Surgical Innovation
2022, Vol. 29(2) 292–294

DOI: 10.1177/15533506211037787
journals.sagepub.com/home/sri
SAGE

Intracardiac Echocardiography for Point-of-Care Guided Left Ventricular Assist Device Implantation: Surgical Implications for COVID-19

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Abstract

Data from animal models is now available to initiate assessment of human safety and feasibility of wide-angle three-dimensional intracardiac echocardiography (3D ICE) to guide point-of-care implantation of percutaneous left ventricular assist devices in critical care settings. Assessment of these combined new technologies could be best achieved within a surgical institution with pre-existing expertise in separate utilization of ICE and Impella.

Keywords

left ventricular assist device, Impella, intracardiac echocardiography, COVID-19

Twenty-five implantations of the Impella CP® temporary mechanical left ventricular assist device (LVAD) were completed in a translational study using for the first time wide-angle three-dimensional intracardiac echocardiography (3D ICE) for guidance.[1] There are wider implications from this proof of concept for the surgical management of critically ill patients, particularly for COVID-19 sufferers who develop cardiomyopathy.

COVID-19 and Myocardial Dysfunction

The reported frequency of myocardial dysfunction in patients with COVID-19 infection is around 40%,[2] with a third of patients admitted to the ICU requiring cardiac support. Although only 4% of COVID-19 patients receiving ECMO required mechanical cardiac support,[3-5] each of those cases poses complex individual clinical, organizational and ethical dilemmas. The United States Food and Drug Administration has issued an Emergency Use Authorization (EUA) for emergency use of the Impella Left Ventricular (LV) Support Systems for providing temporary LV unloading and support to treat critical care patients with confirmed coronavirus disease 2019 (COVID-19) infection.[6] The implantation of LVADs is traditionally performed in the hybrid operating room by cardiac surgeons or in the catheterization laboratory setting, presenting significant epidemiological risks when patients are highly contagious.

Guiding Implantation of Percutaneous LVADs

Axial flow LVADs are inserted via a large artery (femoral, subclavian, or axillary) percutaneously or via vascular graft and introduced retrograde via the aorta and aortic valve into the left ventricle. The blood inlet port is positioned mid-cavity within the ventricle and the miniature motor immediately below the blood outlet is sited in the ascending aorta. The reinforced catheter traverses the aortic valve and allows up to 5 L/min of flow to be delivered from the failing left ventricle into the systemic circulation. Traditional techniques for implantation involve positional guidance with fluoroscopy presenting

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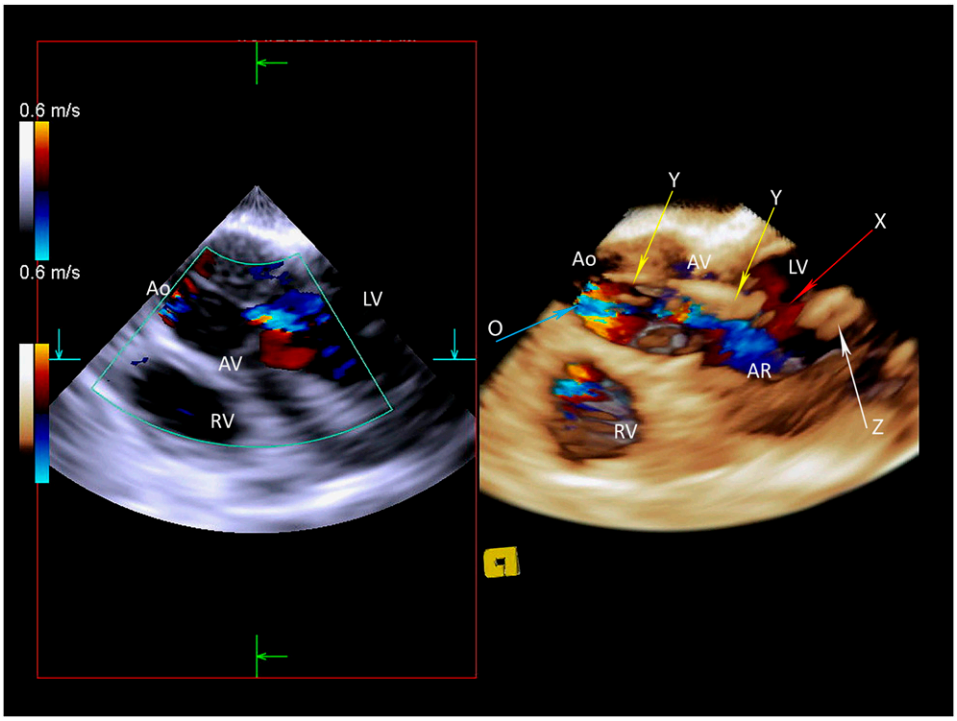

