Q & A Report		
ISTU On-Air Webinar Series: January 21, 2021		
#	Question	Answer(s)
1	How are you treating/degassing the skull specimen(s?) used in your in vitro studies to prevent bubbles from effecting your intracranial acoustic field?	We degass the skulls in deionised water for 48 hours at −400 mbar. We've done some CT studies after degassing, and at least at the resolution afforded by clinical scanners, we don't notice any air left.
2	Great talk! I am particularly interested in the scattering of harmonic components through the skull. What are your recommendations when choosing the power law absorption coefficient since we can only assign a single value for skull and brain?	It's a limitation of k-Wave that only one power law exponent can be used. One approach would be to choose a power law exponent somewhere in the middle of the range and then adjust the prefactor values to give the correct absorption for each tissue type at the fundamental. There is some discussion of this approach on the k-
3	Do you recommend k-wave for tissue displacement estimations?	It will depend on the details, but you can use k-Wave to directly output particle velocity, from which you can calculate displacement.
4	Really nice talk! A few questions: 1- Have you done any validation to show how accurate acoustic modeling is for skull (vs Elastic modeling)? 2- Compared to Finite-Difference Time Domain, how stable is k-wave when it comes to hetergenious media where there is a huge difference between acoustical impedence of scatterer and tissues (e.g. skull microCT)? Thank you!	We have run some fluid vs elastic simulations, e.g., see https://dx.doi.org/10.1088/1361-6560/aa5e98. Others have done similar things. There are no particular problems modelling skull in k-Wave, e.g., see https://dx.doi.org/10.1121/1.4976339.
5	It seems that the examples you show assume water around the head. Is this your recommendation? The scattering pattern should be very different for air around the head.	My feeling is that it won't make much difference (I don't expect much energy to travel back out through the skull, reflect off the air, and travel back into the brain case). But I've never actually compared it.
6	Great talk. How important would it be to simulate ultrasound propagation through the skull at very high resolution?	I'm not sure. It won't be feasible in general for studies based on clinical CT. At low resolution, the key will be having good effective medium properties that give the same field.
7	Junjie Yao (Duke Univ): Nice talk. Is the k-wave or the deep learning model considering the wave-mode conversion from longti to shear and vice versa? thx	The deep learning model currently solves the Helmholtz equation, so no. k-Wave has both fluid and elastic models.
8	Can we collect enough diagnostic acoustic feedback for treatment planning?	It's not my area of expertise. Assuming you're talking about transcranial applications, if using microbubbles then I believe passive acoustic mapping is an option. I'm not sure it's possible using conventional diagnostic imaging.
9	What would you think the greatest current need for improving transcranial simulations?	Accurately mapping the acoustic and thermal properties from medical images.
10	Do you have good model or experimental results on skull at 350 kHz or so?	It depends on what your looking for. You could look at e.g., https://doi.org/10.1088/0031-9155/57/23/8005.
11	Should we email you directly for interest in TRUSST? Is it open to trainees early in their career?	Yes please get in touch. It's open to all career stages.
12	From a clinical perspective, it it permissible to crudely approximate the true parameters for the skull and use the estimates of uncertainty to compute the required margins for exposure settings (in ablative therapy)?	I think this is a good way to get a handle on uncertainty, and something that several groups have been thinking about. If we can put error bars on simulations in general, that would be very powerful.
13	What is the acoustic difference between a life skull and a water filled skull?	It depends on how the skull has been prepared, but it's usually missing the bone marrow inside the pore space as well as the connected soft tissue. The properties of most tissues are also temperature dependent, but I'm not sure anyone has looked at that carefully for skull.
14	How close are we in terms of speed and accuracy to incorporate simulation into actual clincal workflow? How do we determine that simulation is "good enough" for treatment planning and guidance?	I think we are there for model-based re-focusing. Lots of studies have shown good performance (speed and accuracy) in this regard. I think we have some way to go to quantitatively predict intracranial pressure fields. The biggest barrier is uncertainty in the material properties. Getting the focal position is ok, getting the amplitude accurately is harder, see e.g., https://dx.doi.org/10.1088/1361-6560/aa5e98.
15	Thank you for the talk and for k-Wave itself, do you find that the araldite and veroblack phantoms perform well for investigating beam aberration?	We haven't used them explicitly for this purpose, but they are good cortical bone mimics (Araldite in particular), so I think they could be.
