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CASE SERIES
Cardiac imaging

Echocardiography from a transhepatic approach in left ventricular assist device patients with difficult transthoracic imaging

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Background Left ventricular assist devices (LVADs) are increasingly used in the treatment of end-stage heart failure. One important limitation in the follow-up of these patients is the very difficult echocardiographic image, because of the interposition of implanted materials.

Case summary We present here a case series of LVAD patients with severely limited transthoracic echocardiographic windows in whom the echocardiographic analysis of the left and right ventricular function could be obtained from a very unusual approach, using a right intercostal transhepatic window, allowing visualization of the heart chambers and quantification of function even in these very challenging cases. In one case, the result was confirmed by computed tomography. In the second case, computed tomography images were unreliable because of strong artefacts from the LVAD system and implantable cardioverter-defibrillator leads, but the transhepatic approach still provided sufficient image quality in order to allow the imaging follow-up of the patient. In the third case, the transhepatic window was the only approach that provided echocardiographic images, and due to the good visualization of the heart cavities, this imaging technique was considered sufficient for follow-up studies in this stable subject with LVAD as destination therapy.

Discussion The transhepatic window may represent a good alternative in selected LVAD patients with very difficult acoustic access in traditional transthoracic views. Modified or alternate echocardiographic windows may reduce the need for invasive procedures (transoesophageal echocardiography) or imaging methods using radiations.

Keywords Transhepatic echocardiography • Left ventricular assist device • Ejection fraction • Ventricular function • Case series

Learning points

- Transthoracic echocardiography can be challenging in left ventricular assist device (LVAD) patients because of the implanted materials.
- The transhepatic window may represent a good alternative in selected LVAD patients with very difficult acoustic access in traditional transthoracic views.
- Using modified or alternate echocardiographic windows may reduce the need for invasive procedures or imaging methods using radiations.

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Introduction

Left ventricular assist devices (LVADs) are increasingly used in advanced heart failure patients either as bridge to other therapeutic options or as destination therapy.[1] In very selected cases, long-standing LVAD support may lead to significant left ventricular (LV) recovery and can even render patients eligible for LVAD explantation. Vital to this decision is a correct estimation of LV dimensions and ejection fraction (EF). Unfortunately, LVAD patients usually have very difficult echocardiographic images, secondary to the interposition of implanted materials.[2] In some cases, where the traditional acoustic windows are drastically limited, and the ultrasound is blocked by implanted material, even LV contrast agents[3,4] cannot improve the visualization of the heart. Therefore, in these patients, we systematically use an alternate transhepatic window.[5] In this report, we illustrate the clinical value of this new approach. Informed consent was obtained from the patients for publication of this case series.

Timeline

Case 1	
December 2016	Refractory acute cardiogenic chock with multi-organ failure, because of dilated cardiomyopathy, secondary to severe aortic insufficiency.
December 2016	Emergency aortic valve replacement with biologic prosthetic valve and left ventricular assist device (LVAD) (HeartMate 3) implantation.
2016–18	Progressive improvement in clinical status and effort capacity, NYHA class 1.
November 2018	Fully asymptomatic, NYHA I. Echocardiography: normal cavity dimensions, but most of the systolic phase of the heart cycle obscured by LVAD cannula.
November 2018	Contrast echocardiography: no image improvement. Transhepatic echocardiography: Left ventricular ejection fraction (LVEF) = 51%, good right ventricular function.
January 2019	Computed tomography heart: LVEF confirmed at 51%, reasonable good right ventricular function.
April 2019	Weaning trial: good response, possible LVAD explant candidate.
April 2019- first half 2020	LVAD weaning/explantation programme.
Case 2	
2003	Dilated cardiomyopathy (Titin coding gene mutation).
2007	Implantable cardioverter-defibrillator (ICD) implanted for dilated cardiomyopathy.
2012	Right ventricular lead dysfunction; old lead abandoned, placing new lead.
August 2018	Refractory cardiogenic shock in the context of severe chronic heart failure.
August 2018	Left ventricular assist device (LVAD) (HeartMate 3) implantation and aortic valve replacement with biologic prosthetic valve.
2018–19	Progressive improvement in clinical status and effort capacity.
2018-2020	Clinically stable. Echocardiography: total lack of any exploitable transthoracic window because of LVAD.
September 2018	Electrocardiogram-gated computed tomography angiography: endocardial border in the mid and apical segments could not be delineated because of severe artefacts generated by the LVAD, ICD leads, and LVAD cannula.
September 2018	Transhepatic echocardiography: All four cavities visualized LVEF = 16% No other imaging technique was considered necessary.
September 2018 to first half 2020	The patient is clinically and echocardiographically stable, on the transplantation waiting list.
Case 3	
1998–2002	Chemotherapy and surgery for colon and pancreatic cancer.
2015	Dilated cardiomyopathy.
March 2019	HeartMate 3 left ventricular assist device (LVAD) as destination therapy.
2019–2020	Progressive improvement in clinical status and effort capacity.
2019–2020	Clinically stable. Echocardiography: total lack of any exploitable classical echocardiography window because of LVAD.
July 2019	Transhepatic echocardiography: All four cavities visualized LVEF = 6% TAPSE = 12 mm No other imaging technique was considered necessary.
2019 to first half 2020	The patient is clinically and echocardiographically stable.

