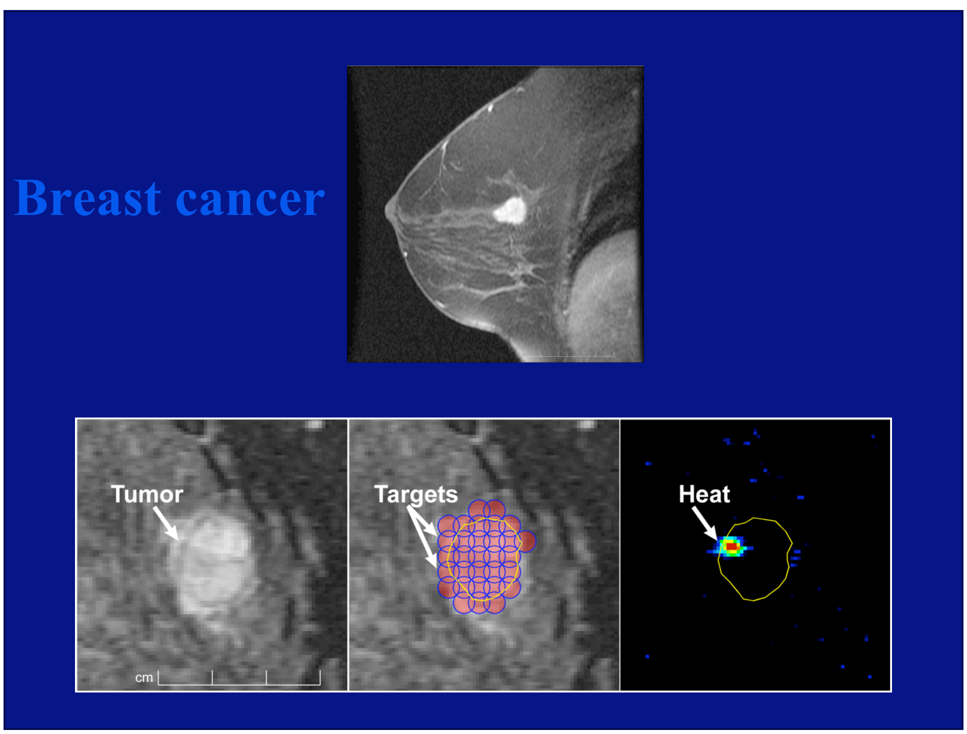
End of treatment



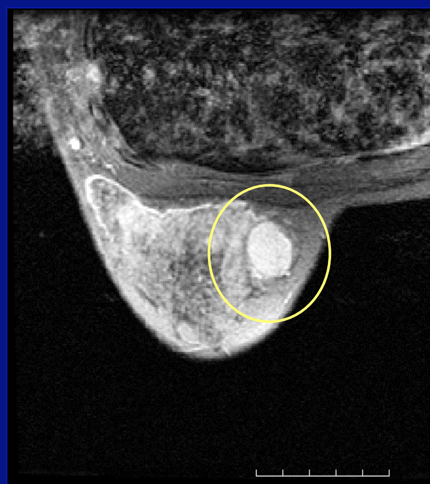
The treated layer with all the accumulated dose (blue).

