STUDY OF THE EFFECT OF CRANIAL HOLES

DUE TO EMISSARY VEINS AND INHOMOGENEITIES IN THE THICKNESS OF THE SKULL WHEN FOCUSING A TRANSCRANIAL ULTRASOUND BEAM

María Cristina Dejoz-Díez, Sergio Jiménez-Gambín, Noé Jiménez, Francisco Camarena

Instituto de Instrumentación para Imagen Molecular, CSIC- Universitat Politècnica de València, 46022 València (Spain)

UNIVERSITAT POLITÈCNICA DE VALÈNCIA

INTRODUCTION

Background

Focused ultrasound is currently used in many emerging therapeutic applications for the non-invasive treatment of neurological disorders and pathologies inside the central nervous system. The accurate focusing ultrasound beam can be achieved with good planning, which can be determined by performing simulations.

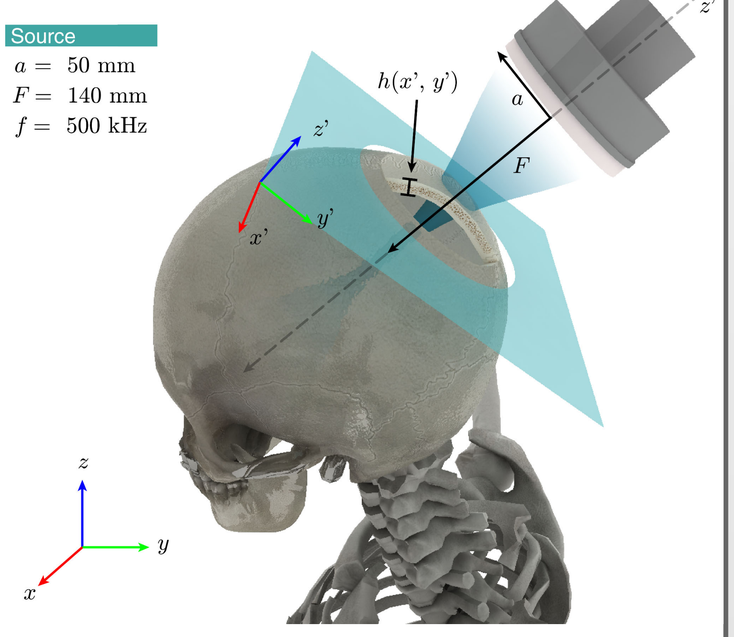
Goals

To estimate a priori the quantitative indexes of the beam by a fast and preliminar analysis the CT data of the patient's skull.

METHODS

Ultrasound fields produced by a 500 kHz single-element focused transducer were simulated using *k*-space methods. The acoustic properties of the skull were obtained from CT-scan of an ex-vivo excised skull at La Fe hospital (Valencia, Spain). The resolution was 1,3 mm on the *z* direction and 0,33 mm at the *x* and *y* direction.

Thickness distribution



Independent variables

Index of quality of the CT data from $h(x', y')$

- $\mu(h)$ → Average thickness
- $\sigma(h)$ → Thickness standard deviation
- $\sigma_\theta(h)$ → Symmetry rate: *radial mean of the angular standard deviation of the thickness in polar coordinates as:*

$$\sigma_\theta(h) = \frac{1}{R}\int_0^R \sqrt{[h(\theta) - \mu(h(\theta))]^2}\,dr$$

Simulations

The method is based on the pseudo-spectral time-domain solution of the constitutive relations for acoustic waves in heterogenous media including frequency-power law absorption:

$$\frac{\partial \rho}{\partial t} = -\rho_0 \nabla \cdot \mathbf{u} - \mathbf{u} \cdot \nabla \rho_0,$$

$$\frac{\partial \mathbf{u}}{\partial t} = -\frac{1}{\rho_0}\nabla p,$$

$$p = c_0^2 \left(\rho + \mathbf{d} \cdot \nabla \rho_0 - \mathrm{L}\rho\right),$$

