

Radiation-free Planning for Pediatric Transcranial Focused Ultrasound using T1-w MRI-derived Synthetic CT

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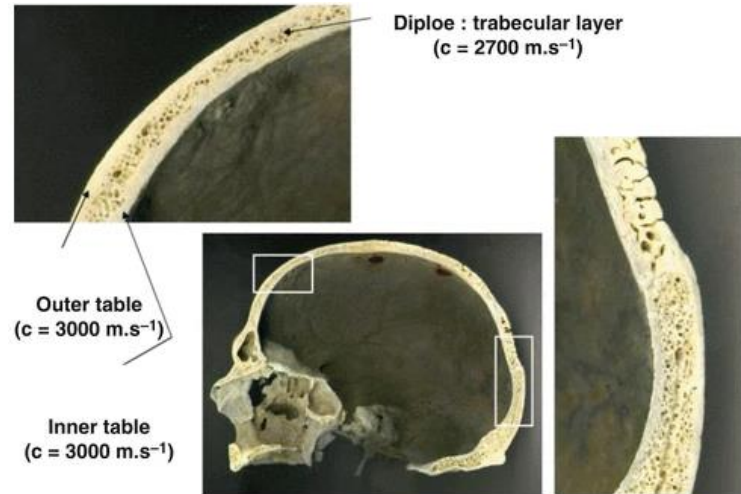
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Wilfred and Joyce Posluns Centre for Image-Guided
Innovation and Therapeutic Intervention



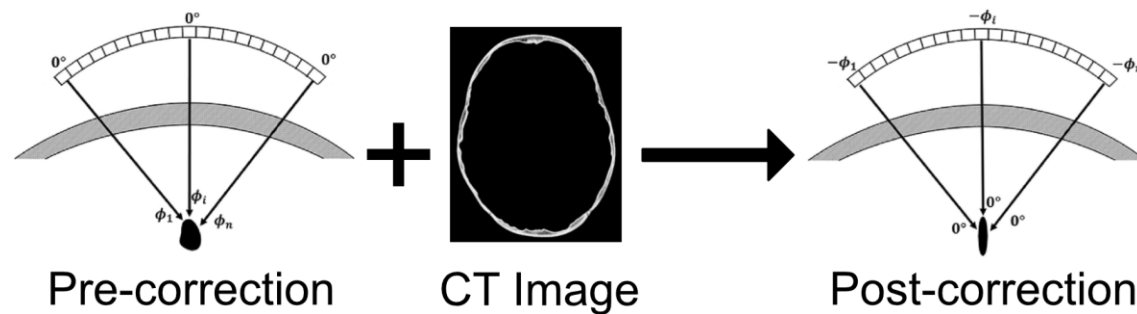
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Skull Heterogeneity Impedes Transcranial FUS (tFUS)



(Aubry et al. *Ther. Ultras.* 2016)



Adapted from Wang et al. *iRadiology* 2024

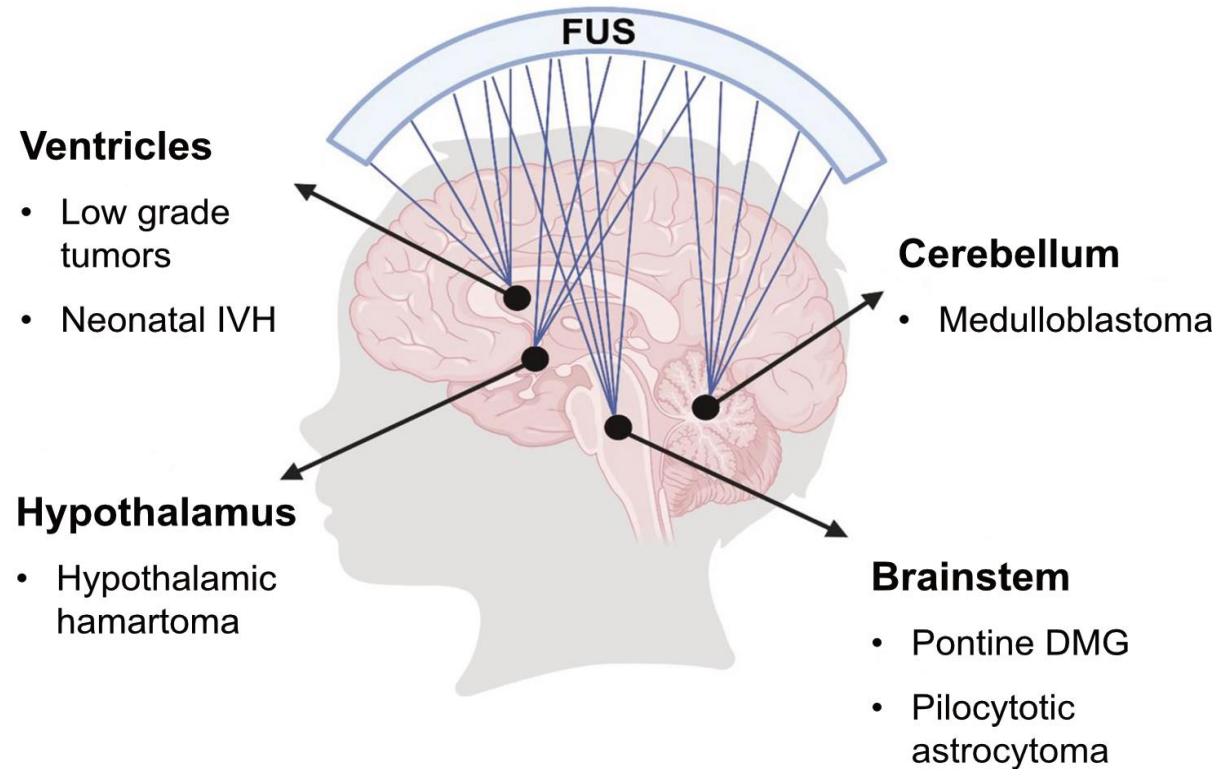
- The presence of the **skull** complicates transcranial FUS

(Aubry et al. *Ther. Ultras.* 2016)

- A priori* knowledge of the skull's acoustic properties enables **aberration correction**

(Wang et al. *iRadiology* 2024)

Emerging Pediatric Applications of tFUS



- tFUS is being investigated for clinical pediatric applications

(Hersh et al. *Childs Nerv. Sys.* 2025)

- Radiation exposure from CT presents a particular harm to children

(National Cancer Institute, 2018)

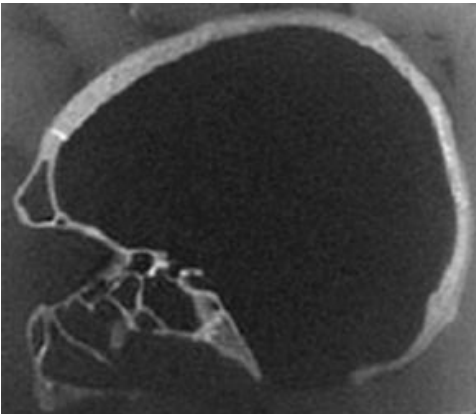
- Anesthesia is commonly administered which carries clinical risks and practical challenges