Note: The red pinpoints are fiducial points

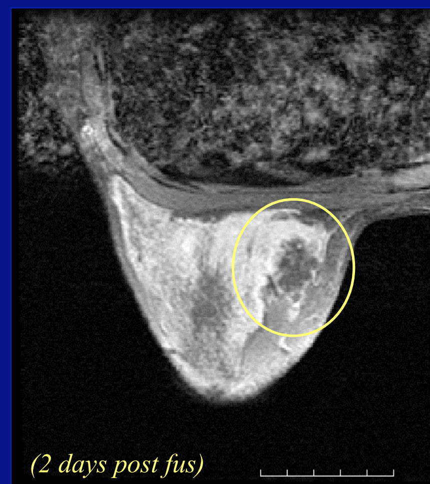

Pre- FUS
#216 P-III
POST FUS


Breast cancer
Tumor
cm
Targets
Heat

Pre-FUS

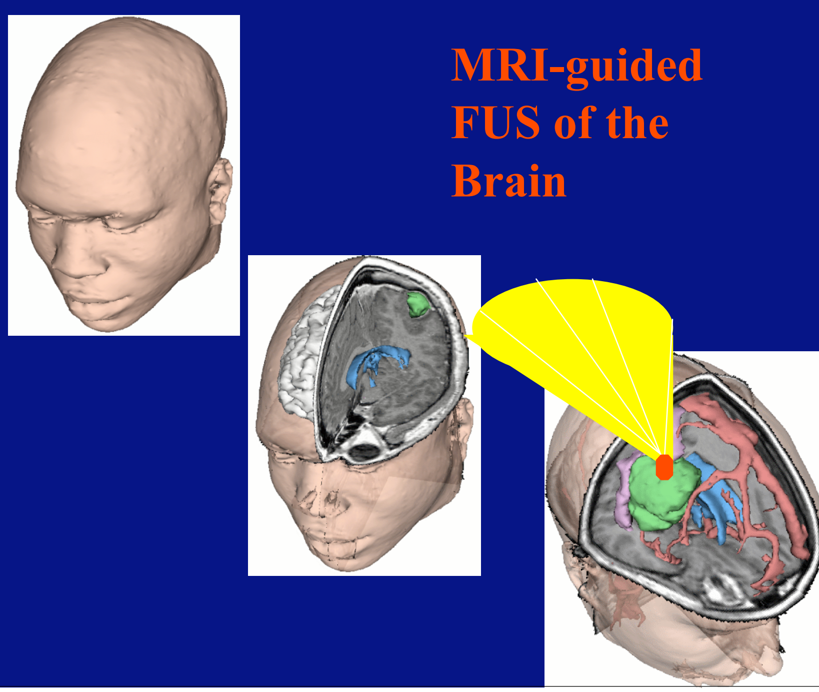


Post-FUS

