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# Editorial: Innovative developments in multi-modality elastography

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## Editorial on the Research Topic

### Innovative developments in multi-modality elastography

At the crossroads between biomechanics, medical imaging and wave physics, elastography has been widely developed over the last 30 years. These innovations go hand in hand with the tremendous expansion of knowledge and technological leaps medical imaging has undergone in the past decades. Whatever the modality, elastography relies on three key steps: 1) biological soft tissue is stressed; 2) the resulting displacement, strain or strain rate fields are encoded on images; 3) mechanical property maps are reconstructed from the previously encoded fields. Since the initial proposal of static elastography [1], numerous static [2,3], strain [4–7] and dynamic shear wave [8] imaging methods have emerged. Today, the most widely deployed, dynamic methods include vibro-acoustography [9], Acoustic Radiation Force Impulse (ARFI) [10–12], Transient Elastography (TE) [13–15], Shear Wave Elasticity Imaging (SWEI) [8,16], MRI Elastography (MRE) [17,18] and Optical Coherence Elastography (OCE) [19,20]. Reference is made here to some of the main founding studies of these different approaches, many of which have been widely extended subsequently. Each of these methods has its own advantages and disadvantages with respect to the application to which they are dedicated, and it is important to emphasize their complementarity. For example, MRE methods, even if more complex to implement, allow to obtain measurements with a contrast and an attenuation independent of the penetrated tissues when using ultrasonic or optical methods which, for their part, provide a much more “real-time” information. These aspects have been widely compared in the past in comparative studies and literature reviews [21,22]. However, and as it appears later *via* the different articles presented in this topic, the overlapping of these different methods

allows today to move towards complementary approaches tending to blur these differences by getting the best of each method according to the targeted clinical application. We can mention as an example the use of focused ultrasound for the generation of shear waves in MRE [23–26].

In addition to developments in imaging methods themselves, the most notable advances in recent years have focused on both *in vivo* soft tissue excitation methods and on methods for reconstructing mechanical maps. Even if they are not yet the most important developments, we can for example underline the emergence passive elastography [27–29] and Deep Learning [30,31] as excitation and reconstruction methods, respectively. Through *in vivo* mechanical characterizations across different scales and ranges of behavior of biological soft tissues, elastography enables today the exploration of a very wide spectrum of medical applications, ranging from diagnosis in clinical practice to the understanding and modeling of many healthy and pathological organs.

## Current challenges and perspectives in elastography

From the early days, elastography methods have brought together physicists, engineers and physicians with diverse and complementary backgrounds, ranging from medical imaging to wave physics and mechanics. Recent developments have further broadened this spectrum of skills by including new fields of research and applications, such as data science, artificial intelligence, interventional radiology and organ modeling. The diversity in researcher profiles involved in elastography calls for the need of communication channels that facilitate exchanges and synergies between different scientific communities that traditionally do not speak to one another.

In this context, the present topic aims to capture the current elastography landscape, whatever the imaging modality, and highlight the transdisciplinary potential of the tools and methods developed by each of the communities. In order to fully understand these new developments as well as the issues and applications associated with them, this topic first proposes five literature reviews on:

- elastic waves generation: on the one hand for MRE specifically [Gnanago et al.](#), and on the other hand for passive elastography [Brum et al.](#);
- the use of machine learning for model-free mechanical property mapping [Hoerig et al.](#);
- multi-scale opportunities of ultrasonic and optical elastography methods [Ormachea and Zvietcovich](#);
- specific clinical applications of MRE for the characterization of malignant tumors [Pagé et al.](#)

In addition, original research papers of this topic focus on methodological developments for multimodal elastography, with particular emphasis on reconstruction methods for poroelasticity [Aichele and Catheline](#), [Sowinski et al.](#), [Theodorou et al.](#), scattering, strain [Liu et al.](#), [Rippy et al.](#) and multiscale mechanics [Garczyńska et al.](#), [Garczyńska et al.](#), as well as on the development of multimodal numerical models [Torres et al.](#) and experimental phantoms [Chatelin et al.](#), [Yushchenko et al.](#) Finally, it was shown in some clinical applications that multimodal elastography can be leveraged in order to take full advantage of the complementarities across modalities as illustrated in some clinical studies [Goudot et al.](#), [Kreff et al.](#), [Pan et al.](#), [Li et al.](#)

To conclude, this Research Topic successfully highlighted that despite using different approaches, strong interrelationships and transfers between different modalities appear most fundamental and beneficial for the future development of elastography.

## Author contributions

All authors listed have made a substantial, direct, and intellectual contribution to the work and approved it for publication.

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## Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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