Case presentation

Case 1

A 26-year-old male patient received a HeartMate 3 and an aortic bioprosthesis 2 years before inclusion in this study, for severe cardiogenic shock due to dilated cardiomyopathy, secondary to severe aortic insufficiency. On follow-up, he showed remarkable general clinical improvement and a significant improvement in his effort capacity. During a 6-min walk test, he could achieve 653 m for a

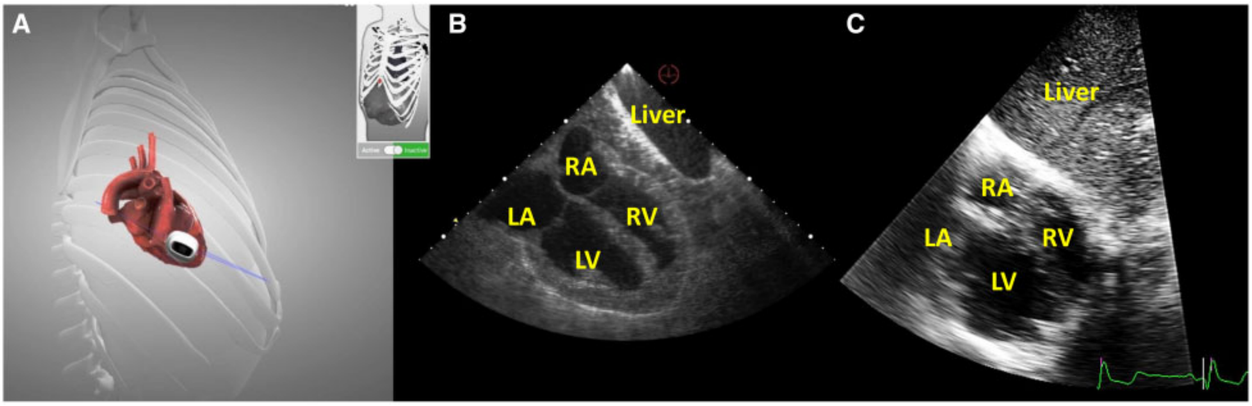


Figure 1 The transhepatic approach. (*A* and *B*) Computer-simulated echocardiography: the transhepatic window is obtained by starting from the subcostal window and sliding along the first adjacent right intercostal space. The liver is interposed between the probe and the heart; (*C*) Transhepatic echocardiographic image in our patient.

maximum heart rate of 135/min, reaching a maximal perceived dyspnoea level of 6/10 on the modified Borg scale.[6] The transthoracic echocardiography demonstrated normal cavity dimensions and suggested a significant improvement in function, but EF could not be measured due to the lack of apical window and only partial visualization of the heart cycle in the other classical views (Supplementary material online, *Movie S1*). Use of LV contrast did not significantly improve the outcome (Supplementary material online, *Movie S2*).

In LVAD patients with poor echocardiographic windows, we regularly use a right intercostal transhepatic approach as supplementary window,[5] allowing visualization of all heart cavities. In this view, the ultrasound field is no longer interrupted by implanted material, allowing visualization of all heart cavities. This view is demonstrated on a simulation software (HeartWorks Simulator v2.0.60.0, Cardiff, UK; *Figure 1*).