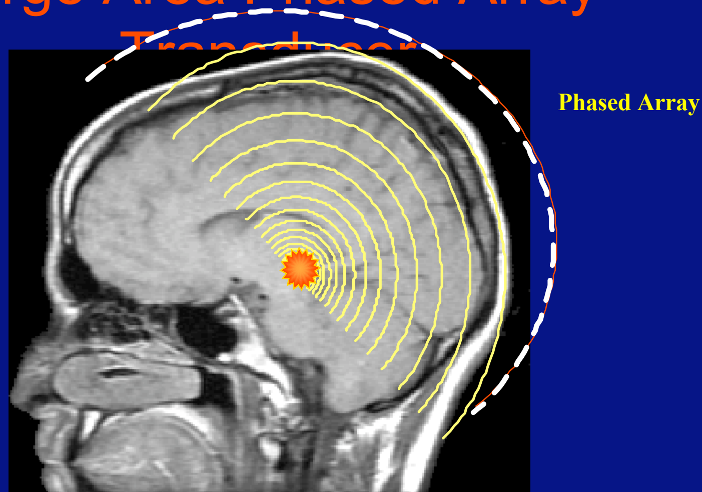


FIBROADENOMA

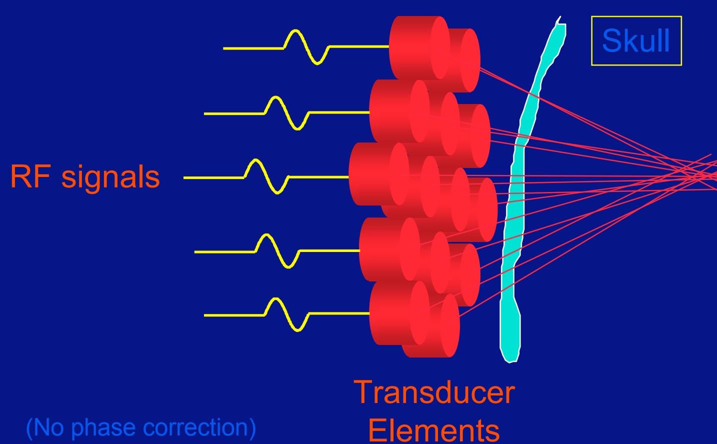
MRI-guided FUS of the Brain



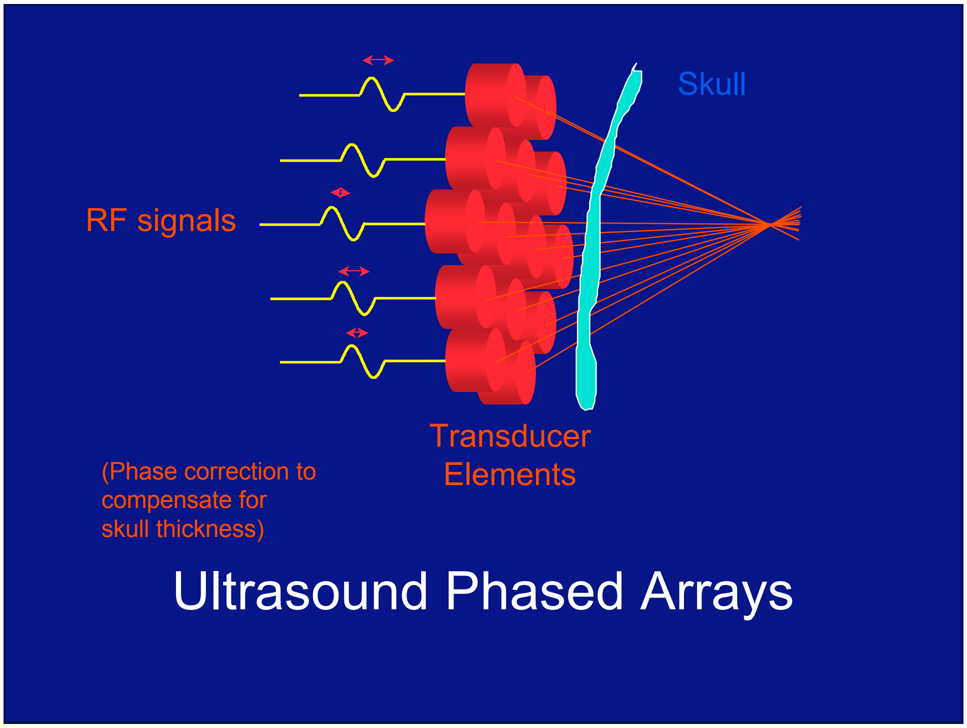
Focused Ultrasound in Brain with A Large Area Phased Array Transducer