(Hayatghaibi et al. *JAMA Pediatr.*, 2023)

A CT-free workflow would enable pediatric tFUS without the clinical risks and practical challenges

Generating a synthetic CT (sCT) from MRI

ZTE + Analytical mapping

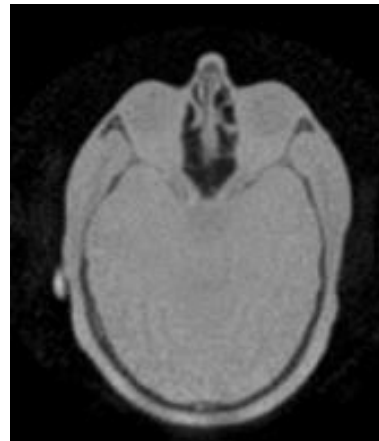


N=16 adult

Caballero et al, 2016



UTE + Deep learning

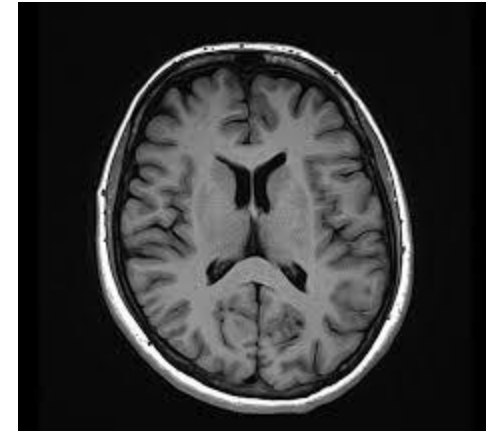


N=41 adult

Su et al, 2016



T1W + Deep learning

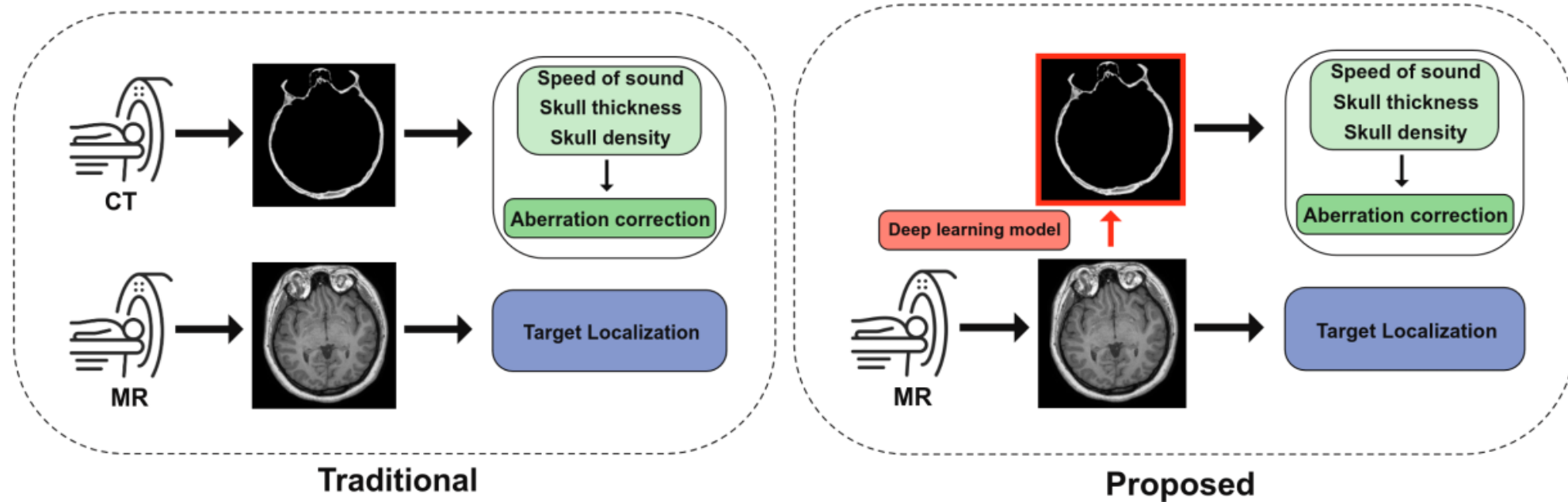


N=86 adult

Liu et al, 2016

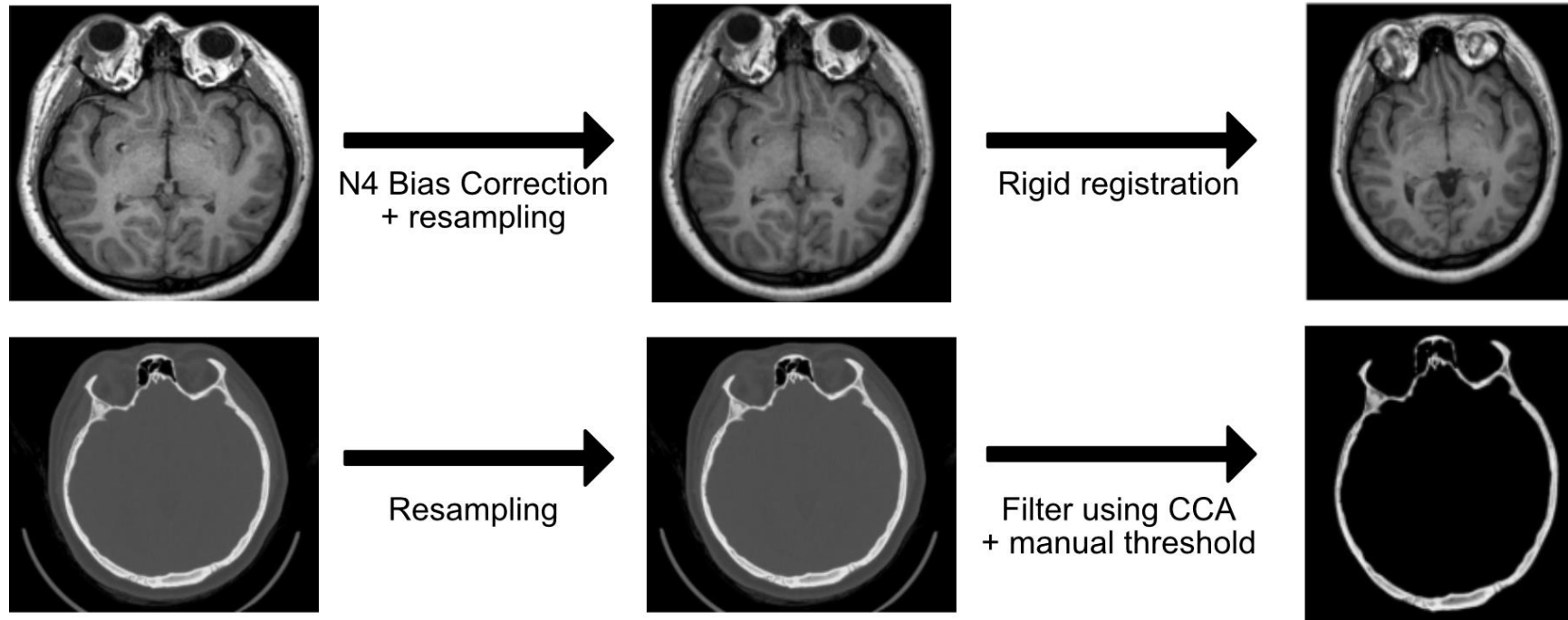
No literature on sCT generation in pediatric patients