By applying this approach in our patient, we could obtain a modified four-chamber view with similar orientation as on the simulation study (*Figure 1*, *Movie 1*). The right ventricle (RV) could also be assessed by anterior angulation of the probe and clockwise rotation (Supplementary material online, *Movie S3*), demonstrating a good RV function. Left ventricular ejection fraction was estimated using an automated border detection algorithm (Tomtec Imaging System 4.6, Unterschleissheim Germany, *Figure 2*, *Movie 2*), despite a lower resolution at a depth of 26 cm. In order to confirm these findings, the patient underwent an electrocardiogram (ECG)-gated cardiac computed tomography (CT) (*Figure 3*, *Movie 3*, Supplementary material online, *Movie S4*). The estimated LVEF was 51%, with very similar volumes as compared with echocardiography (*Figure 2*). Considering the very significant recovery, the patient entered a weaning/explantation programme.

Case 2

A 57-year-old male received a HeartMate 3 as a bridge to transplant 1 year before inclusion in this study, for cardiogenic shock in the context of severe chronic heart failure secondary to a dilated cardiomyopathy (Titin coding gene mutation). Because of pre-existing

Movie 1 Patient 1. Modified four-chamber view obtained by transhepatic approach. All four cavities are visualized, allowing quantification of function. The resolution is decreased because of the depth and interposition of the liver.

significant degenerative aortic regurgitation, an aortic bioprosthesis was also implanted during the same intervention. The clinical evolution thereafter was favourable.

After the intervention, the follow-up echocardiography studies were rendered extremely difficult by total lack of any exploitable transthoracic window (*Figure 4A* and *B*; Supplementary material online, *Movie S5*). The patient underwent then an ECG-gated cardiac CT, but in spite of rather good visualization of the basal segments, the endocardial border in the mid and apical segments could not be delineated because of severe artefacts generated by the LVAD,

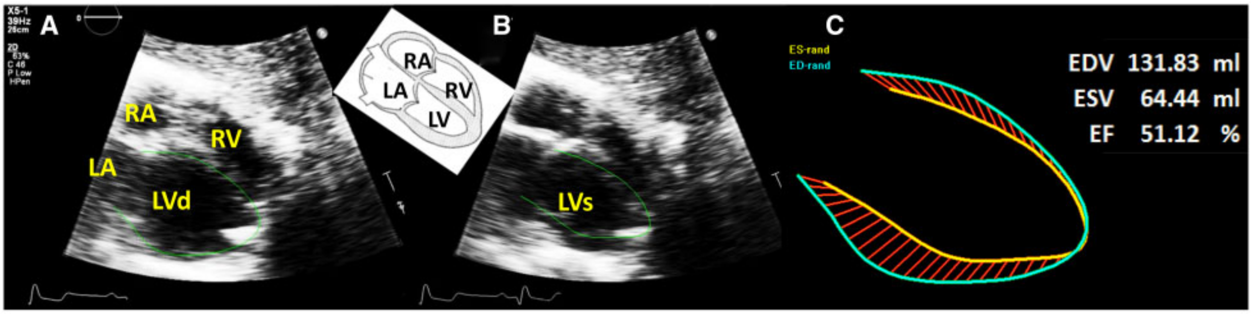
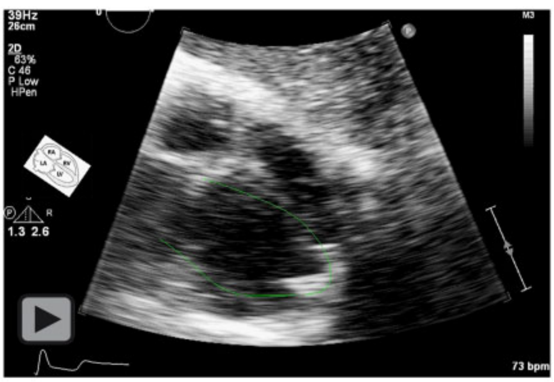
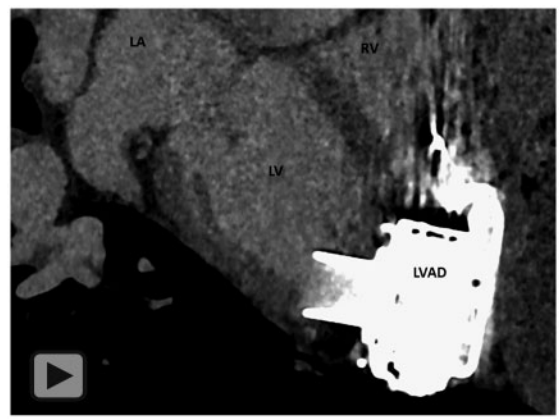


Figure 2 Patient 1.Transhepatic echocardiographic image zoomed on the modified four-chamber view. (*A*) Left ventricular end-diastolic (LVd) volume tracing; (*B*) end-systolic (LVs) tracing and (*C*) ejection fraction calculated by echocardiographic automated border tracking.



