AN EXPLORATION IN TRANSCRANIAL MRI-GUIDED FOCUSED ULTRASOUND

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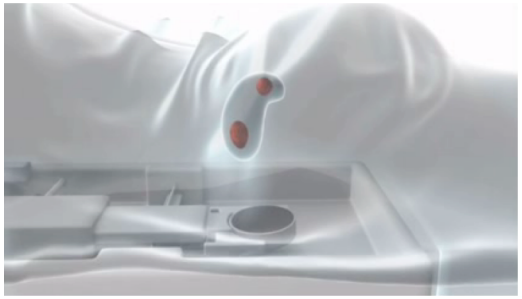
SCIT SEMINAR

MAY 24, 2018

MRI-GUIDED FOCUSED ULTRASOUND

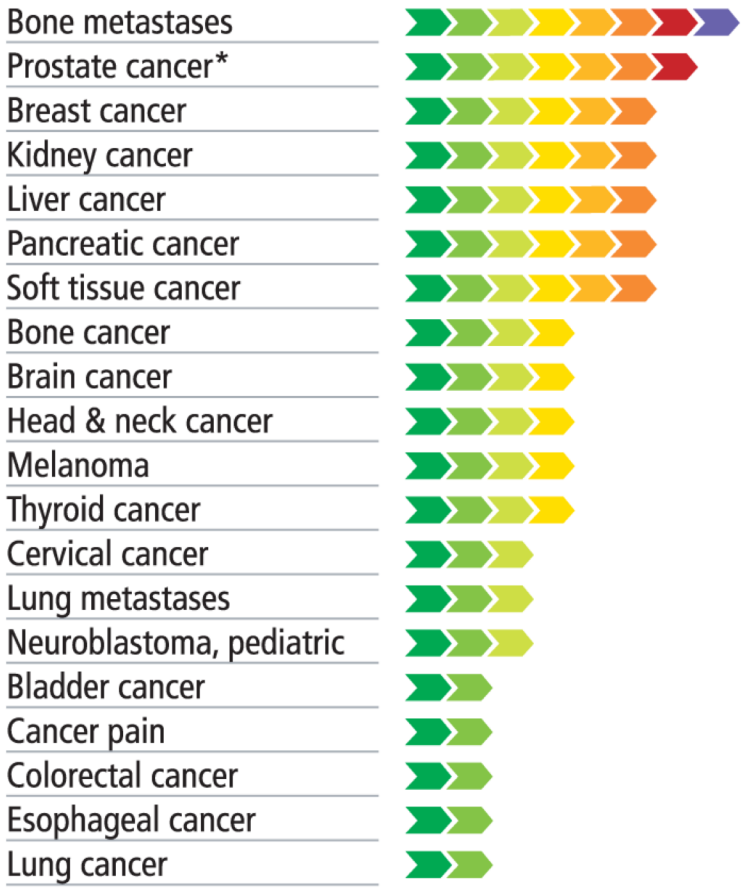
- Ultrasound: targeted tissue heating (→ necrosis)
- MRI: visualize treatment (planning, monitoring)
- Less trauma to patient than invasive surgery