Objective



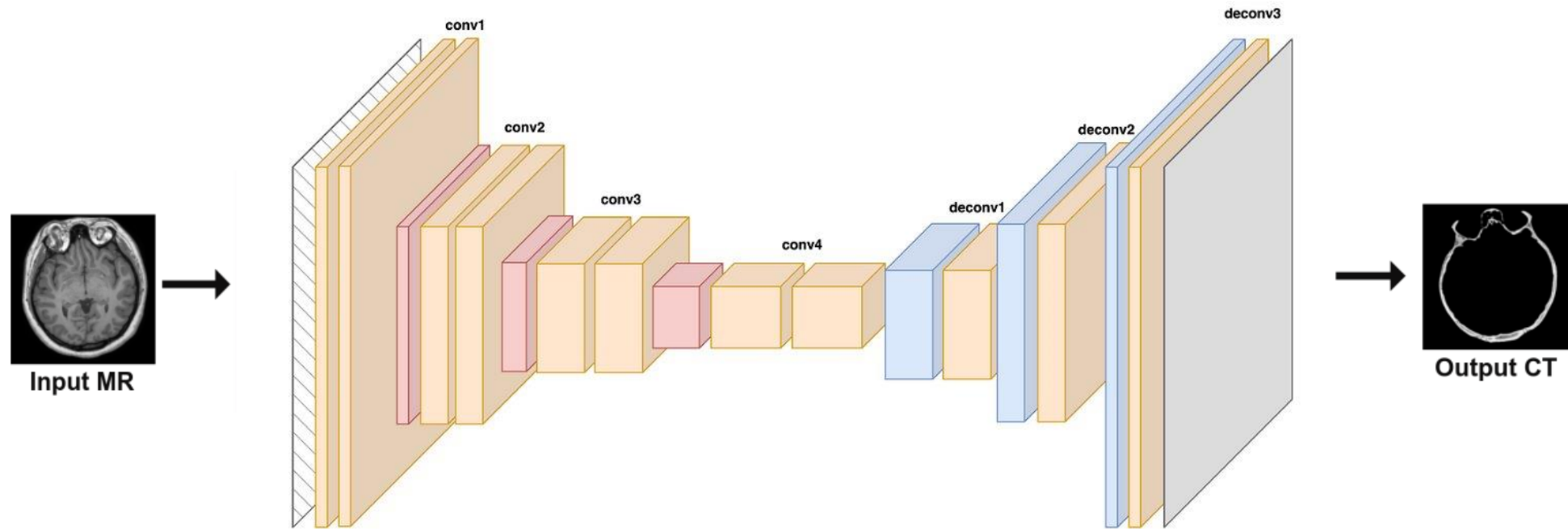
Use deep learning to generate sCT scans capable of quantitatively matching the performance of rCT scans in the pre-treatment planning of pediatric tFUS procedures.

Imaging Data and Preprocessing



92 subject datasets obtained, preprocessed, and partitioned

Deep Learning Architecture and Training

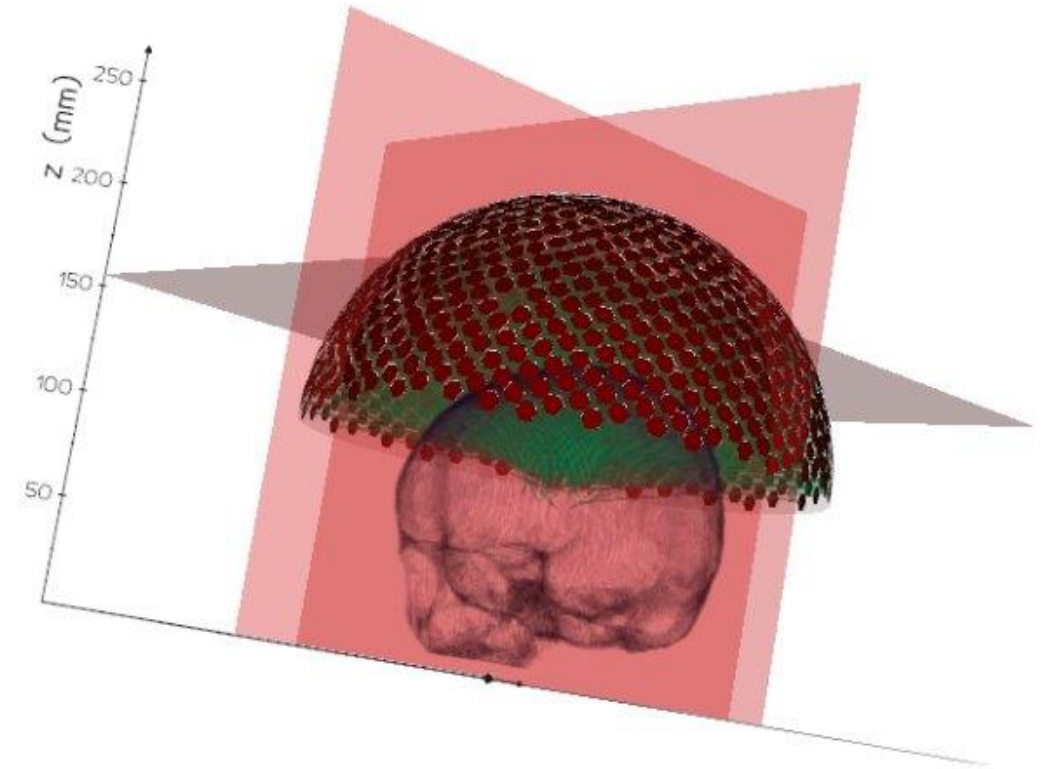


(Ronneberger et al. *arXiv* 2015)

- Residual UNet architecture widely used in medical imaging tasks
- Mean squared error loss function
- Adam optimizer; initial learning rate of $1e-4$

Ray-Tracing for Skull Metric Computation

- **Image similarity** metrics (MAE, DSC)
- **Skull metrics** (elements, thickness, density ratio)
- We developed and validated **Arraynge**, a simulation platform that wraps k-Wave