Figure 1. 3D ICE with volume Color Doppler (CD) image of Impella CP with correct position within left ventricle. LV – left ventricle, RV – right ventricle, AV – aortic valve, AR – aortic valve regurgitation, Ao – ascending aorta. *Left panel:* 2D ICE navigation image *Right panel:* 3D ICE CD image Red arrow (labelled "X") – Impella inflow. Yellow arrows (labelled "Y") – Impella CP catheter positioned across the aortic valve. White arrow (labelled "Z") – Teardrop of the Impella in mid-LV cavity. Blue arrow (labelled "O") – Impella outflow at the level of sinotubular junction of the aorta..

a dangerous logistical challenge for highly unstable, hypoxemic, and infectious patients. Transoesophageal echocardiography (TEE) offers good quality of cardiac imaging in ventilated patients, but it is considered an aerosol-generating procedure and thus presents extra risk of infectious exposure of the staff.[7] Furthermore, TEE can be very problematic in non-intubated hypoxic patients and in patients with medical contraindications for this semi-invasive procedure.

Intracardiac 3D Ultrasonography

Recent developments in technology allow real-time three-dimensional intraluminal imaging using catheter-based volumetric ultrasonography with similar principles utilized in 3D TEE. The first commercially available 90 cm long 12.5 Fr wide-angle elevation 3D ICE catheter provides imaging with an azimuthal angle of 90° and an elevation angle of 50°, while scanning at 16 cm depth with up to 20 volumes per second using 6–8 MHz frequency. Importantly, ICE can be performed as a point-of-care intervention, offering immediate proximity to the structures of interest and unique comprehensive views especially pertinent for the aortic valve, left ventricular outflow tract, proximal ascending aorta, basal and mid-left ventricular walls and cavity, tricuspid valve, and right heart chambers. This includes sequential components of LVAD implantation tools (including metal and plastic guidewires and catheters thicker than .035//), making it a unique option for comprehensive pre-, intra- and post-procedural assessment (Figure 1). The technique can be performed under local anesthesia in humans, eliminating the need for sedation or general anesthesia and airway protection in patients requiring TEE. It eliminates radiation exposure from image intensifiers and reduces the number of required personnel. As a point-of-care guide for placement of intracardiac pumps in the ICU, ICE optimizes logistics and time management, eliminates intra-hospital transfers, and reduces risks of infection for other patients and staff.

There is a balance to the benefits gained. A 14 Fr vascular sheath introducer increases risks of severe vascular injury and resulting bleeding, thrombosis, or infection. Intimate contact with cardiac tissue can lead to arrhythmias and cardiac arrest. There is further risk of clot formation inside the large vascular sheath and resulting pulmonary embolism.[8] There is also an ever-present risk of incorrect identification of structures during early

adoption of the technique, leading to misdiagnosis or severe complications. Limitations in spatial and temporal resolution of 3D ICE make imaging of thin guidewires with diameter of ≤.018′ unreliable. The implications of malposition and tangling of guidewires are profoundly serious and have been reflected in reported complications.[1] Poor imaging details of the left ventricular apex and the mitral valve are usually non-essential for transaortic-inserted LVADs but has absolute importance for surgical and minimally invasive apically implanted types of LVADs.

