Feasibility of watershed detection by point-of-care ultrasound in patients receiving bifemoral venoarterial extracorporeal membrane oxygenation: A prospective observational study

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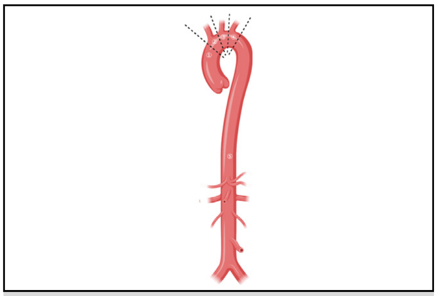

The watershed location changes along with cardiac function.

CENTRAL MESSAGE

Point-of-care ultrasound is performed to monitor the watershed position in VA-ECMO patients, which can help us to make clinical decisions.

The transition point at which antegrade pulsatile blood flow from the left ventricle and the retrograde nonpulsatile extracorporeal membrane oxygenation (ECMO) blood flow collides is referred to as the watershed in bifemoral venoarterial (VA)-ECMO.[1] We aimed to explore a feasible assessment procedure to monitor the watershed by point-of-care ultrasound (POCUS) and improve clinical management for VA-ECMO patients.

METHODS

POCUS was performed as soon as possible after ECMO initiation. Transthoracic echocardiography and vascular ultrasound were performed concomitantly to observe the aortic arch, bilateral carotid arteries, bilateral radial arteries, and abdominal aorta. Once pulsatile blood flow was detected, the following assessment procedures by ultrasound should be achieved to analyze a watershed area, as Figure 1 shows. POCUS was done daily to monitor the watershed location. This study was approved by the Medical Ethics Committee of Zhongnan Hospital, Wuhan University (approval number 2022133, August 15, 2022). We obtained informed written consent for the publication of their study data from legal representatives of each patient.

RESULTS

Here we describe 2 cases to show our findings.

Case 1

A 26-year-old female patient with out-of-hospital cardiac arrest achieved return of spontaneous circulation and was transferred to our Emergency Department. She was suspiciously diagnosed with fulminant myocarditis. After admission, she developed cardiac arrest again and received extracorporeal cardiopulmonary resuscitation due to recurrent ventricular fibrillation. POCUS was performed after ECMO initiation. The spectral Doppler ultrasound images of the left common carotid artery and right common carotid artery both showed high intermittent peaks spectrums after initiation (ECMO flow, 3.5 L), although the spectral Doppler ultrasound images of the left radial artery after initiation (ECMO flow, 3.5 L) and change of ECMO flow (ECMO flow, 2.5 L, and improvement of the heart function) showed different spectrums (Figure E1).

Case 2

A 50-year-old female patient with cardiac arrest achieved return of spontaneous circulation after cardiopulmonary resuscitation for 30 minutes. Because of cardiogenic shock after return of spontaneous circulation, she received VA-ECMO support via bifemoral vessels. The spectral Doppler ultrasound images of the aortic arch and its branches showed flat spectrums after ECMO initiation,

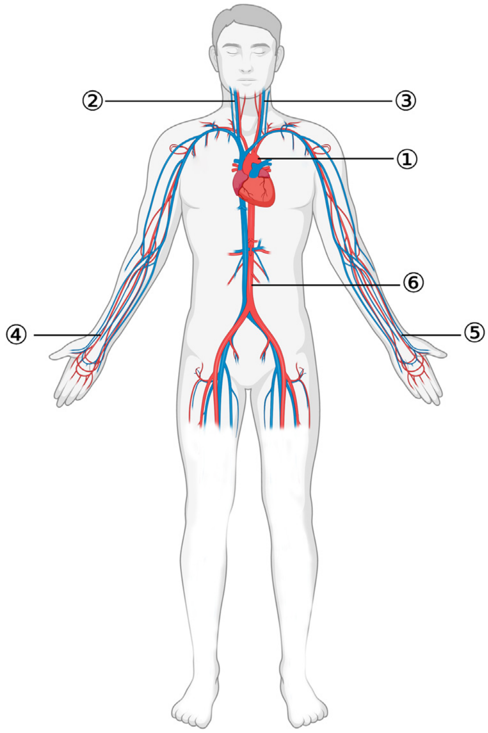

FIGURE 1. Assessment procedure ① Aortic arch and its branches. ② Right common carotid artery. ③ Left common carotid artery. ④ Right radial artery. ⑤ Left radial artery. ⑥ Abdominal aorta. Figure was created with Biorender.com.