www.insightec.com

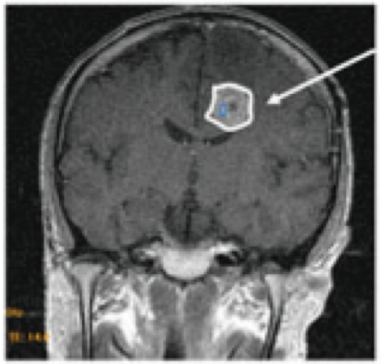
www.philips.com

MRI-GUIDED FOCUSED ULTRASOUND: ONCOLOGICAL APPLICATIONS

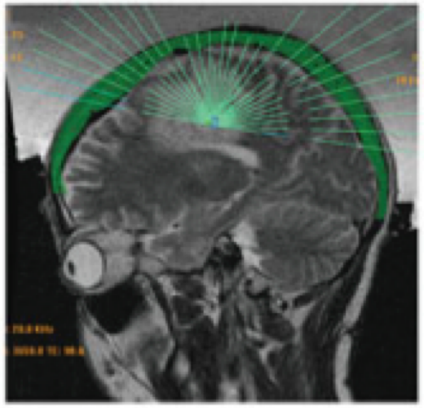


MRI-GUIDED FOCUSED ULTRASOUND: ONCOLOGICAL APPLICATIONS IN BRAIN

Tumor volume



Noninvasive tumor ablation



Blood-brain barrier opening for adjuvant chemotherapy

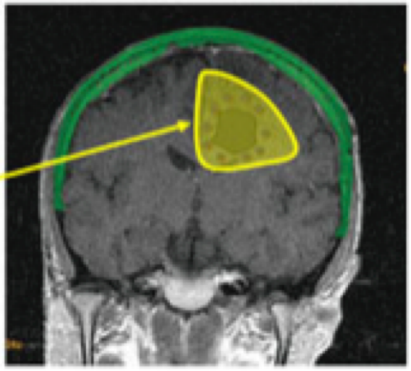
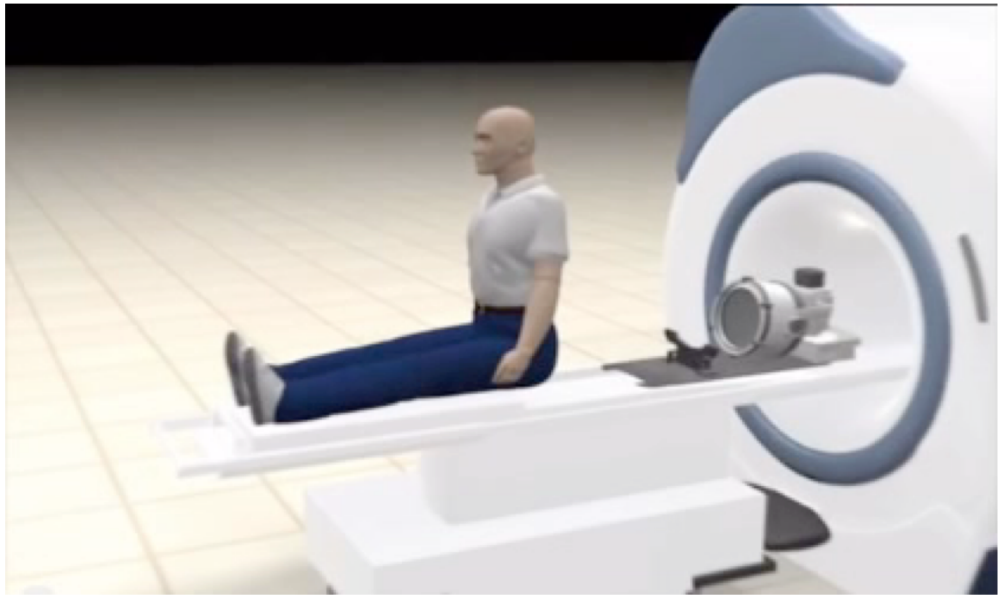


Figure adapted from Martin et al., Curr Radiol Rep 2013

MRI-GUIDED FOCUSED ULTRASOUND: BRAIN



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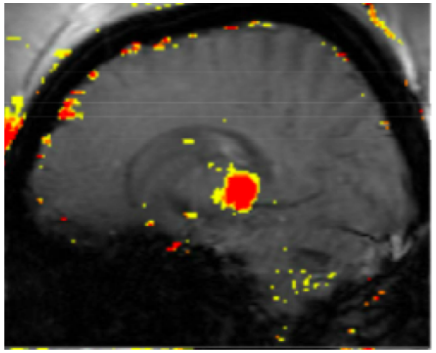
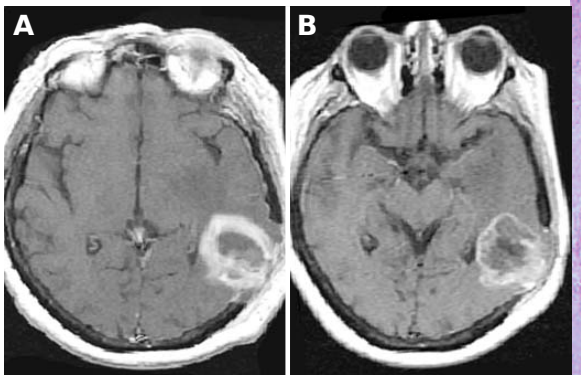
MRI temperature monitoring