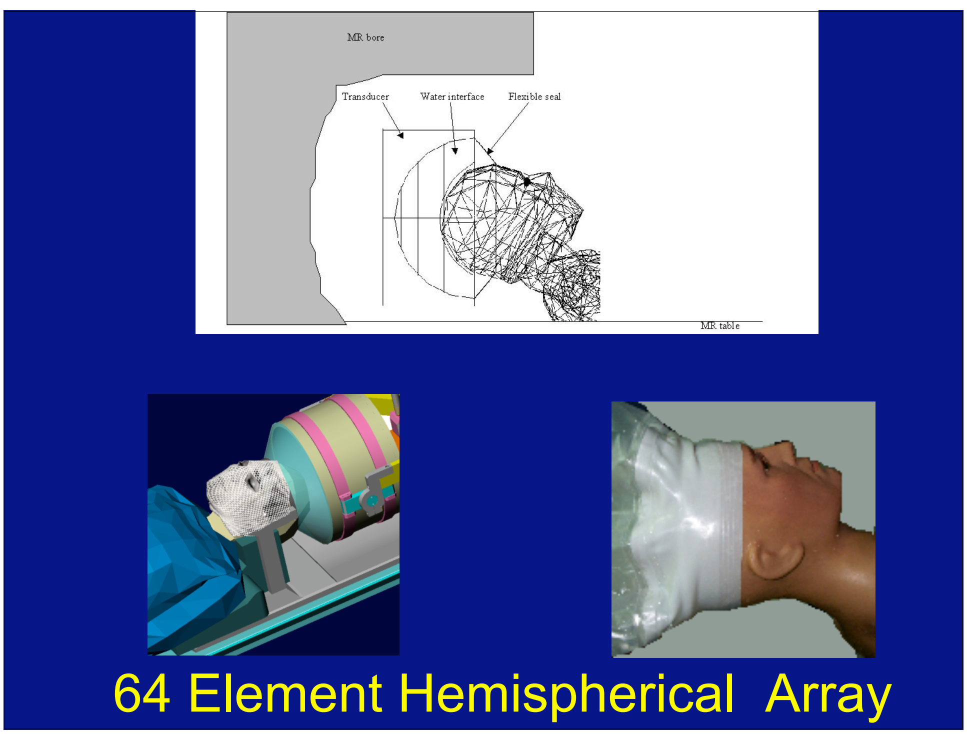


Provided by Hynynen et al.



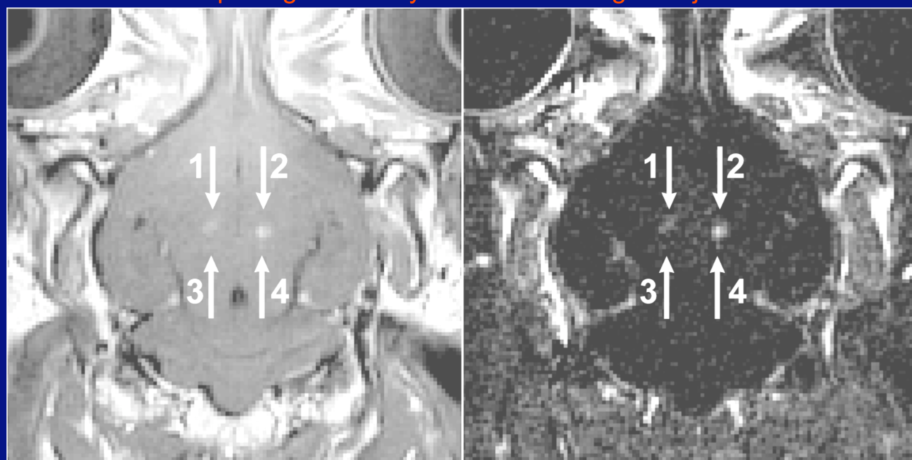
Ultrasound Phased Arrays


Skull
RF signals
Transducer
Elements
(Phase correction to
compensate for
skull thickness)
Ultrasound Phased Arrays


MR bore
Transducer
Water interface
Flexible seal
MR table
64 Element Hemispherical Array