Transcranial Acoustic Simulations

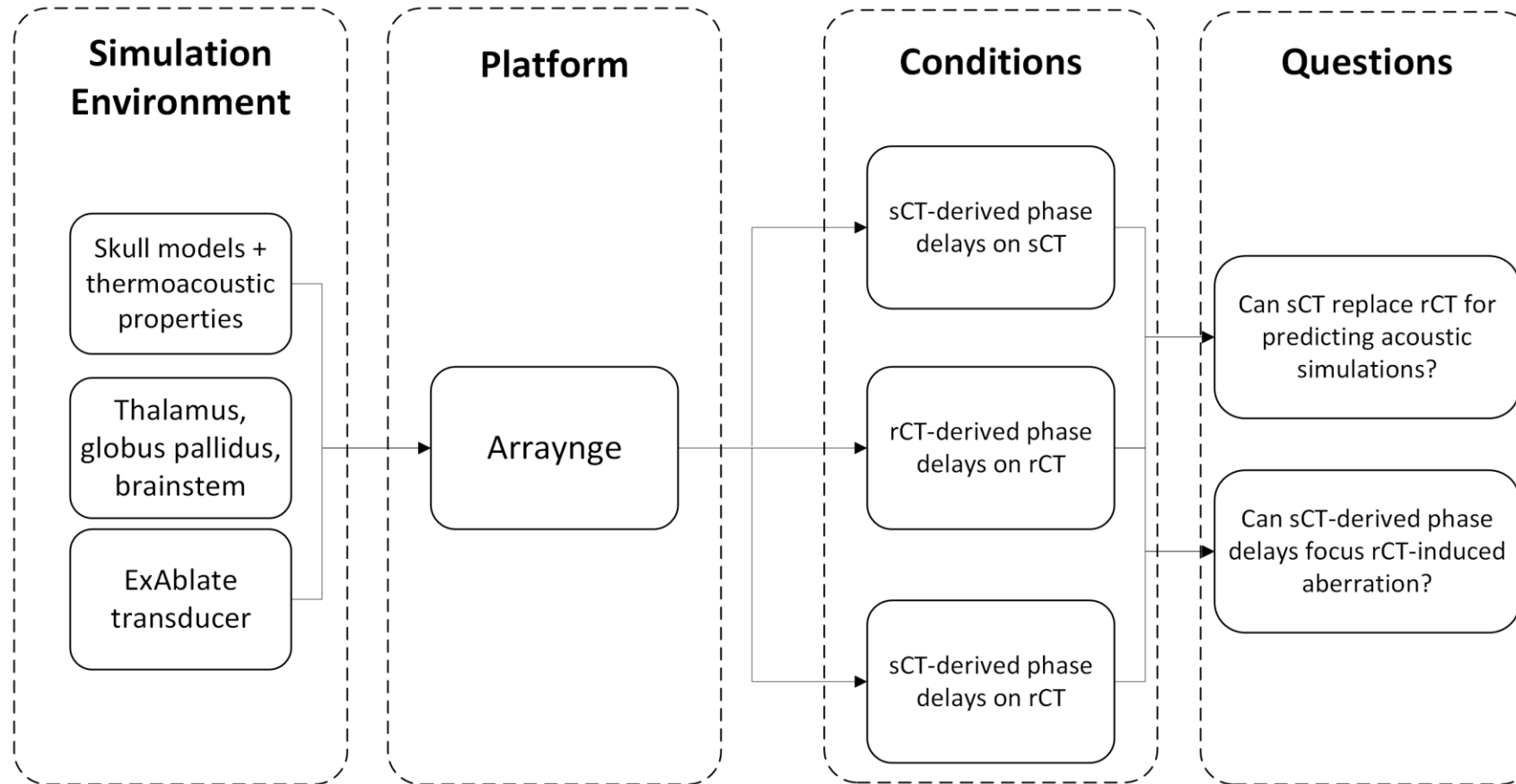
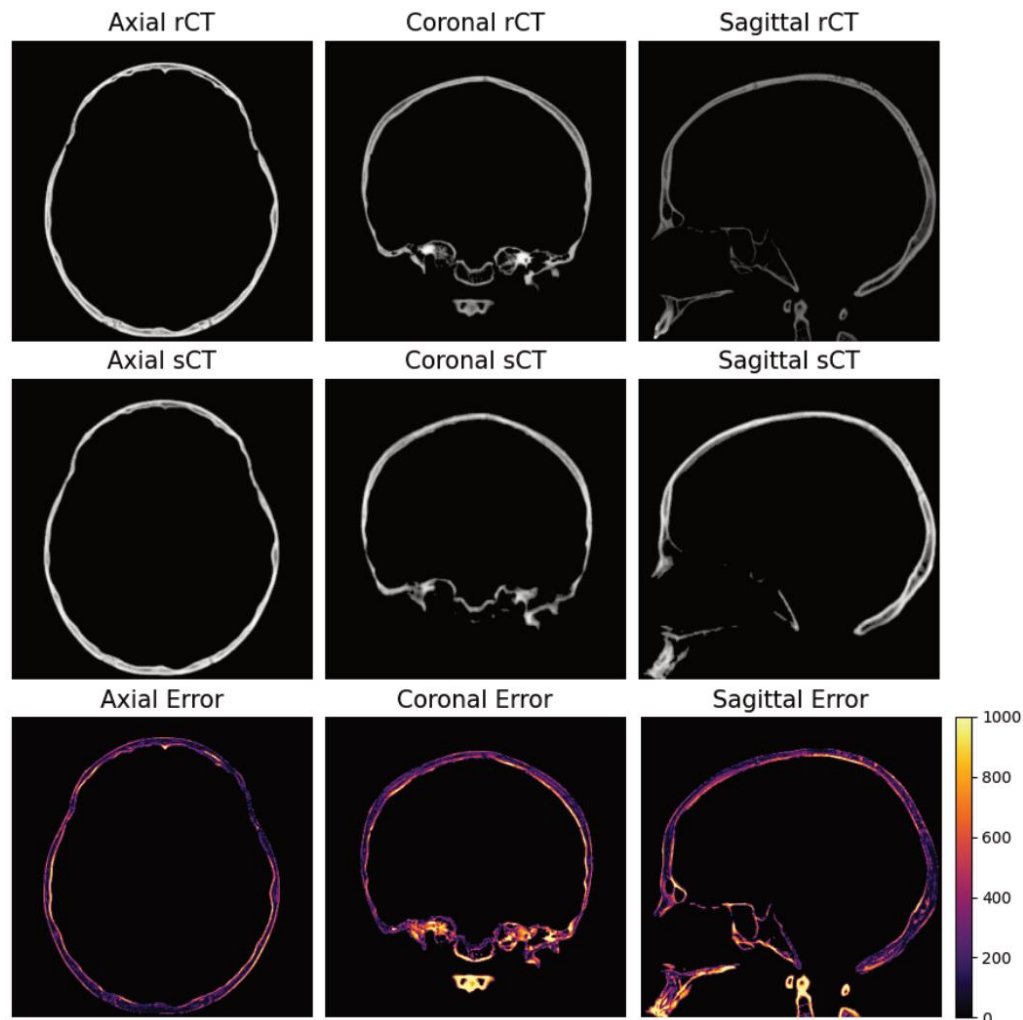
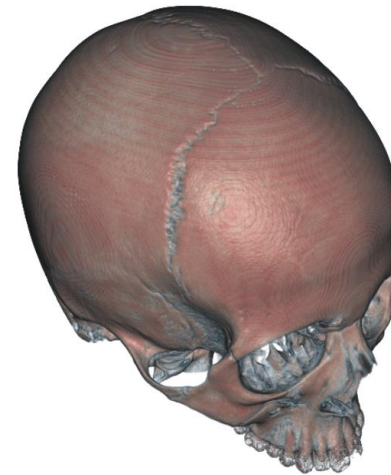
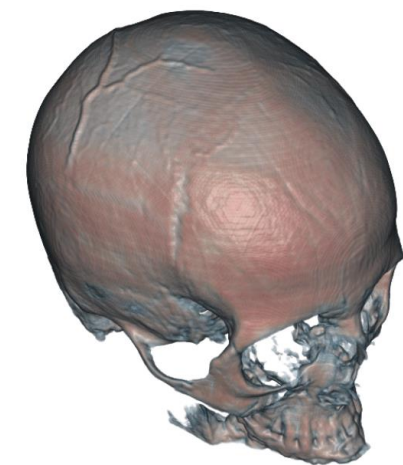
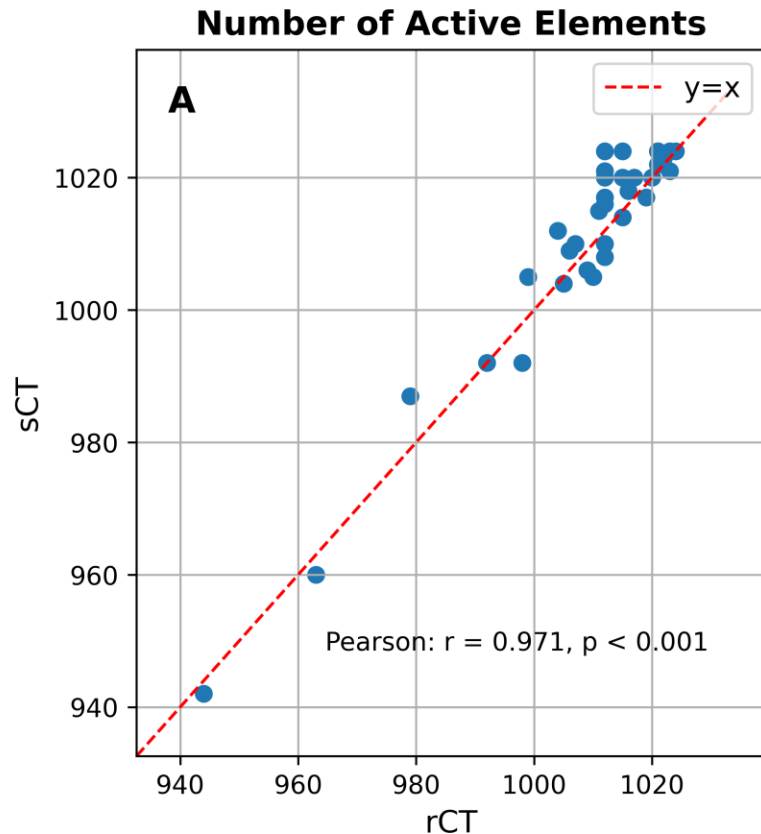