Movie 2 Patient 1. Focused modified four-chamber view in transhepatic approach. Automatic border tracking of the left ventricular endocardium (green line).



Movie 3 Patient 1. Electrocardiogram-gated cardiac computed tomography. The orientation of the images was modified in order to align with the echocardiographic images in transhepatic view. Dynamic images corresponding to *Figure 2*.

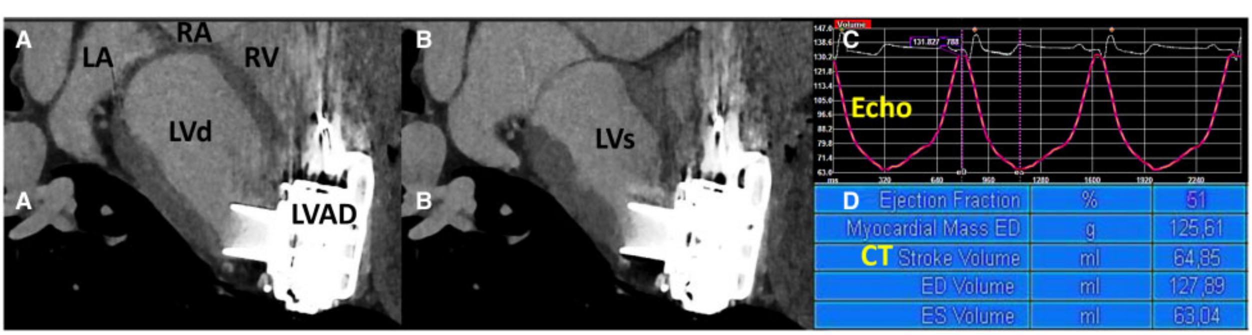


Figure 3 Patient 1. Left ventricular ejection fraction estimated by electrocardiogram-gated cardiac computed tomography. The orientation of the images was modified in order to align with the echocardiographic images in transhepatic view. (*A*) End-diastolic (LVd) frame; (*B*) end-systolic (LVs) frame; (*C* and *D*) left ventricular volumes and ejection fraction by computed tomography are very close to those obtained by echocardiography.