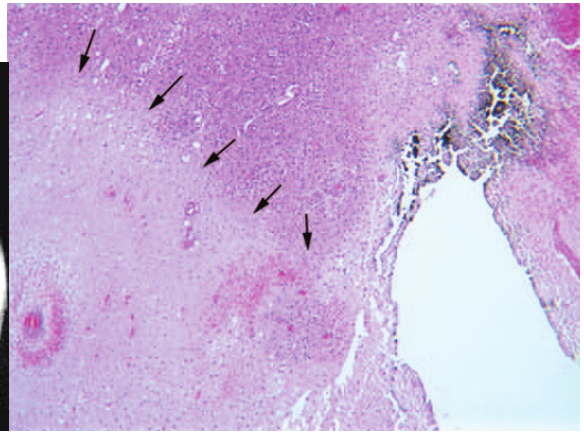
Rieke et al., JMRI 2013

T1-weighted MRI



Before treatment

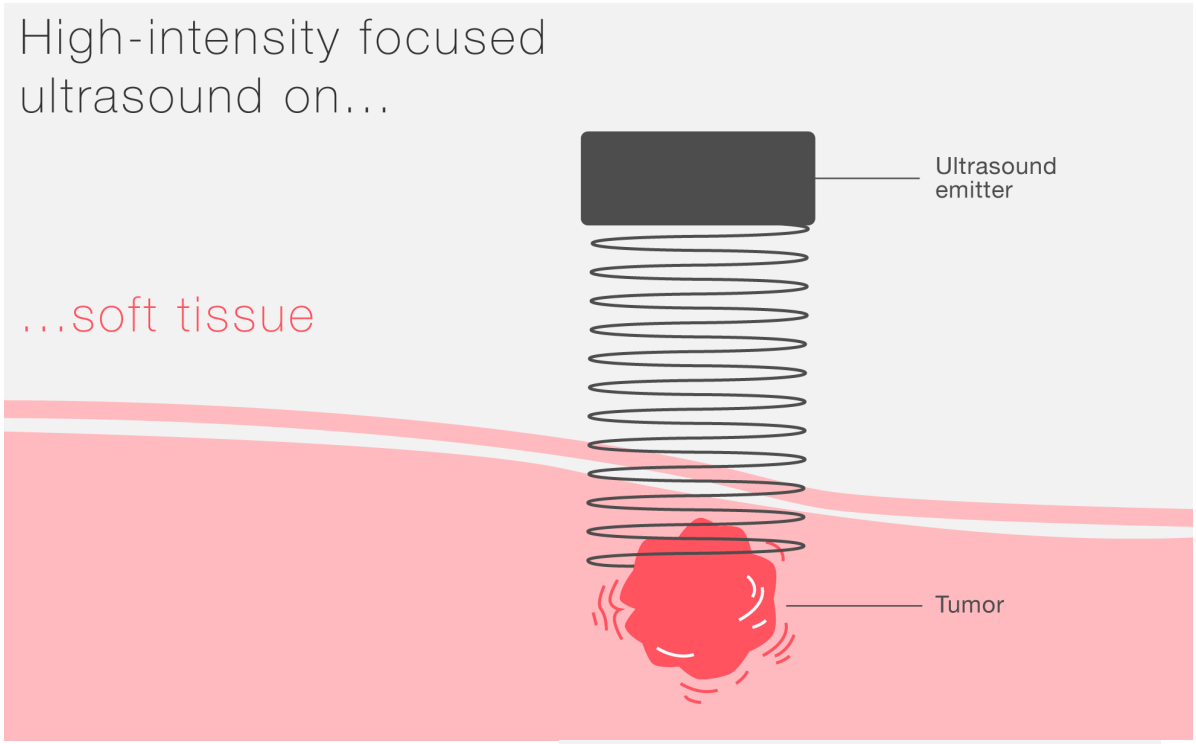
After treatment



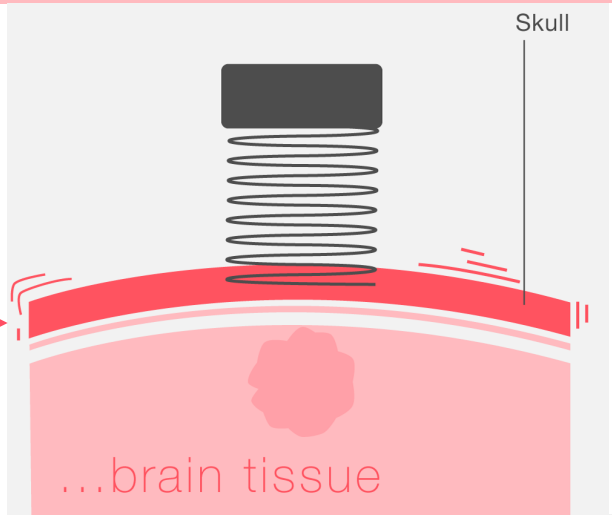
Micrograph of resected tumor shows coagulative necrosis (arrows)