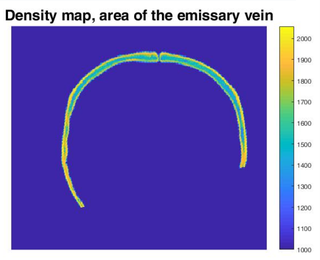
Focusing quality indexes

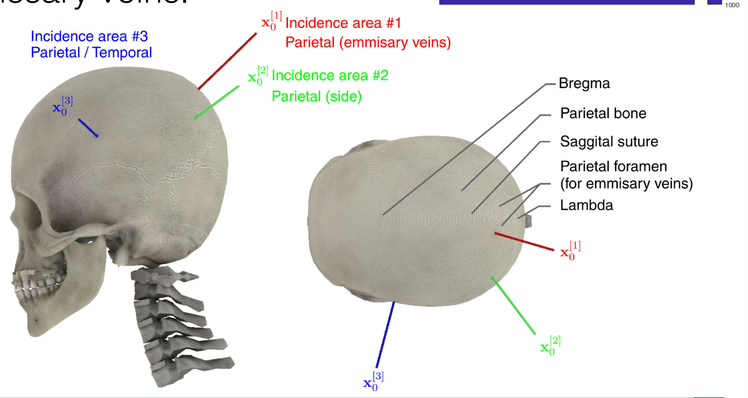
- $P_{\max}$ → Maximum pressure at focus
- Δx → Lateral beam deviation

ANALYSIS

Attack areas

Three zones ($\mathbf{x}_0^{[1]}$, $\mathbf{x}_0^{[2]}$, $\mathbf{x}_0^{[3]}$) belonging to the parietal bone have been attacked. In $\mathbf{x}_0^{[1]}$ a hole is present due to emissary veins.

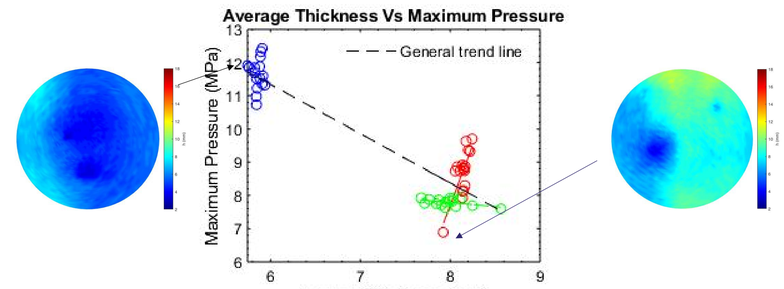


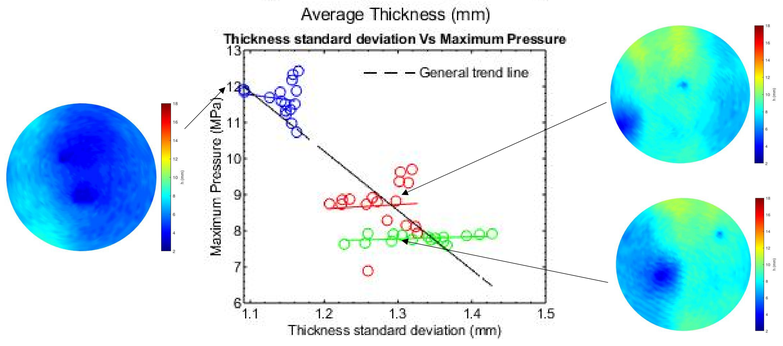


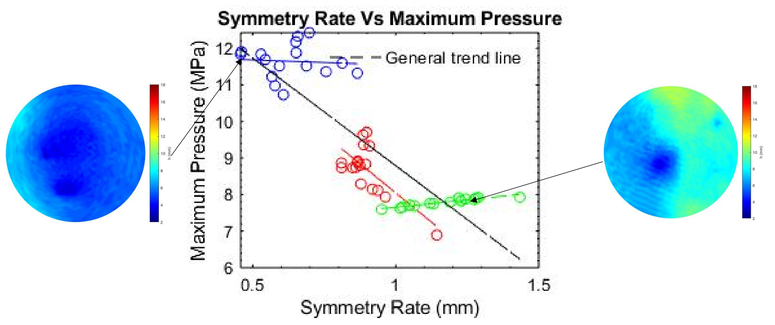
RESULTS

The results are shown according to the quality indices.