Rabbit Brain In Vivo

- Focal BBB Opening Shown by MRI Contrast Agent Injection

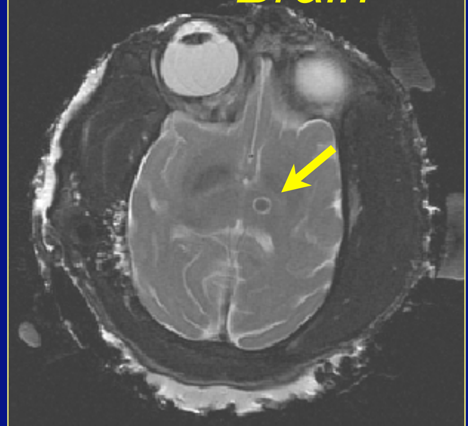


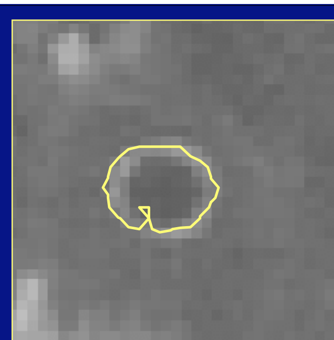
contrast enhanced scan

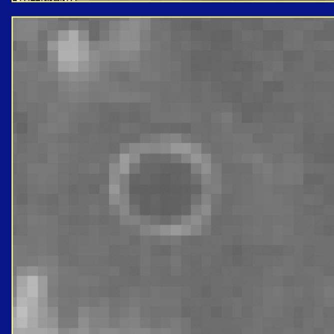
Subtraction Image:
After – Before Contrast Injection

Provided by Hynynen et al.

FUS Monkey Brain







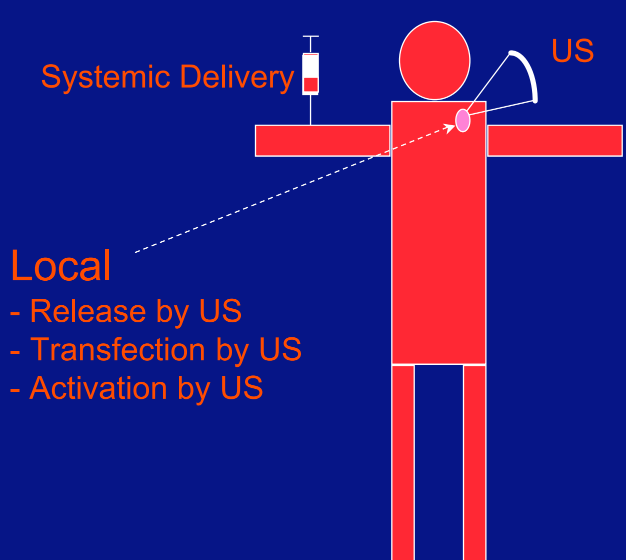
Provided by Hynynen et al.

Targeted Delivery of Macromolecular Agents by FUS induced cavitation energy

1. Focal opening of blood brain barrier

2. Increase in permeability of blood vessels

3. Increased cell membrane permeability



Localized Gene Therapy using Focused Ultrasound

MRI Guided FUS Summary

1. Noninvasive Image Guided Focal Energy Delivery:
   - On-line Localization
   - Exposure Monitoring
   - Close loop control of Energy Delivery

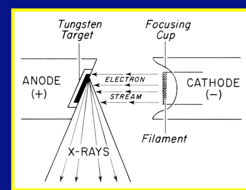
2. Clinical Applications:
   - **Tumor**: Tissue coagulation, vaporization, debulking
   - **Blood vessel**: occlusion, thrombolysis
   - **Blood brain barrier**: targeted drug delivery
   - **Cell membranes**: gene therapy, drug activation

Multimodality Intervention

Combination of fluoroscopy and MR imaging → complimentary

Concept for hybrid system

fixed anode x-ray tube with anode-cathode axis aligned with B_0



B_0

flat panel detector should (in principle) be immune to magnetic fields

Courtesy of Norbert J. Pelc, Sc.D.

APPLICATIONS

- **should exploit relative strengths**
- **X-ray**
  - **speed**
  - **spatial resolution**
  - **projection format**
  - **ease of use**
- **MR**
  - **soft tissue detail**
  - **physiology**
  - **therapy monitoring**

XMR configurations

- 2 gantry + "railroad track"
- front of conventional system

- vertical field "open"
- "double-donut" magnet

reduced impact of each on the other
higher performance

increased integration
safer

Courtesy of Norbert J. Pelc, Sc.D.