Ram et al., Neurosurgery 2006

TUMOR ABLATION IN (NON-)BRAIN TISSUE

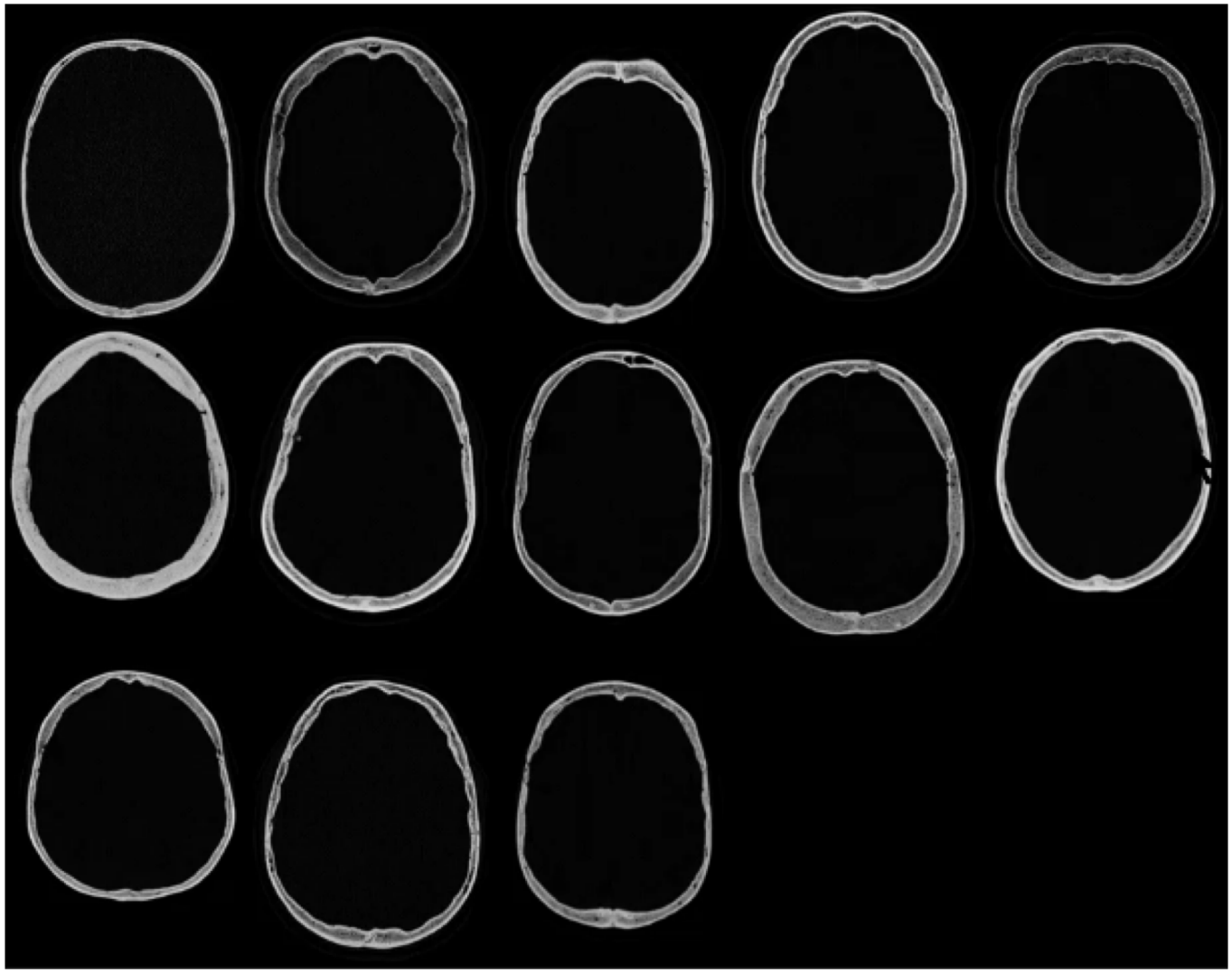


Skull!



http://www.pbs.org/wgbh/nova/next/body/hifu

SKULL SHAPE, THICKNESS, COMPOSITION CAN DISTORT ULTRASOUND FOCUS



VISUALIZE FOCAL SPOT USING MR-ARFI (ACOUSTIC RADIATION FORCE IMAGING)

Skull distorts ultrasound beam
→ errors in focal spot position and intensity

MR-ARFI for non-invasive, non-thermal focal spot imaging

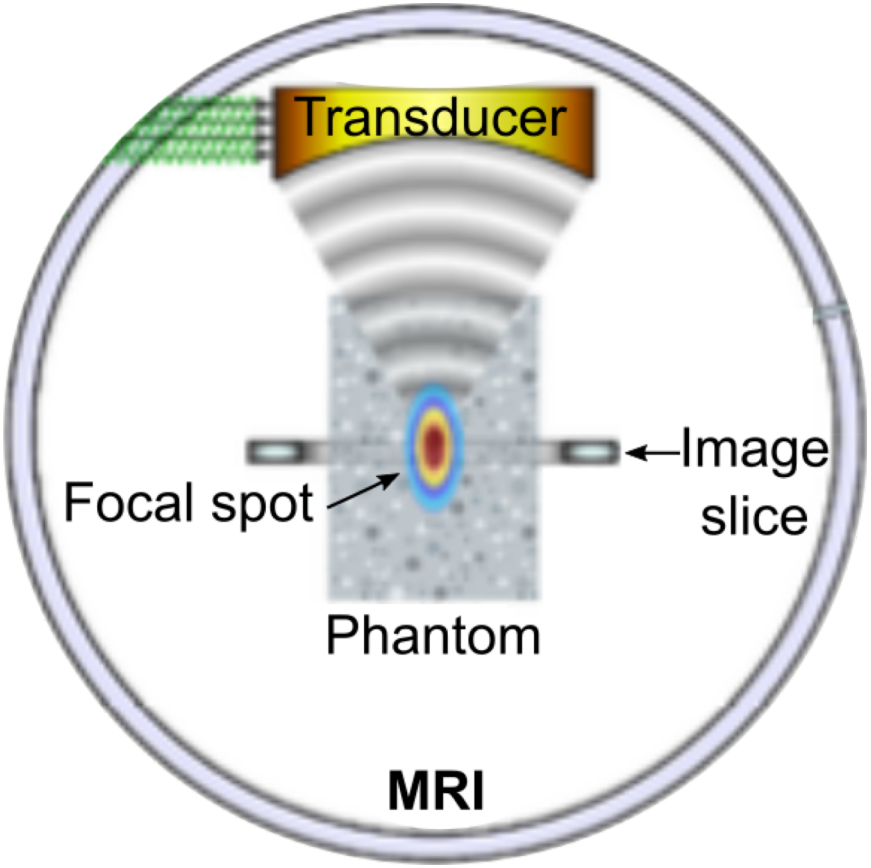


Figure adapted from Mougenot *et al.*, 2016

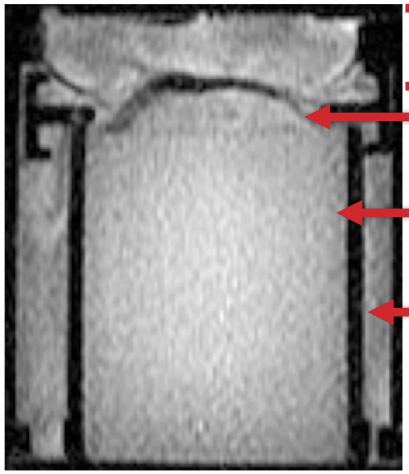
MR-ARFI EXPERIMENT SETUP

Sheep skull (replica)