16	Great presentation, thank you! What about simulations of ablation in skull? Is there a problem with nonlinearity and a frequency of sound that has to be covered?	This has been recently investiagted in https://doi.org/10.1109/TMI.2020.2989121. I think the wave propagation is still fairly linear at the skull surface though (see e.g., https://doi.org/10.1121/1.5126685).
17	Why not use supervised learning, feeding in simulation setup and outputting the pressure field? Do you see an advantage/disadvantage to this appraoch, compared to unsupervised learning?	The main reason is that to generate simulated ground truth data for supervised learning from a large training set of skulls (we use a training set of 9,000 in our recent paper https://arxiv.org/abs/2010.15761) takes a long time. Certainly, it's possible in 2D, but it starts to become a challenge in 3D. Then if you want to tweak something in the training examples (e.g., the CT -> medium property mapping, the driving frequency, the transducer position, etc), the simulations may have to be run again. By using a physics-based loss function and unsupervised learning, we avoid this
18	Do you think that simulation could enable plane wave imaging behind the skull one day ? (for functional ultrasound imaging of the brain)	Recent work using ultrasound computed tomography suggests transcranial ultrasound imaging might be possible one day, e.g., https://doi.org/10.1038/s41746-020-0240-8.
19	Awesome talk! For clinical usability, any thoughts on putting together a generalized, device-agnostic treatment planning system with a clinically usable UI? Or should it be left up to the manufacturers of the HIFU/HITU devices?	There is certainly a precedent for it in radiotherapy. However, it would require some standardisation of formats and cooperation with different manufacturers.
20	Do you plan to update k-wave with variable mesh in one simulation?	We've looked at this, e.g., https://dx.doi.org/10.1016/j.jcp.2018.06.009. However, making such an approach work robustly enough to handle all the edge cases that k-Wave users might throw at it is a challenge. As such, there are no immediate plans to put this in the main toolbox.
21	Nice talk, Brad. Determining acoustical properties of skull bone typically involves comparing models to measurements, in an iterative fashion until some level of convergence is obtained. This may lead to model-specific acoustical properties of skull bone (which differ from model to model). Do you think this might explain some of the differences in acoustical properties reported in the literature to date?	Absolutely. There is also variation on how the measurements are performed (whether they include the effects of sound speed disperison, etc), and if imaging is used, what resolution the images are taken at (etc).
22	Can you briefly discuss using k-wave for nonlinear propagation?	See https://dx.doi.org/10.1121/1.4712021.

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23	Is it more challenging to match pressure amplitude than the phase information between simulation and experiment?	It depends what you mean by phase information. If you mean the phase needed for model-based refocusing, yes, that's much easier. It's because you only need to be within 90 degrees of the optimal value to still get the waves to coherently add. See e.g., https://dx.doi.org/10.1121/1.4976339.
24	Any thoughts we should consider heating of skull over time as there may be transient defocusing effect for ablation procedure…	I've never seen data on the temperature dependent properties of skull bone. It definitely would be interesting to see if any temperature dependence is strong enough to defocus the beam.
25	Do you have experience validating the k-Wave pressure field simulation through layers of soft tissue? And if so, do you (in general) see this as more or less difficult than doing the same through the skull? Are there challenges besides registration and acoustic property estimation that need to be considered for soft tissue pressure field prediction?	We validated k-Wave in layered soft tissue mimics, see https://dx.doi.org/10.1109/TUFFC.2019.2941795. This paper also includes a nice table of other experimental validation studies. I think practically the difficulty is about the same. You need to accurately know the material geometry, material properties, and transducer position.
26	When referring to your slide on convergence criteria, does higher sampling refer to closer grid spacing or more time resolution? Or both?	In general, both.
27	5,"Do partial volume effects produce significant problems at the interface between cortical/trabecular bone, as well as at the interface between the cortical layers and water?	Yes. The density of marrow (which fills the pore space) is not too dissimilar to water (at least compared to bone).
28	6,"Which commercially available HIFU system has the most compact focal spot, particularly in the axial direction, so that damage to capsular tissue of organs is minimized?	I'm not up to date with these details for currently available systems unfortunately. You could try starting with the "State of the field" report published by the Focused Ultrasound Foundation to get a current list of manufacturers, and expand your search from there.