Applications of hybrid system

- ➡ Diagnostic procedures
- Vascular interventions
- Surgical guidance
- ➡ Chemoembolization
- ➡ Biopsies
- ➡ TIPS (Transjugular Intrahepatic Portosystemic Shunt)
- PTHC (Percutaneous Transhepatic Colangiogram)
- Vertebral Augmentation (Vertebroplasty
- Electrophysiology

3 generations

1. Fixed detectors
   (1 or 2 planes)
2. Rotating detector (C-arm)
3. MR alone

IMAGE GUIDED
MULTIMODALITY
MULTIAPPLICATION
IMAGE GUIDED
OPERATING ROOM

MRI/PET/CT/FLUORO/US

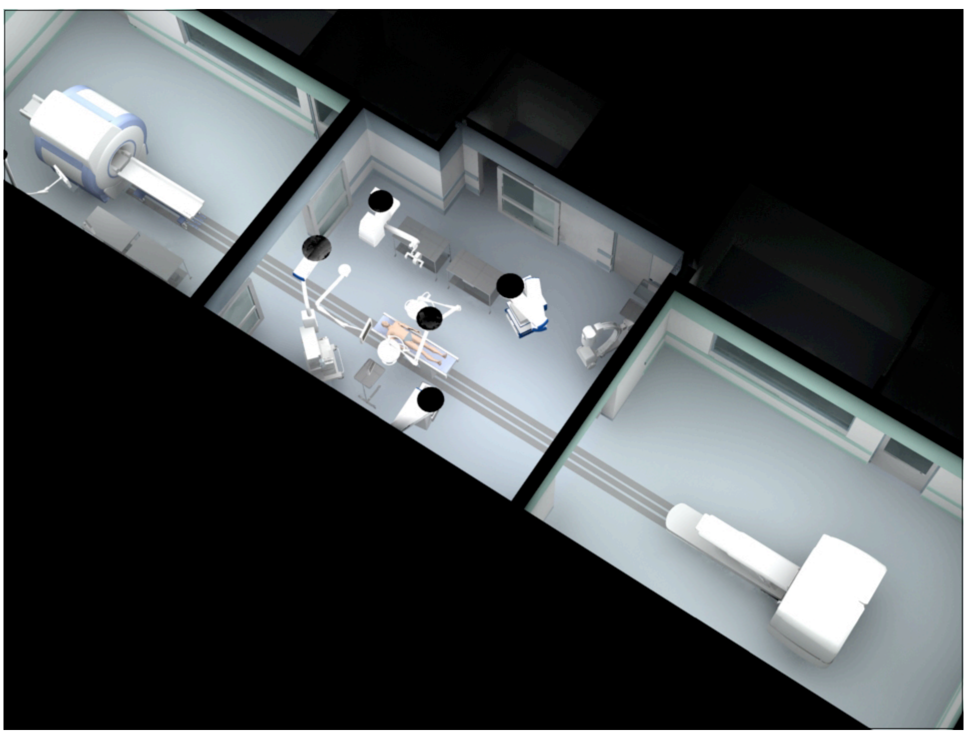
Endoscope, optical imaging,

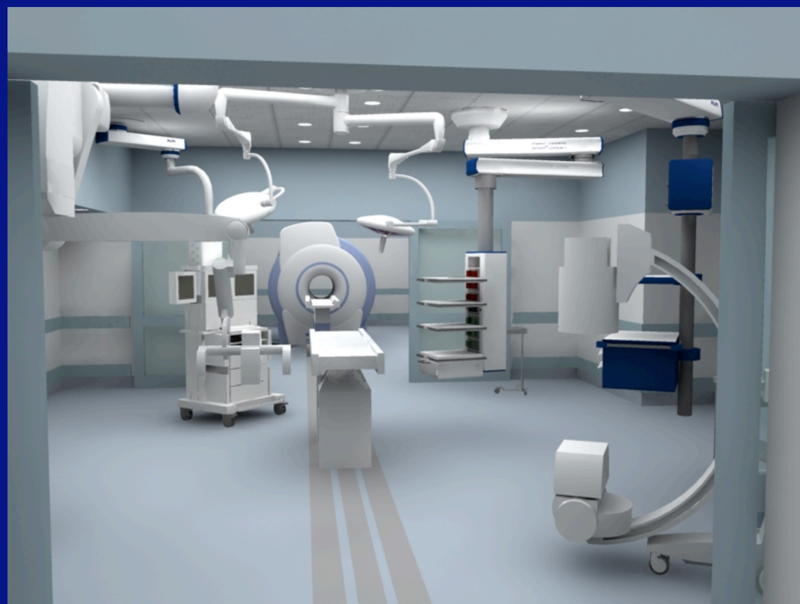
Surgical microscope

Anesthesia

Monitoring

IT





I.G.O.R.
Image Guided Operating Room

Dr. F. Jolesz

Brigham & Women's Hospital

PAYETTE
ASSOCIATES

Combined MR/CT/PET Imaging for Surgery