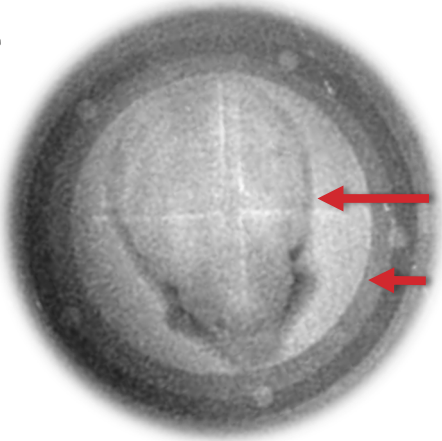
CT of skull cap

Transducer

Phantom set up



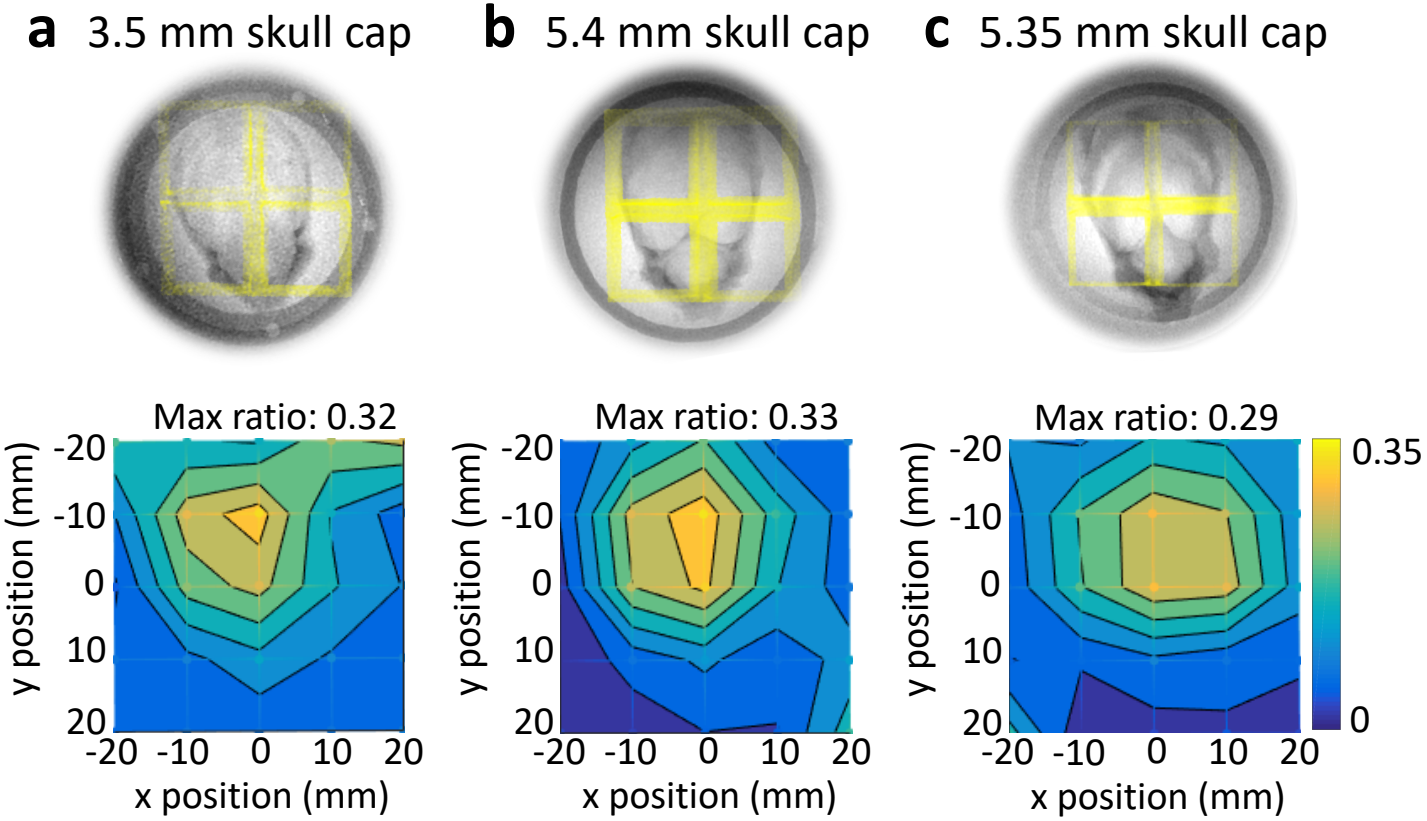
Top-down view



FOCAL SPOT STEERING ACROSS THE SKULL: 5X5 GRID OF FOCAL SPOT LOCATIONS

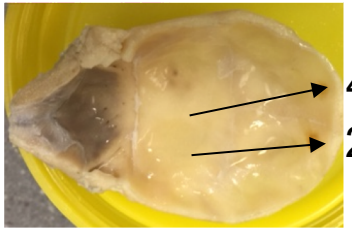
Composite image showing *ex vivo* skull cap boundary, gel phantom, and transducer axes

Contour map of peak displacement ratio with/without skull cap at each focal spot location