Image Similarity

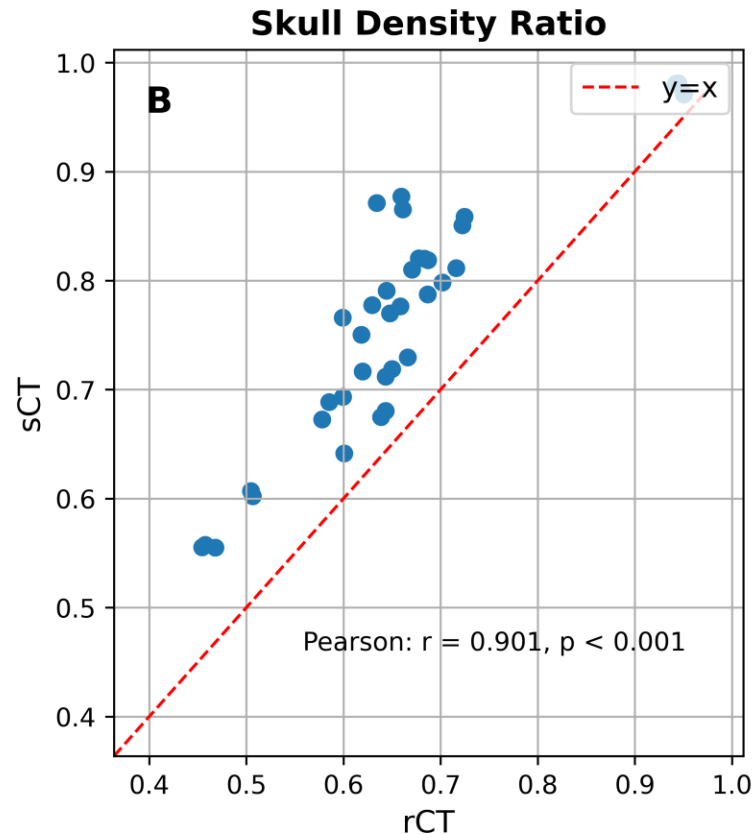
**Real CT****Synthetic CT**

Metric	Value
Mean average error [HU]	328.0 ± 37.4
Dice similarity coefficient [0-1]	0.86 ± 0.02

