Lundi 22 Novembre 2021 11H à 12H (Amphi. D)

Dr. Charlie Demené
ESPCI Paris

Ultrasound for the brain: new tools for reading (and writing) in the neural and cerebrovascular circuits

Ultrasound (US) waves are scarcely used in clinical neuroscience and neurology, whether for imaging and therapeutic use. The diagnosis of cerebrovascular and cerebral pathologies relies mostly on magnetic resonance imaging (MRI) and computed tomography (CT), because current clinically available ultrasound-based imaging systems offer poor sensitivity and contrast in the brain. Their use is limited to a few examinations generally involving blood flow speed measurements, such as stenosis monitoring. A notable exception is neonatal cerebral imaging, as the openings in the neonate skull enable higher frequency imaging. Regarding therapeutics, the most renowned applications of ultrasound are tumor ablation and essential tremor curing. Beyond those procedures that physically remove a portion of the brain, research is also conducted on US-based neuromodulation, i.e. altering the function of neural circuits with ultrasound while keeping the cerebral tissue intact, for example to cure depression. However most of those latter studies are conducted with low frequency ultrasound (<1MHz), making spatial control of the neuromodulated area difficult, while cell-specificity of that kind of stimulation remains unknown.

In my presentation I would like to present to you some of my work and a few directions we are following at Physique pour la Médecine, in order to build clinically usable ultrasound tools for neuroscience and neurology. First I will show you how we can use ultrafast ultrasound imaging to perform functional ultrasound imaging (fUS), i.e. how we can use it to see the brain at work, especially in the case of human neonates in a clinical setting, a work we have done in collaboration with the Hospital Robert Debré in Paris. From this functional imaging we can derive connectivity imaging, informative about the function and maturation of the neural circuits, which evolves rapidly in the first days and months of life. From these connectivity imaging tools we started to build a neuroimager that can monitor the cerebral states of preterms and neonate at risk in order to improve their medical care. When pursuing the idea of translating this type of tool in human adults, a skull problem arises. In a clinical setting this problem is usually partially circumvented using ultrasound contrast agents (encapsulated microbubbles). Therefore, in collaboration with the Hopitaux Universitaires de Genève, we elaborated on this to drastically improve the sensitivity and resolution of cerebral ultrasound imaging: by combining ultrafast ultrasound imaging at low frequency (2MHz), microbubbles injection, and aberration correction techniques, we could map through the skull the cerebral vasculature in adults with a resolution down to 25µm, which is far beyond the capabilities of current clinical imaging modalities such as CT and MRI. Moreover this technique, called transcranial ultrasound localisation microscopy (t-ULM) gives functional information about the local hemodynamics in those small vessels, such as the blood flow speeds. This represents a first step toward sophisticated ultrasound tools for neuroimaging in adults. Finally, imaging the brain function is very important for diagnosis, but being able to alter that function is of highest interest. I will show in the last part how we developed sonogenetic tools, in collaboration with the Institut de la Vision, in order to be able to selectively activate with ultrasound certain types of neurons with very high spatial and temporal resolution. This type of tool paves the way for a new generation of brain machine interfaces, and offers numerous possibilities for neurological disorders and disabilities.

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Contact : ayache.bouakaz@univ-tours.fr