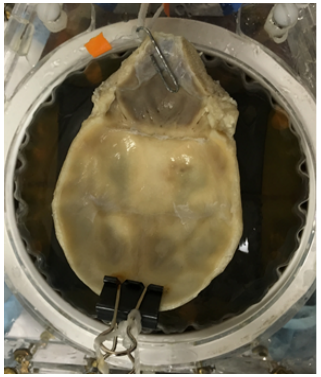


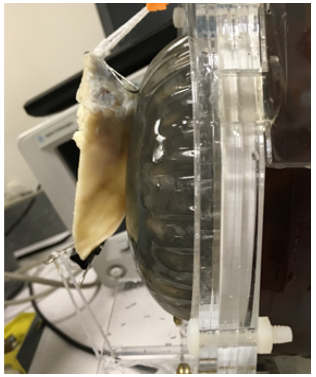
SKULL CAP MEASUREMENTS

Skull cap thickness averaged over medial and lateral measurements



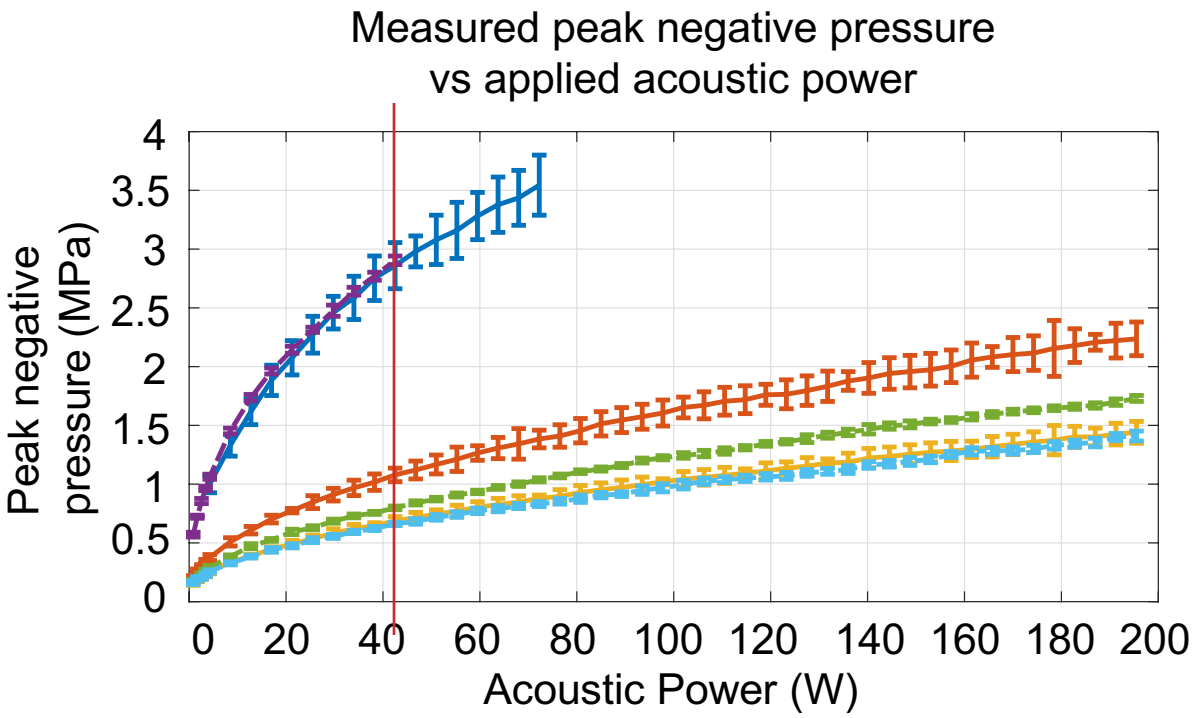
a) Skull + Transducer Setup





Gaur et al., ISMRM 2018

HYDROPHONE MEASUREMENTS



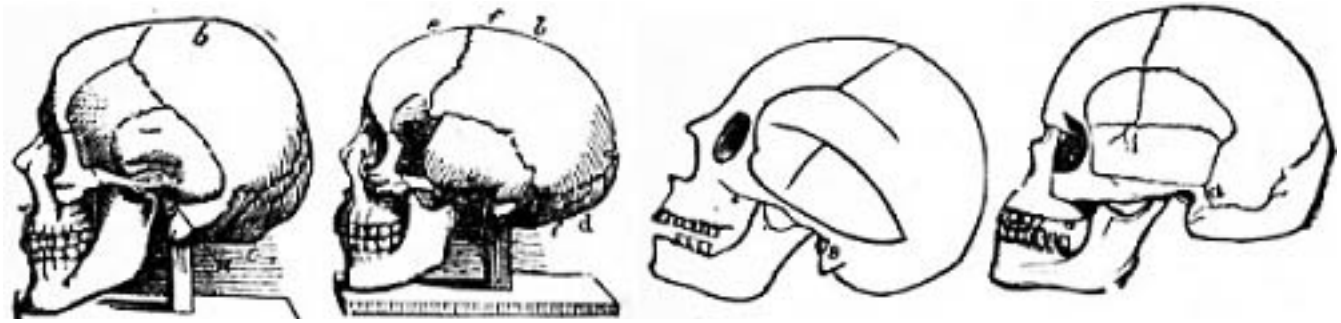
Ex vivo skull cap thickness (mm)	Relative transmitted pressure (compared to water) at 42.5 W	Simulated relative pressure
3.5	33%	49%
5.4	27%	41%
5.35	23%	35%
7	21%	29%
Water only	n/a	n/a
Water only	n/a	n/a

~20%

~17%

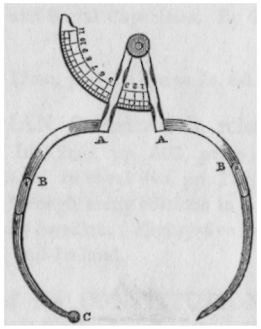
Gaur et al., ISMRM 2018

SKULLS VARY IN SHAPE, THICKNESS, AND COMPOSITION

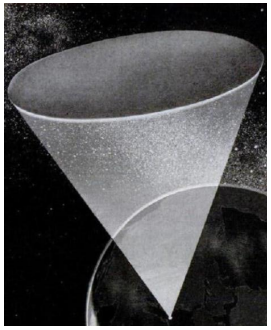


What metrics can we use to predict focal spot intensity?