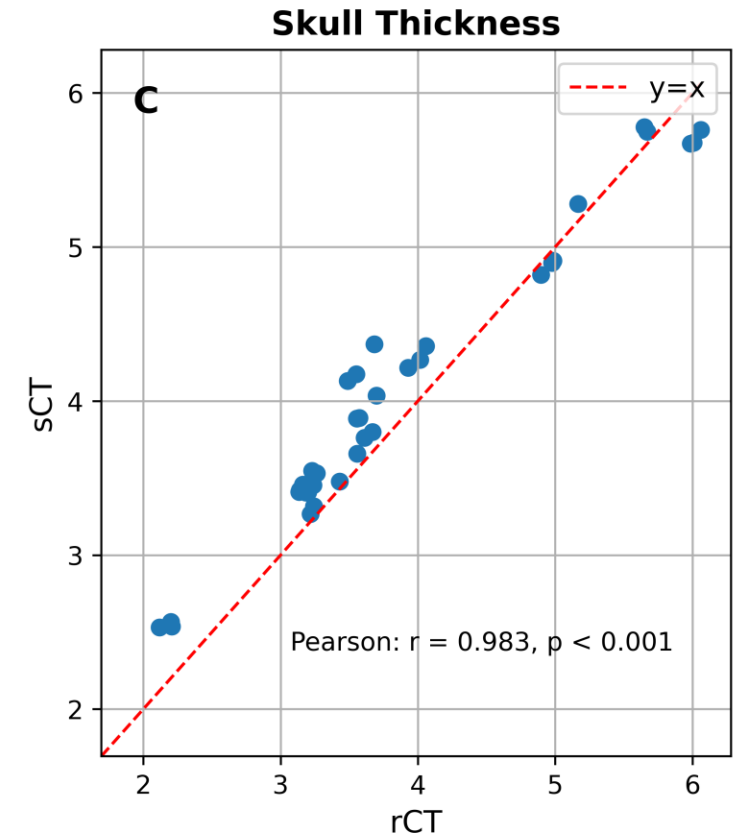
Skull Metric Similarity



Mean diff. = $0.76 \pm 0.71\%$



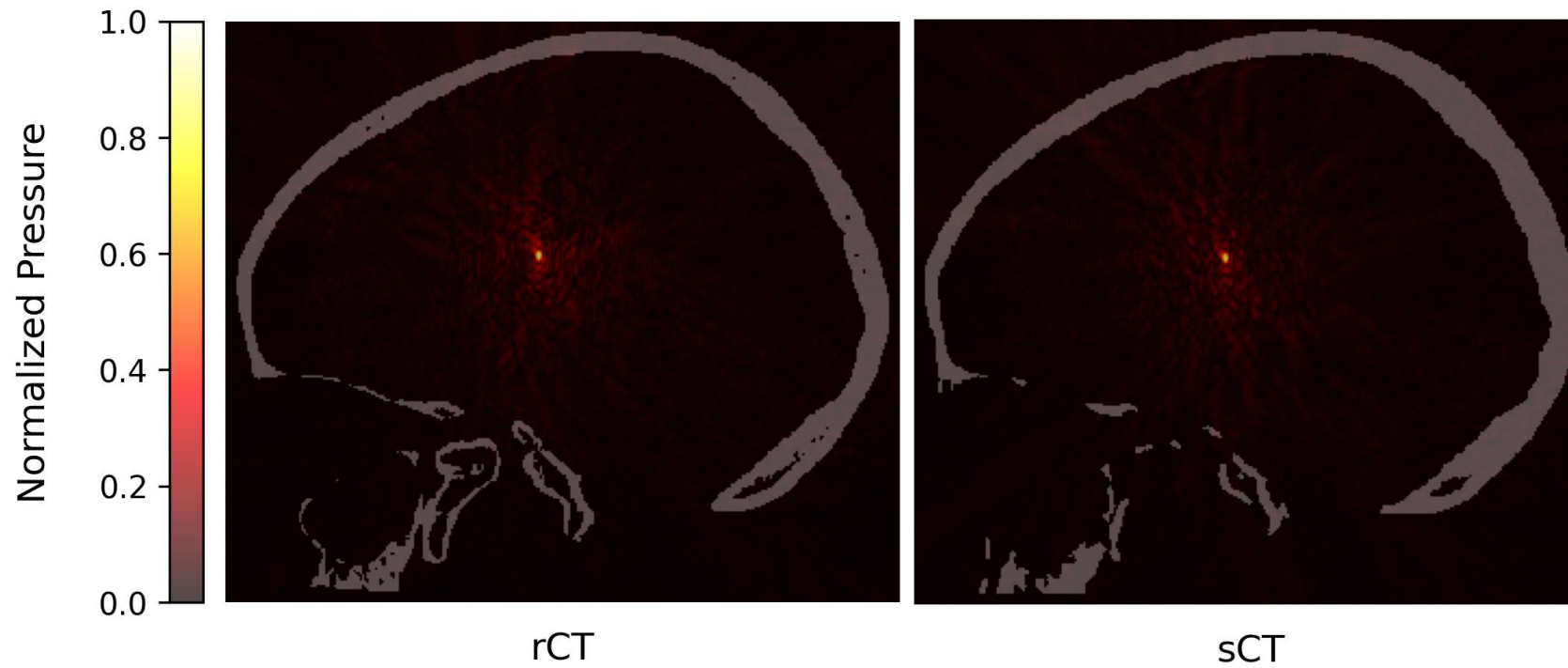
Mean diff. = $15.4 \pm 7.93\%$



Mean diff. = $5.40 \pm 4.21\%$

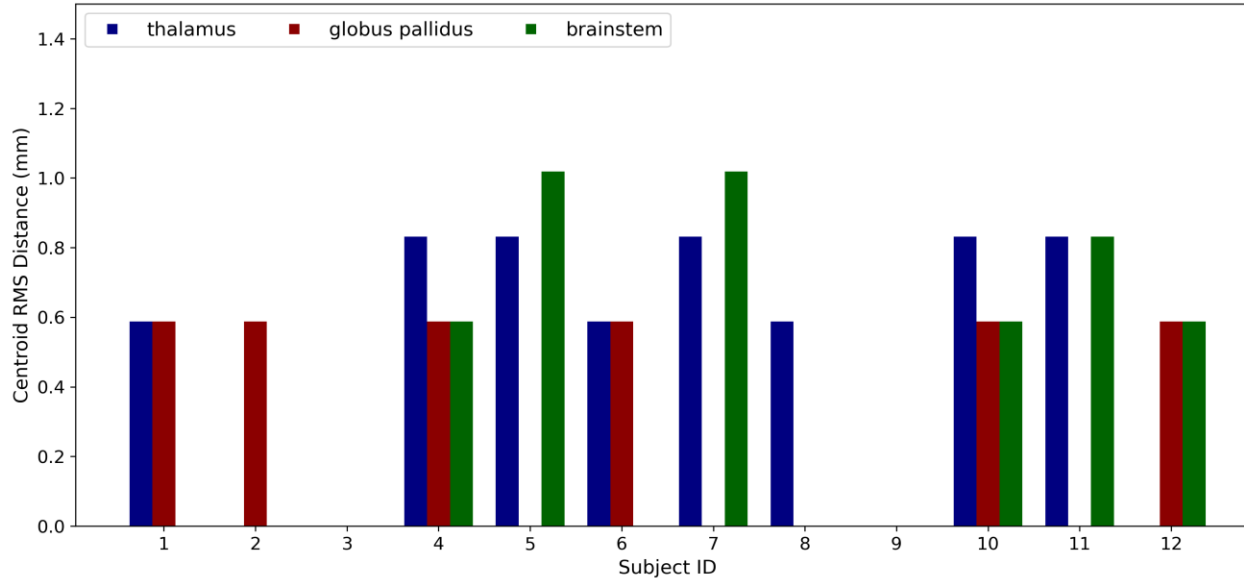
Pressure Field Similarity: Volume Comparison