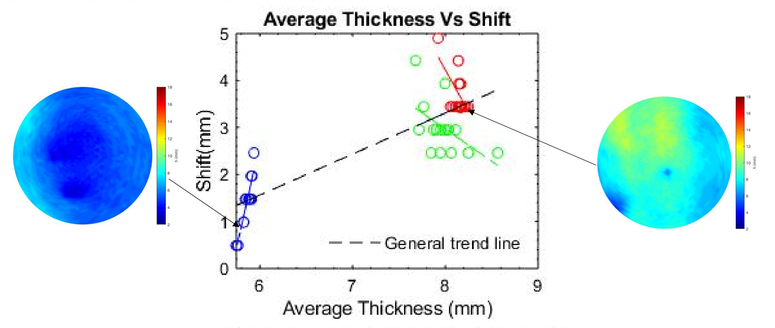
Maximum pressure amplitude

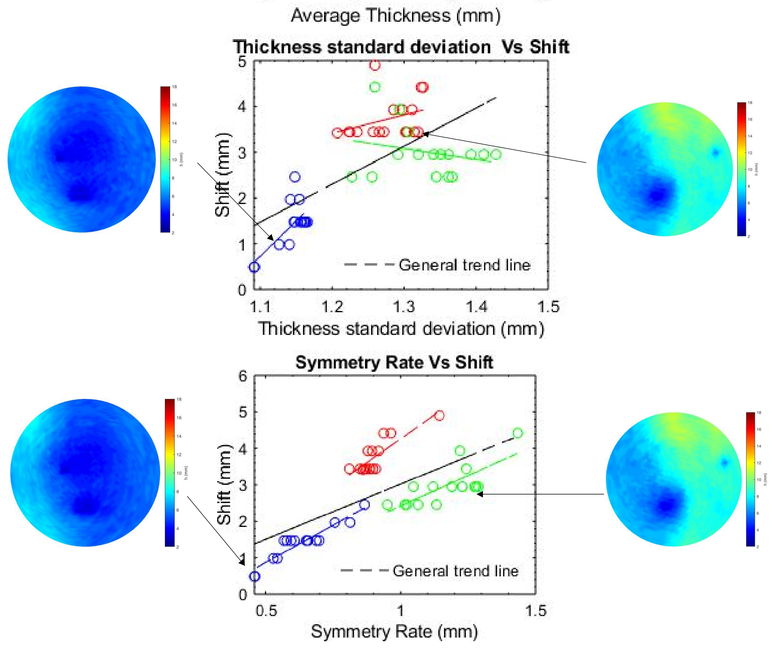






Lateral beam deviation



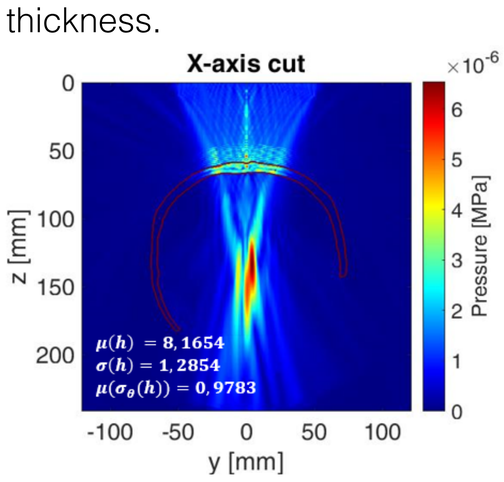


RESULTS (Cont.)

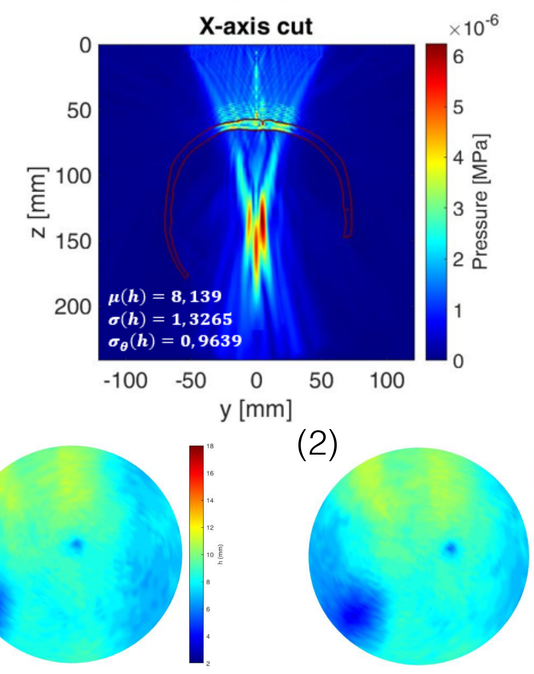
Attack area: Emissary vein

When striking through the hole caused by the emissary vein, we see the appearance of a double focus. This is due to both the presence of the hole and the asymmetry of the thickness.

(1)



(2)



(1) (2)

CONCLUSIONS

Conclusions

(1) A rough estimation of the quality of the beam can be performed by analyzing the CT data before focusing planning.

(2) In particular: The greater the thickness, the thickness variations or the asymmetry, the lower the maximum pressure the higher the lateral deviation.

(3) For the tested cases, when a hole due to an emissary vein is present the amplitude of the focus is greater for the same thickness, and symmetry indexes, but it also slightly increases the lateral deviation with respect to an area that do not present parietal foramens.

Next steps

(1) Study the variations of the density of the skull, i.e., the cortical and cancellous bones (diploë), which are linked to refraction and attenuation of the beam.

(2) Compare with raytracing strategies.

ACKNOWLEDGEMENTS

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