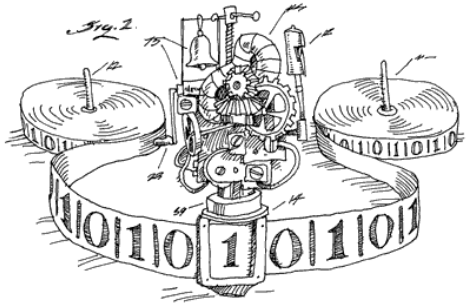
Thickness?



FUS (MR-ARFI)?

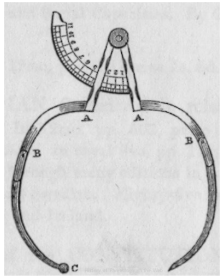


Simulation?



MEASUREMENTS VS HYDROPHONE INTENSITY

Thickness?



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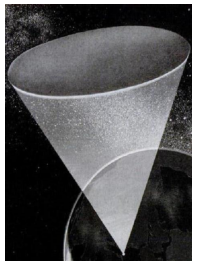
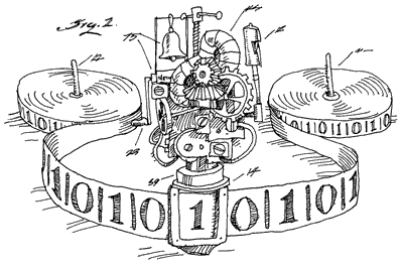
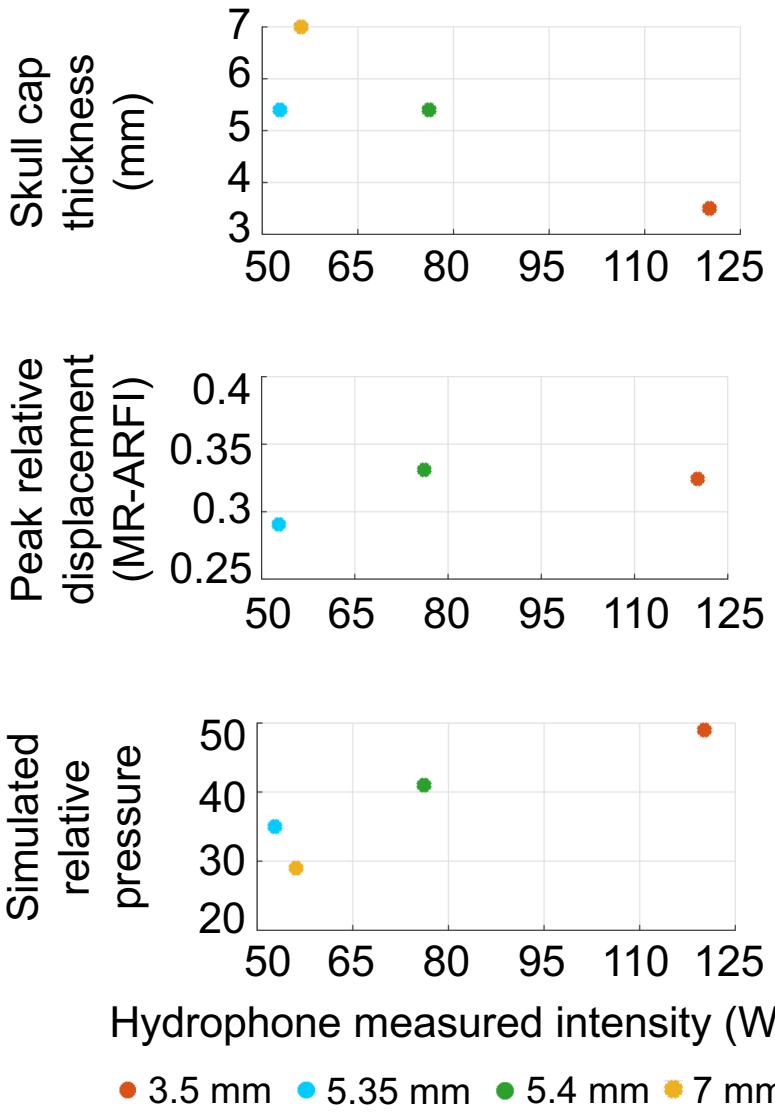