Pressure Overlay on Real and Synthetic CT

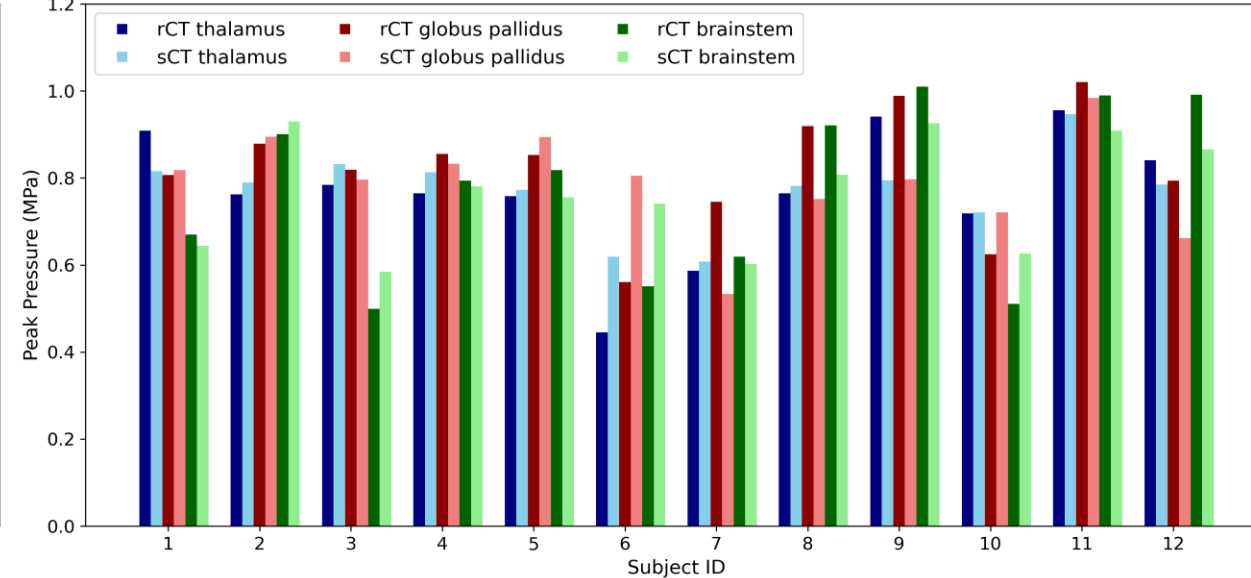


Pressure Field Similarity: Volume Comparison

Centroid RMS Distance Comparison: rCT vs sCT Volumes



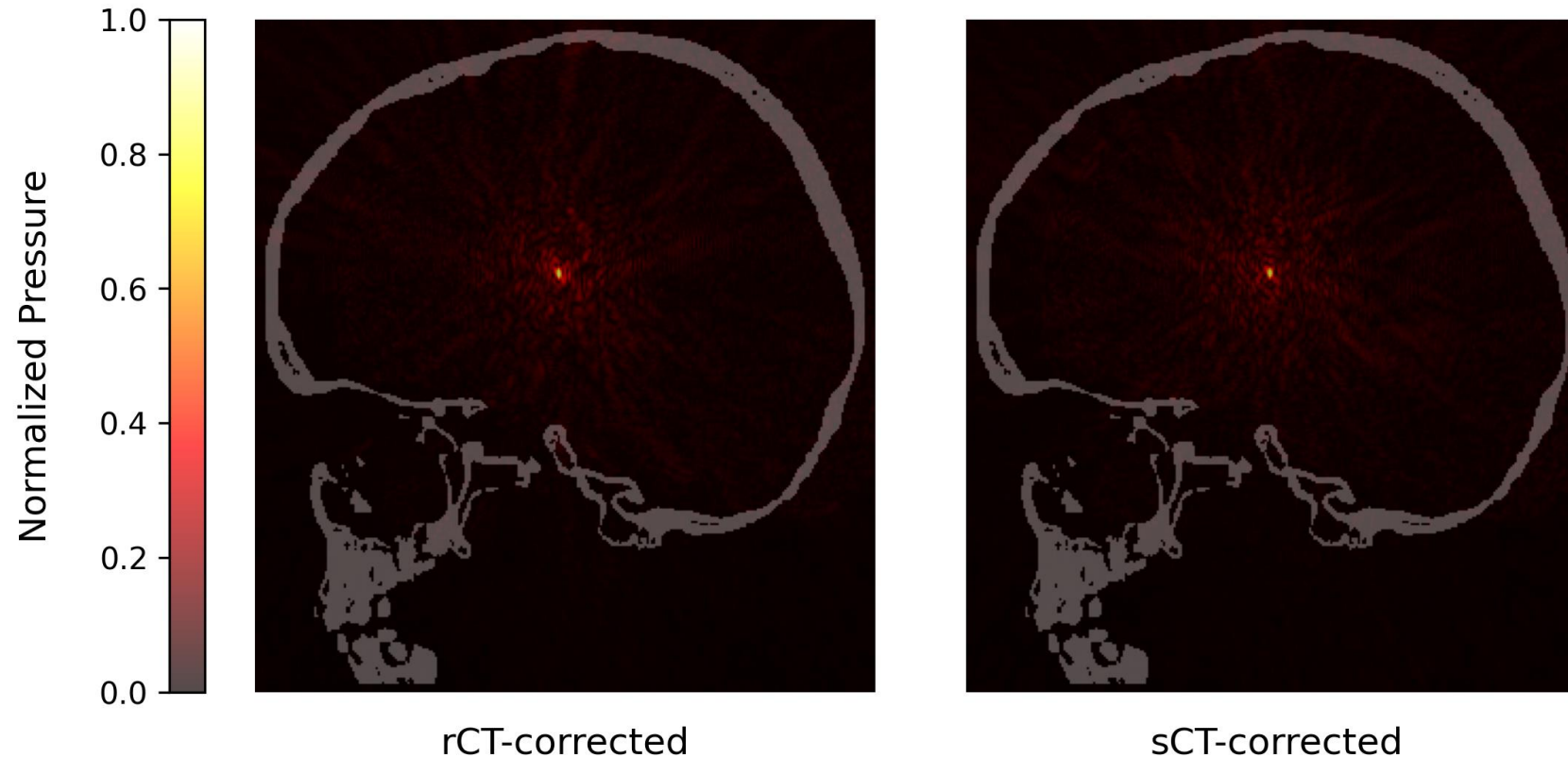
Peak Pressure Comparison: rCT vs sCT Volumes



Metric	Value
Peak press. dist. [mm]	0
Cent press. dist. [mm]	0.39 ± 0.37
Peak press. perc. diff. [%]	10.82 ± 10.95
Focal vol. perc. diff [%]	7.19 ± 7.29

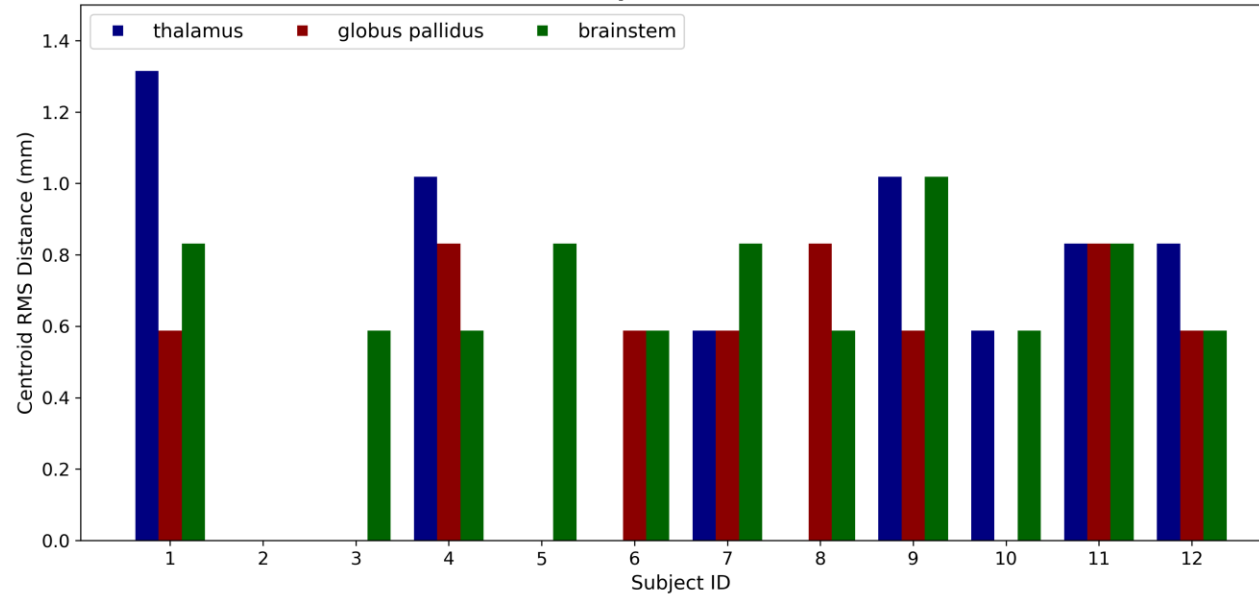
Pressure Field Similarity: PAC-Source Comparison