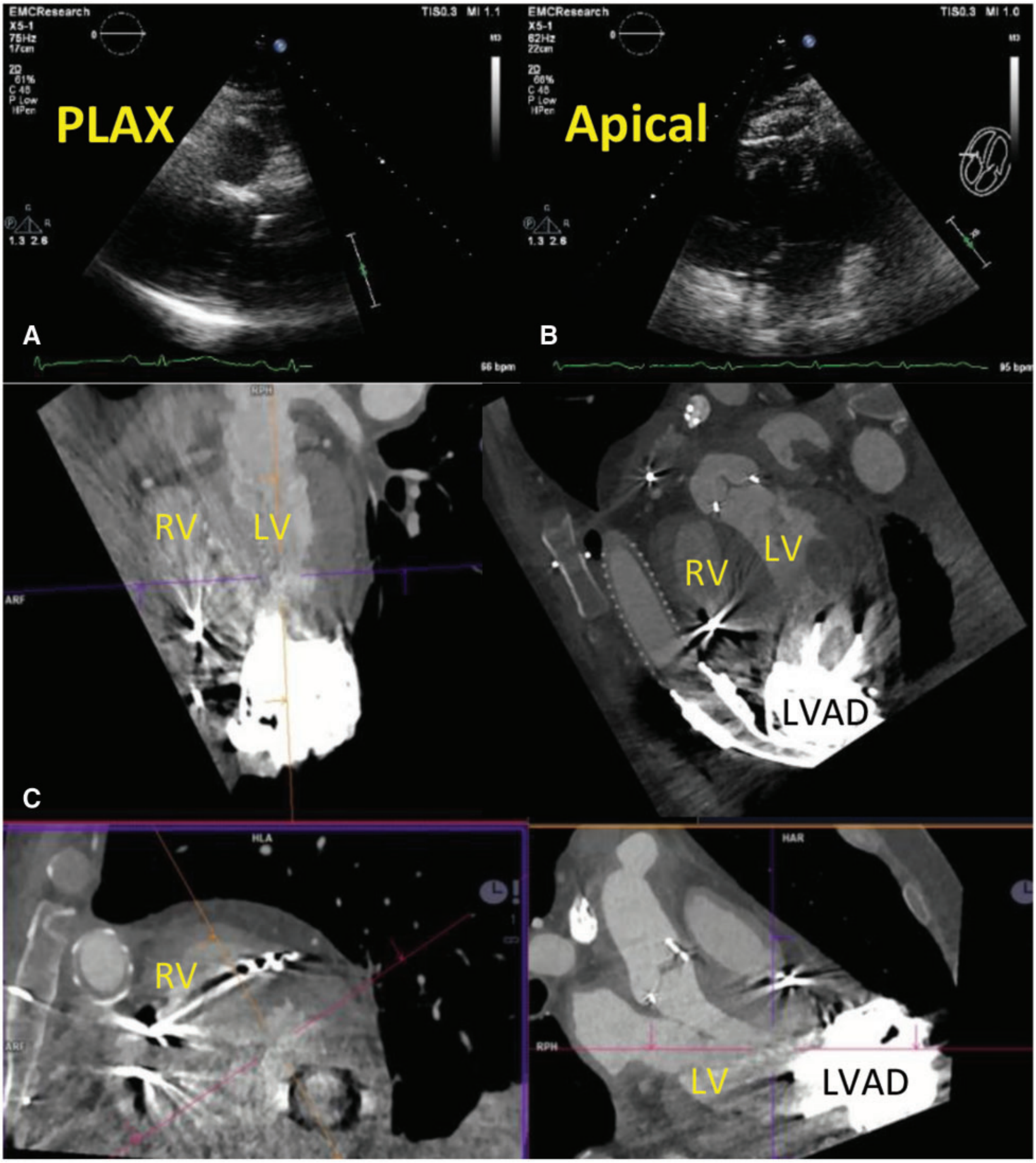


Figure 4 Patient 2. Classical echocardiography and electrocardiogram-gated computed tomography. (*A* and *B*) Echocardiography in classical windows provides uninterpretable images; (*C*) computed tomography images are rendered unreliable, especially in the apical two-thirds of the left ventricle by the intense artefacts from the left ventricular assist device system and defibrillator leads (of note, there are two ICD leads in the RV, one old abandoned lead and one active lead).

implantable cardioverter-defibrillator (ICD) leads (it is noteworthy that the patient had two ICD leads in the RV, one old abandoned lead and one active lead), and LVAD cannula (*Figure 4C*, Supplementary material online, *Movie S6*). This made the assessment of the LVEF unreliable even with CT.

We had to choose an alternative option that allowed assessment of LV function, especially for serial follow-up studies. A new echocardiographic study was performed, this time with the adjunction of a transhepatic approach. From this view, the four cardiac cavities were visible, with some loss in resolution due to the increase in depth.