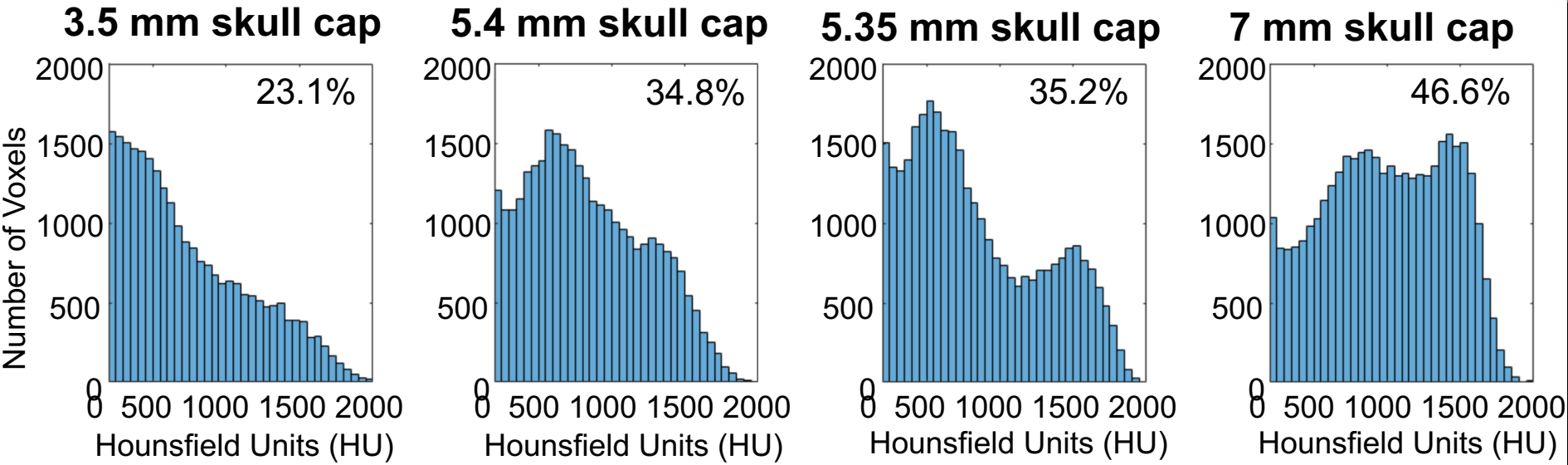
Simulation?





Gaur et al., ISMRM 2018

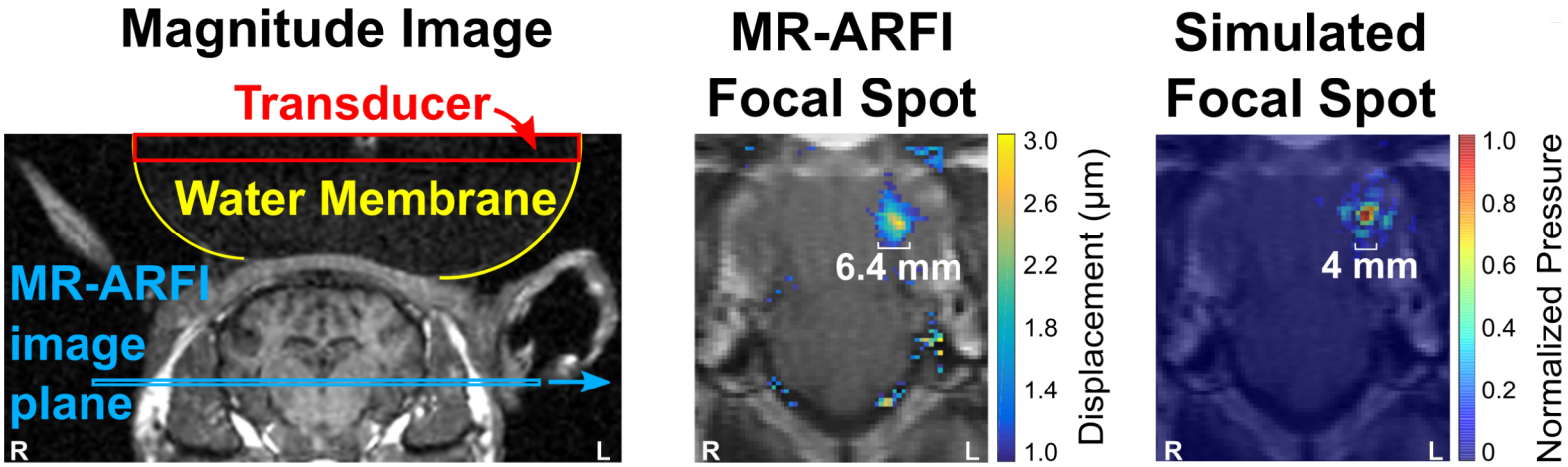
HU DISTRIBUTION ACROSS SKULL CAPS



Top right: % of voxels corresponding to skull (HU > 500), similar to thickness

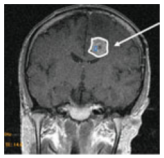
Gaur et al., ISMRM 2018

IN VIVO MR-ARFI

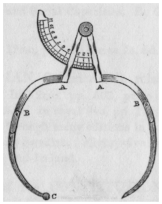


Gaur et al., ISMRM 2018

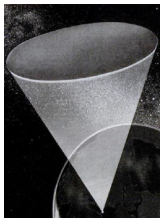
SUMMARY



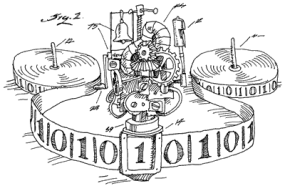
MRI-guided focused ultrasound is a viable treatment option for brain cancer patients



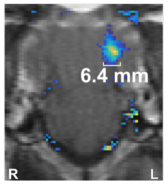
Skull thickness measures are a starting point for estimating acoustic pressure at a given power level but not completely sufficient



MR-ARFI provides additional information relating to focal spot intensity, including variations with each skull's shape and thickness



Simulations can provide important pre-treatment information and account for variations in bone composition



MR-ARFI can be used *in vivo* for non-invasive, non-thermal focal spot targeting

ACKNOWLEDGEMENTS

Collaborators: Ningrui Li (simulations, CT scans, hydrophone measurements), Rachelle Bitton (MR-ARFI), Yamil Saenz (sheep studies), Elias Godoy (tissue recovery), and Lior Molvin (CT scans).

Funding: NIH T32 EB009653, T32 CA009695, R01 MH111825, R01 EB019005, and P01 CA 159992.

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