- Neurological
- Oncology
- Cardiovascular
- Orthopedic
- Urology
- Gynecology

Combined MR/CT/PET Imaging for Surgery

- Open Surgery
- Endoscopic Surgery
- Percutaneous Procedures
  - Catheter based (vascular)
  - Probe placement (RF, cryo, laser)
- Non-invasive Surgery (FUS)

Justification for PET/CT

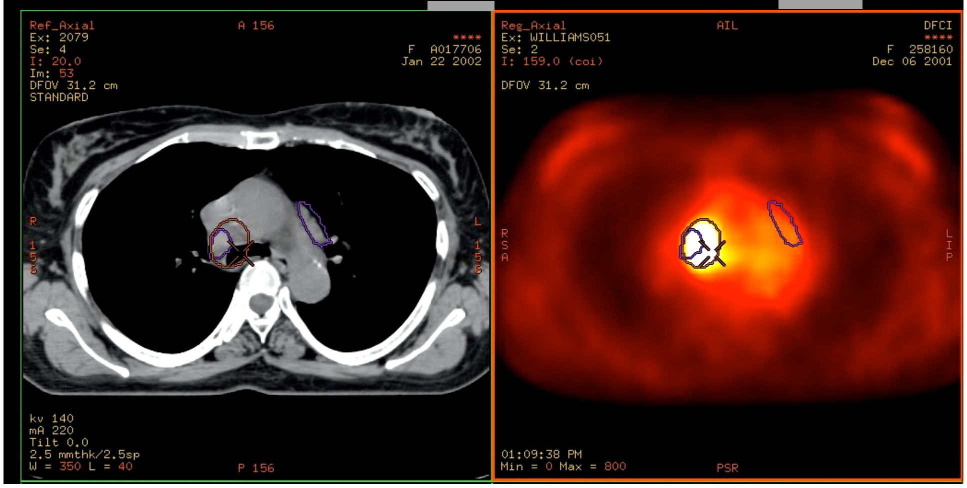
- Noninvasive, real time assessment of the safety of tumor resection margins
- Assessment of metabolically active tumor volume
- Metabolically guided tumor biopsy
- Synergism between IGOR and molecular imaging program

Potential Radiation Oncology Uses of Combined MR/CT/PET Suite

- ***Simulation***
  - **CT/PET Without MR**
  - **CT/PET With MR**

- ***Brachytherapy***
  - **Head and Neck**
  - **Gynecological**
  - **Prostate**