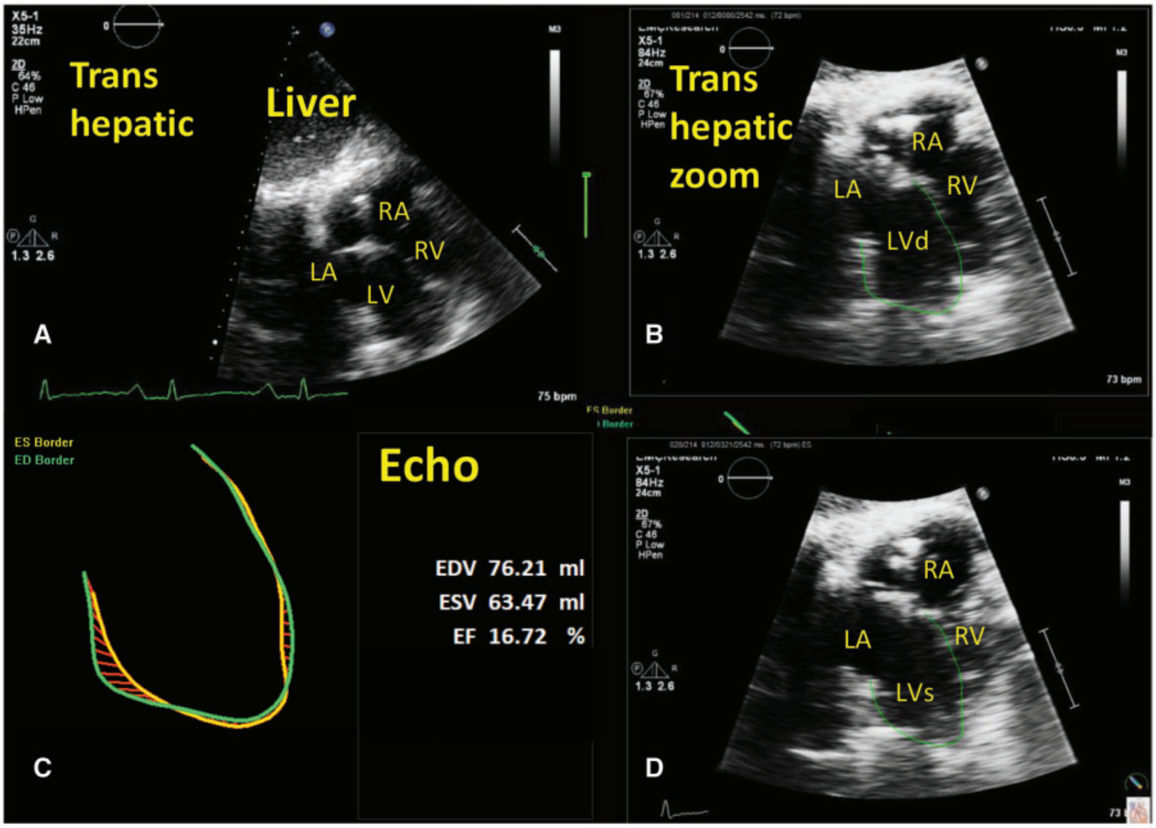


Figure 5 Patient 2. Transhepatic echocardiography. (*A*) General view with the liver in the upper part of the image. All cavities are visualized; (*B* and *D*) end-diastolic and end-systolic frames with endocardial tracking; (*C*) ejection fraction calculated by echocardiographic automated border tracking.

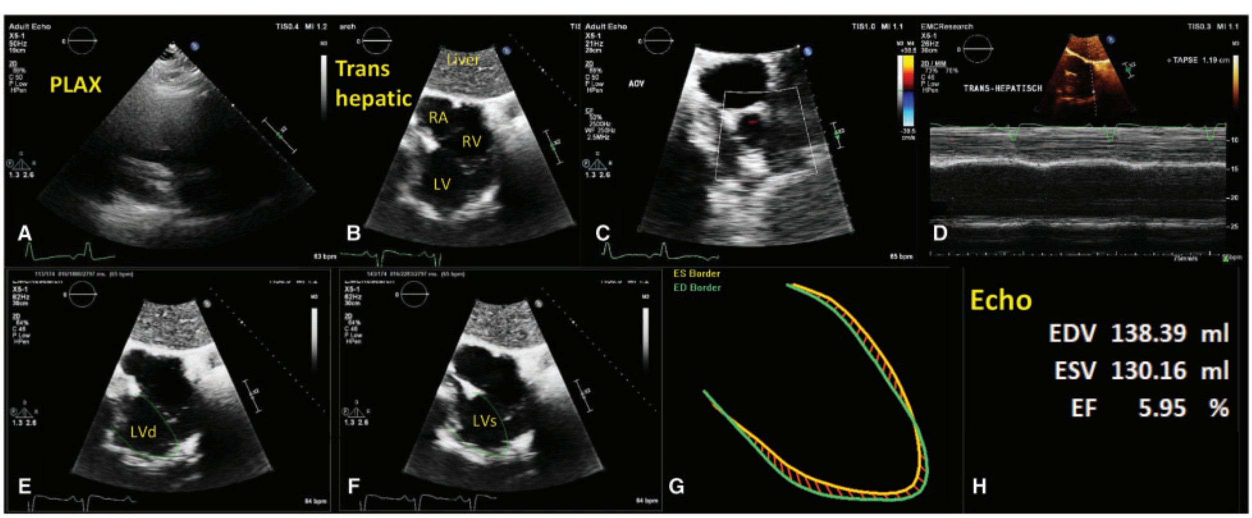


Figure 6 Patient 3. Echocardiography. (*A*) Classical windows are practically uninterpretable; (*B*) in transhepatic view the left and right ventricle are well visualized; (*C*) aortic valve interrogation in transhepatic short axis, obtained by probe rotation and tilting; (*D*) TAPSE measurement in transhepatic approach; (*E* and *F*) end-diastolic and end-systolic frames with endocardial tracking; (*G* and *H*) ejection fraction calculated by echocardiographic automated border tracking.

