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Short Communication

General Perspective of Intravascular Photoacoustic Imaging (IVPA) and Intravascular Ultrasound (IVUS)

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DESCRIPTION

With ultrasound imaging supplying spatial location and morphology and Photoacoustic (PA) imaging highlighting the molecular makeup of the plaque, combined ultrasound and photoacoustic imaging has received substantial interest for intravascular imaging, such as the detection of athermanous plaques [1]. Traditional ultrasound imaging systems use piezoelectric ultrasonic transducers, which have small transducer elements and constrained frequency bandwidths. As they offer effective and ultrabroadband ultrasound generation and sensitive and ultrabroadband ultrasound detection, recent improvements on optical technologies for both ultrasound generation and detection have shown significant promise [2].

As a result, all-optical ultrasound imaging has a great chance of developing into a cutting-edge ultrasound imaging technique. Intravascular imaging is an invasive technique that captures images of sick blood vessels and provides precise pathology assessments. For instance, the buildup of fatty material on the inside walls of arteries is the cause of atherosclerosis, a major contributor to cardiovascular disease [3]. An elevated area on arterial walls known as atheromatous plaque is mostly made up of lipids, calcium, fibrous structures, and macrophage cells. The inside vessel wall becomes accumulated with atheromatous plaque, which narrows the vessels and prevents blood flow [4].

The standard imaging technique for blood vessels is angiography, but it is difficult to gather important data on atheromatous plaques without imaging the inside wall of blood vessels. Intravascular Ultrasound (IVUS) has been used to offer structure information of coronary arteries with high spatial resolution (70 µm-200 µm) as a supplemental imaging modality to angiography to address this issue [5]. The amount of stenosis can be calculated using the size of the vessel and lumen, the plaque's shape, and its location. Yet, the content of the plaques more than the degree of stenosis determines how vulnerable they are. Hence, an imaging technique that can distinguish between different types of plaque is widely desired for accurate diagnosis. Intravascular Photoacoustic Imaging (IVPA) has the potential to categorize different forms of plaque. Based on the photoacoustic effect, which is when tissues absorb light in response to pulsed laser excitation, a local temperature rise occurs, causing fast thermal expansion of the tissues, which produces acoustic waves as photoacoustic signals [6]. Ultrasound receivers can pick up these sonic waves, and by spatially resolving these signals, it is possible to reconstruct images that reveal the distribution of chromospheres' optical absorption. The recent increase in IVPA imaging speed opened the door for its clinical application. Due to the quick fall in light fluency with tissue depth, PA imaging has a relatively low imaging depth, which restricts its use for imaging intact plaque morphology and artery walls [7]. A fiber-optic system for delivering light and an ultrasound transducer for PA signal reception often make up an IVPA catheter. Pulse-echo ultrasound imaging is possible with the same instrument since the transducer transmits ultrasound signals in the meantime. The advantages of both IVUS (deep penetration) and IVPA are combined in this approach (composite contrast) [8].

With IVPA imaging catheters, the ultrasonic transducers are typically made of piezoelectric materials. A transducer with a low frequency bandwidth of <8 MHz is necessary to obtain high IVPA sensitivity, but a transducer with a large frequency bandwidth of >20 MHz is preferred for high-resolution IVUS imaging. In order to meet the demands of both sensitive IVPA and high-resolution IVUS imaging, dual-element transducers were investigated; however, they added to the complexity and increased the diameter of the combined IVUS and IVPA catheter [9]. For IVPA imaging, a Polyvinylidene Difluoride (PVDF) transducer with a frequency range of 2 MHz-15 MHz was investigated; a higher frequency is important for enhancing imaging resolution. Moreover, it is challenging to integrate optically opaque piezoelectric transducers with other imaging equipment [10].

CONCLUSION

Four key benefits over current ultrasound imaging systems may be seen in all-optical systems, which are made up of optical ultrasound transmitters and detectors: First off, these imaging

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devices can be easily downsized (1 mm in diameter) because they are fiber-based. Second, optical ultrasonic transmitters and detectors, as opposed to piezoelectric components, have excellent ultrasound transmission efficiency and sensitivity, respectively, despite having small sizes. Finally, all-optical imaging systems can be employed in many clinical procedures where intraoperative MRI is used because of their compatibility with Magnetic Resonance Imaging (MRI). Last but not least, all-optical ultrasound transmitters and receivers enable the integration of ultrasound and photoacoustic imaging, allowing for the use of a single optical fibre to both transmit ultrasound and deliver photoacoustic excitation light. This dual-modality transmission was made possible by the development of Gold Nanoparticles (AuNPs), which are frequently used as contrast agents in photoacoustic imaging and have significant absorption properties.

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