rCT- and sCT-Corrected Pressure Overlay on Real CT

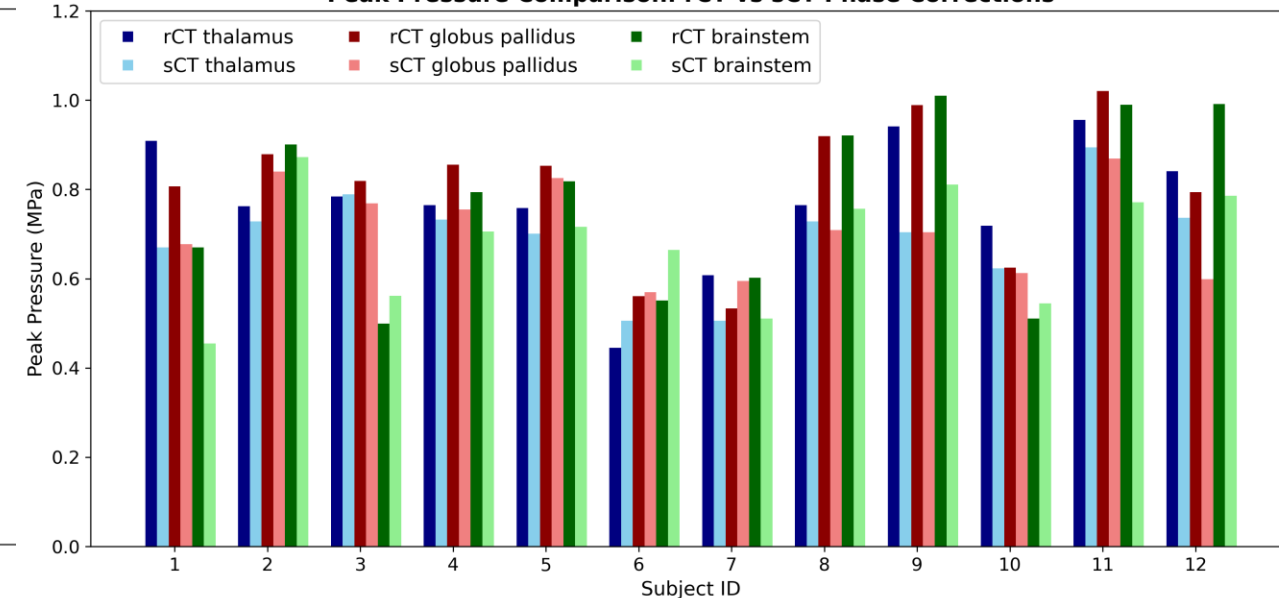


Pressure Field Similarity: PAC-Source Comparison

Centroid RMS Distance Comparison: rCT vs sCT Phase Corrections



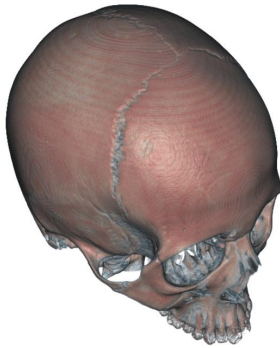
Peak Pressure Comparison: rCT vs sCT Phase Corrections



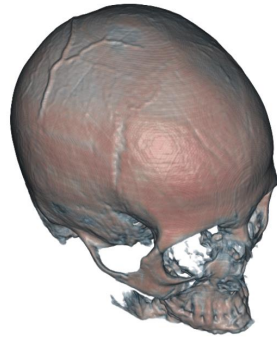
Metric	Value
Peak press. dist. [mm]	0.10 ± 0.24
Cent press. dist. [mm]	0.54 ± 0.37
Peak press. perc. diff. [%]	13.27 ± 8.36
Focal vol. perc. diff [%]	14.38 ± 19.54

Conclusions and Next Steps

Real CT

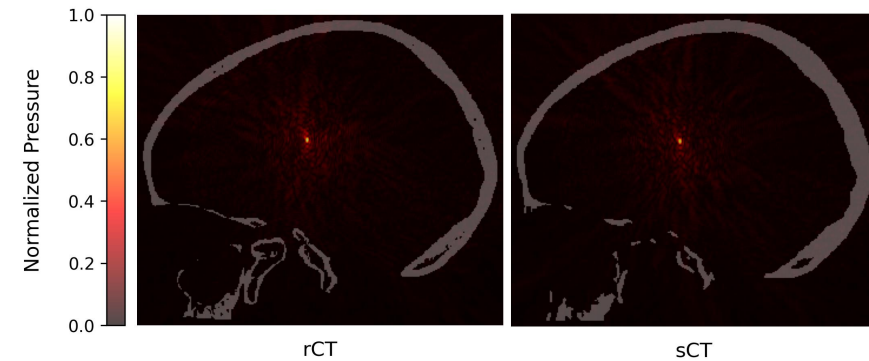


Synthetic CT

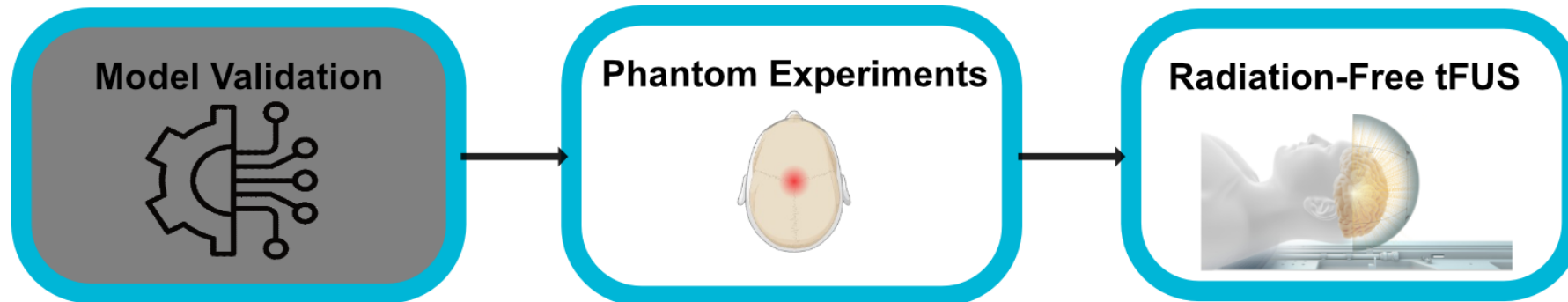


Skull **geometry** and **heterogeneity** is conserved in MR-CT translation

Pressure Overlay on Real and Synthetic CT



Simulated **pressure fields** show equivalency in key metrics



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