Coherent Diverging Wave Compounding Imaging Based on Circular Array for Ultrafast Endoscopic Ultrasonography

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Background, Motivation and Objective

Rapid development of ultrafast ultrasound imaging has paved the way to more and more new modalities of medical ultrasound applications, such as shear wave elastography and super-resolution blood flow imaging. However, they are still hardly implanted on endoscopic ultrasonography (EUS), as the lack of ultrafast imaging method based on the circular array, which can give a larger view (whole 360°) in the alimentary canal than the traditional linear array or convex array. To overcome this issue, a coherent diverging wave compounding (CDWC) imaging method based on a self-manufactured circular array is proposed for ultrafast endoscopic ultrasonography.

Statement of Contribution/Methods

In the proposed method, a set of virtual acoustic point sources are allocated and the diverging waves insonified from each point source are successively simulated by adjusting the emission time-delays of all elements on circular array. As shown in Fig.1(A), diverging waves emitted from different virtual sources can be coherently compounded to generate a synthetic transmit focusing at every location of the imaging plane. Since the circular array and the field of view are both central symmetric, all virtual sources are equidistantly distributed on a circular of which the radius is r. In order to achieve a frame rate as higher as possible with a comparable image quality to the traditional multifocus imaging method, the number of virtual sources are set to be 16. The effects of the radius r on the compounded image quality were also studied both theoretically and experimentally.

Results/Discussion

Simulation, phantom and in vitro experiments were performed with a self-manufactured 8MHz 124 elements circular array with a 5.35 mm radius, as shown in Fig.1(B). Wire phantoms were fabricated to test the lateral resolution in four different depths. We found that, with the increase of the number of virtual sources and the radius r, the lateral resolution of compounded image can be also improved. As shown in Fig.1(C), when 16 virtual sources are equidistantly distributed on a circular with 2.675 mm radius, the lateral resolution results in experiments are matched with the simulation, and a comparable lateral resolution to the traditional multifocus approach can be achieved on the compounded images at a frame rate of 1000 frames/sec. An endoscopic ultrasound image obtained from the in vitro pork intestinum crassum is presented in Fig. 1(D). These results have successfully demonstrated the proposed ultrafast EUS imaging method with high image quality, which could potentially enlighten the thriving development of multifunctional EUS in the near future.

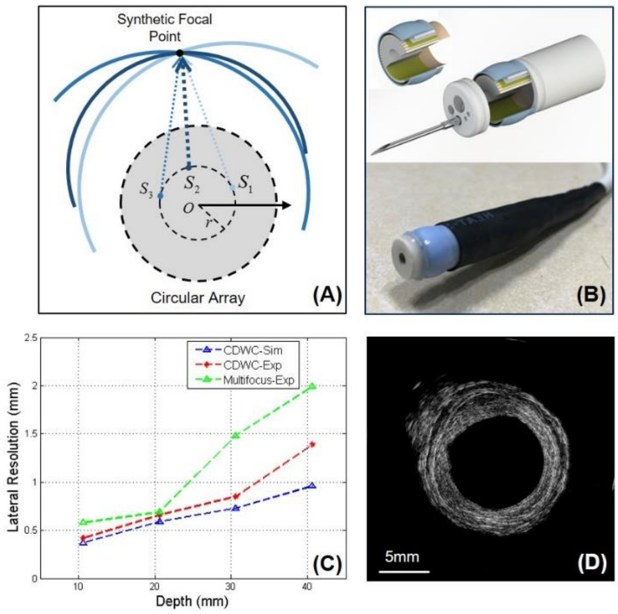

Fig.1: (A) Schematic of CDWC imaging method; (B) Structure schematic and photograph of the self-manufactured circular array; (C) Simulated and experimental results of CDWC imaging method and experimental results of multifocus imaging method in terms of the lateral resolution in four different depths; (D) The endoscopic ultrasound image of pork intestinum crassum obtained by CDWC imaging method.