Right and left ventricular function could be estimated (*Figure 5*, Supplementary material online, *Movie S7*). As all necessary information could be obtained from this examination, other investigations such as transoesophageal echocardiography or nuclear imaging were not considered. The patient is presently clinically stable, on the transplantation waiting list.

Case 3

A 56-year-old male patient received a HeartMate 3 as destination therapy 1 year before inclusion in this study, for severe chronic heart failure with frequent exacerbations, secondary to a dilated cardiomyopathy (post-chemotherapy for colon and pancreatic cancer, 15 years before LVAD implantation).

After LVAD implantation and complete clinical recovery, we noticed the absence of any exploitable echocardiographic transthoracic window (*Figure 6A*). However, the transhepatic window allowed good visualization of both LV and RV (*Figure 6B–H*, Supplementary material online, *Movie S8*), with complete function assessment (severely impaired LV function and moderately reduced tricuspid annulus plane systolic excursion). Furthermore, septal curvature and aortic valve opening could be assessed in transhepatic short-axis views (*Figure 6C*). No other investigation was therefore deemed necessary, particularly given the added risk through radiation, contrast injection or semi-invasive procedures (transoesophageal echocardiography). Follow-up echocardiographic studies demonstrated stable LV and RV function.

Discussion

The follow-up of LVAD patients requires repetitive echocardiographic estimation of LV and RV size and function. This can prove very challenging in a significant number of patients, leading to an excessive use of more invasive procedures (transoesophageal echocardiography) or methods implicating radiation and use of contrast agents (CT studies).

This case series demonstrates the use of an unusual echocardiographic window in a small series of challenging LVAD patients. The right intercostal transhepatic window was proposed based on a combination of multiplane anatomical studies on CT images and computer simulations of the echocardiographic views.[5] In these difficult cases, the transhepatic approach allowed better quantification of LV and RV dimensions and function when compared with classical transthoracic echocardiography. In one case, the result was confirmed by CT. In the 2nd case, CT images were unreliable because of strong artefacts from the LVAD system and ICD, but the transhepatic approach still provided sufficient image quality in order to allow the imaging follow-up of the patient. In the 3rd case, the transhepatic window was the only approach that provided echocardiographic images, and due to the good visualization of the heart cavities, this imaging technique was considered sufficient for follow-up studies in this stable subject with LVAD as destination therapy. Studies in larger population groups may further demonstrate the added value of the transhepatic echocardiographic approach and the practical benefit for LVAD patients on long-term follow-up.

The transhepatic window allowed the visualization of all four cardiac chambers, but the imaging depth and the liver passage lead to a significant drop in resolution and frame rate (*Figure 1*, *Movie 1*, Supplementary material online, *Movies S7* and *S8*). However, this resolution was sufficient in order to answer our most important clinical questions. It is also not certain whether this approach would be useful with other LVAD systems, but given their general resemblance regarding the intrathoracic position and connections, we would expect similar benefits.

Conclusion

The transhepatic approach may represent a good alternative for follow-up echocardiographic studies in selected LVAD patients with very difficult acoustic access in traditional transthoracic windows.

Lead author biography

Mihai Strachinaru received his MD degree and Cardiology specialization in Romania, and his PhD degree with the Erasmus MC Rotterdam, the Netherlands. He studied and worked as a cardiologist in France, Belgium, and the Netherlands. During this period, he developed a keen interest in cardiac non-invasive imaging, especially echocardiography. He currently holds Romanian, French, and European certifications in transthoracic and transoesophageal echocardiography. He currently is *post-doc* researcher with the Erasmus MC Rotterdam, the Netherlands. His research interests include high frame rate imaging in all its aspects, 2D and 3D echocardiography, contrast imaging, and related preclinical and clinical applications

Supplementary material

Supplementary material is available at *European Heart Journal - Case Reports* online.

Slide sets: A fully edited slide set detailing this case and suitable for local presentation is available online as Supplementary data.

Consent: The authors confirm that written consent for submission and publication of this case report, including images and associated text, has been obtained from the patients in line with COPE guidance.

Conflict of interest: None declared.

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