Incorporate PET (metabolic) CT/PET allows registration



Clinical Challenges

- Volume
- Efficiency
- Compensation

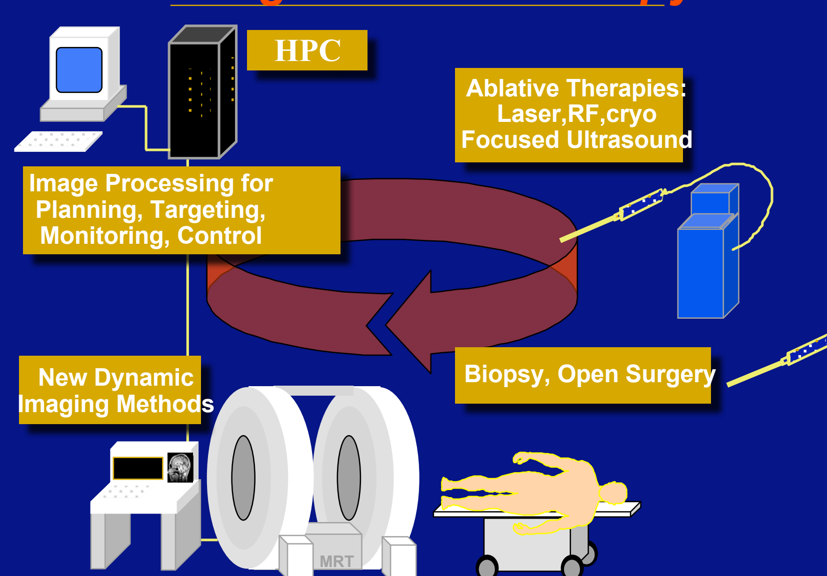
Research Framework

- Technical efficacy and safety
- Diagnostic impact
- Therapeutic impact
- Outcomes

$$\text{VALUE} = \frac{\text{QUALITY}}{\text{COST}}$$

Uwe Reinhardt "The Physician Executive: Will Physicians Take Back Medicine?"

Image-Guided Therapy



Future Performance Requirements for IGT

• Visualization	Computer Vision
• Registration	Multimodality Fusion
• Segmentation	Image Processing
• Quantification	Validation
• Regulation	Control theory
• Integration	System Engineering

Image-guided Therapy

- Multidisciplinary approach
- Interdisciplinary collaboration
- Multimodality approach
- Multiple vendors and industries
- Multiple funding sources
- New training tracks

Technical Improvements

- General
- Specific

Most important challenges of IGT

- Improving the combined presentation of pre-operative and real-time, intraoperative images
- Integrating imaging and treatment related technology into therapy delivery systems
- Testing the clinical utility of image guidance in surgery and cancer therapy
- Support multidisciplinary IGT Research Centers (including infrastructure)

IGT: Training Opportunities

- R25 (NIH sponsored Training Grant)
- Potential applicants include those PhDs and MDs who have already completed their graduate (specialty) training and who are interested in a career in image-guided therapy
- Scientists will be exposed to the "clinical mindset" of their peers, thus facilitating a richer understanding of how respective specialties respond to emergent issues and address patient care needs.

Real bottom line: patient care

- Provide new capabilities that transcend human limitations in surgery
- Increase consistency and quality of surgical treatments
- Promote better outcomes and more cost-effective processes in surgical practice

Acknowledgements

Jolesz, F.A.
Kikinis, R.
Tempany, C.
Pelc, N.
Butts, K.
Daniels, B.
Lewin, J.

Blanco Sequeiros, R
Winalski, C.S.
Lang, P.K.
Schneider, E.
Kacher, D.
Morrison, P.R.
Silverman, S.G.

Support from: NCI, NIBIB, NCRR, NLM, NSF, DOD et al.

Special Thanks to:

Breast Biopsy:

Erika Schneider, Ph.D.	SciTrials, LLC
Kenneth W. Rohling	GE CR&D
Mitchell D. Schnall, M.D., Ph.D.	Hosp. Univ. Penn.

MR Tracking:

Charles L. Dumoulin, Ph.D.	GE CR&D
Stephen P. Souza, Ph.D.	GE CR&D
Robert D. Darrow, M.S.	GE CR&D
Jorg A. Debatin, M.D.	Univ. Zurich

We live in a time of such rapid change and growth of knowledge that only he who is in a fundamental sense a scholar—that is, a person who continues to learn and inquire—can hope to keep pace, let alone play the role of guide.

Nathan M. Pusey (1)

1. Pusey NM. The age of the scholar. Cambridge, Mass: Belknap, 1963.