Clinical Implications

A gap in knowledge remains in the physiological and clinical consequences of percutaneous temporary LVADs and in the optimization of their settings and the best combination with other circulatory support systems, especially with VA ECMO. Urgent studies are required to close this knowledge gap and find new options to guide point-of-care implantation of miniaturized percutaneous LVADs. Interspecies anatomical differences would require consideration in direct translation of implantation techniques from animal studies. However, the similarity of principles using wide pyramidal datasets obtained from inside the cardiac chambers and used for guidance of LVAD positioning, monitoring of complications, and investigating cardiac progress is indisputable.

Conclusion

Data from animal models are now available to initiate assessment of human safety and feasibility of wide-angle 3D ICE to guide point-of-care implantation of percutaneous LVADs in critical care settings. Assessment of these combined new technologies could be best achieved within a surgical institution with pre-existing expertise in separate utilization of ICE and Impella.

Acknowledgments

The authors acknowledge the facilities and the scientific and technical assistance of Sydney Imaging, a Core Research Facility at the Charles Perkins Centre, University of Sydney.

Author Contributions

Konstantin Yastrebov: concept development, technique development, conducting experiments, writing the draft manuscript. and making critical revisions for the manuscript. Laurencie Brunel and Hugh S. Paterson: technique development, conducting experiments, and making critical revisions of the manuscript.Zoe A. Williams: conducting experiments, organizational support, ethics applications, and making critical revisions of the manuscript.Innes K. Wise and Christopher S. Burrows: conducting experiments and making critical revisions of the manuscript.Paul G. Bannon: organizational support and making critical revisions of the manuscript.

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The author(s) received no financial support for the research, authorship, and/or publication of this article.

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References

1. Yastrebov K, Brunel L, Paterson HS, et al. Implantation of Impella CP left ventricular assist device under the guidance of three-dimensional intracardiac echocardiography. *Sci Rep*. 2020;10:17485. DOI: 10.1038/s41598-020-74220-8
2. Ruan Q, Yang K, Wang W, Jiang L, Song J. Clinical predictors of mortality due to COVID-19 based on an analysis of data of 150 patients from Wuhan, China. *Intensive Care Med*. 2020;46:846-848. DOI: 10.1007/s00134-020-05991-x.
3. Advanced pulmonary and cardiac support of COVID-19 patients, emerging recommendations from ASAIO. *Circulation: Heart Fail* 2020;13:e007175. DOI: 10.1161/CIRCHEARTFAILURE.120.007175.
4. Vallabhajosyula S, O'Horo JC, Antharam P, et al. Venoarterial extracorporeal membrane oxygenation with concomitant Impella versus venoarterial extracorporeal membrane oxygenation for cardiogenic shock. *Am Soc Artif Intern Organs J*. 2020;66:497-503. DOI: 10.1097/MAT.0000000000001039.
5. Barbaro RP, MacLaren G, Boonstra PS, et al. Extracorporeal membrane oxygenation support in COVID-19: an international cohort study of the extracorporeal life support organization registry. *Lancet*. 2020;396:1071-1078. DOI: 10.1016/S0140-6736(20)32008-0
6. https://www.fda.gov/media/140762/download. 2020
7. Kirkpatrick JN, Mitchell C, Taub C, Kort S, Hung J, Swaminathan M. ASE statement on protection of patients and echocardiography service providers during the 2019 novel coronavirus outbreak: endorsed by the American college of cardiology. *J Am Soc Echocardiogr*. 2020;33:648-653. DOI: 10.1016/j.echo.2020.04.001
8. Yastrebov K, Brunel L, Paterson HS, Williams ZA, Bannon PG. Three-dimensional intracardiac echocardiography and pulmonary embolism. *Cardiovasc Ultrasound*. 2020;18:36. DOI: 10.1186/s12947-020-00220-3.