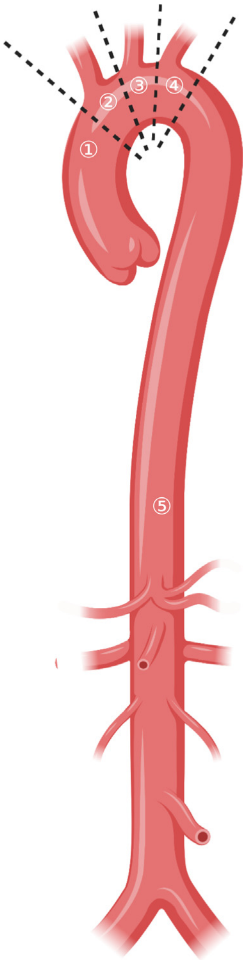

FIGURE 2. The illustration of watershed location. ① Between the aortic root and innominate artery origin. ② Between the innominate artery and left common carotid artery. ③ Between the left common carotid artery and left subclavian artery. ④ Between the left subclavian artery and abdominal aorta. ⑤ Abdominal aorta. Figure was created with Biorender.com.

whereas the left subclavian artery and abdominal aorta showed intermittent high peaks before ECMO weaning (Figure E2).

DISCUSSION

In patients receiving bifemoral VA-ECMO support, the watershed depends on relative blood pressures and blood flows between ECMO and the left ventricle.[2] In case of concomitant respiratory failure, especially in the recovery period of heart, the blood originating from the left ventricle has significantly lower oxygen saturation than blood originating from VA-ECMO, leading to differential hypoxia in patients, known as Harlequin syndrome.[3,4] Moreover, when the watershed is located distal from the carotids, the lower oxygen content of the blood results in a risk of profound hypoxemia to the heart and brain.[2] The location of the watershed is helpful to analyze left ventricle overload or hypoxic state, guide clinical therapies such as adjusting the ECMO flow and mode, and identify time of left ventricular decompression or ECMO weaning.

Many researchers have found some invasive methods to detect the location of the watershed, such as contrast-enhanced computed tomography and angiography. Those invasive methods are subject to the medical equipment and personnel available in addition to disadvantages like radiation exposure or use of contrast media.

In case 1, the bilateral internal common artery showed intermittent high peaks spectrum, and the left radial artery showed a flat spectrum after initiation of VA-ECMO. This phenomenon indicated that the bilateral internal common artery blood flow originated from the heart, but the left radial artery blood flow originated from ECMO. Thus, we concluded that the watershed was located between the left common carotid artery and the left subclavian artery. During treatment, the Doppler spectrum of left radial artery changed to an intermittent high peaks spectrum, which indicated that the watershed position moved distally to the left subclavian artery. This change was consistent with the recovered cardiac function and reduced ECMO flow. In

TABLE 1. The extracorporeal membrane oxygenation watershed location according to different vascular ultrasound images

Vessel	The spectral Doppler ultrasound images of different vessels				
Right common carotid artery/right radial artery	–	+	+	+	+
Left common carotid artery	–	–	+	+	+
Left subclavian artery/left radial artery	–	–	–	+	+
Abdominal aorta	–	–	–	–	+
Watershed location	①	②	③	④	⑤

+, Intermittent high peaks spectrum; –, flat spectrum.

case 2, the spectral Doppler ultrasound of the aortic arch and its branches that received blood flow from the ECMO circuit showed a flat spectrum. We presumed that the watershed was located proximal to the right common carotid artery. Then, the Doppler spectrum of the left subclavian artery and abdominal aorta showed an intermittent high peaks spectrum, indicating that the watershed position moved down to the abdominal aorta, and the patient improved.

CONCLUSIONS

The POCUS images obtained from these 2 cases indicate the feasibility to observe the ECMO watershed (Figure 2 and Table 1). This assessment procedure would be helpful to monitor watersheds, and can be used as routine daily management during ECMO support for patients.

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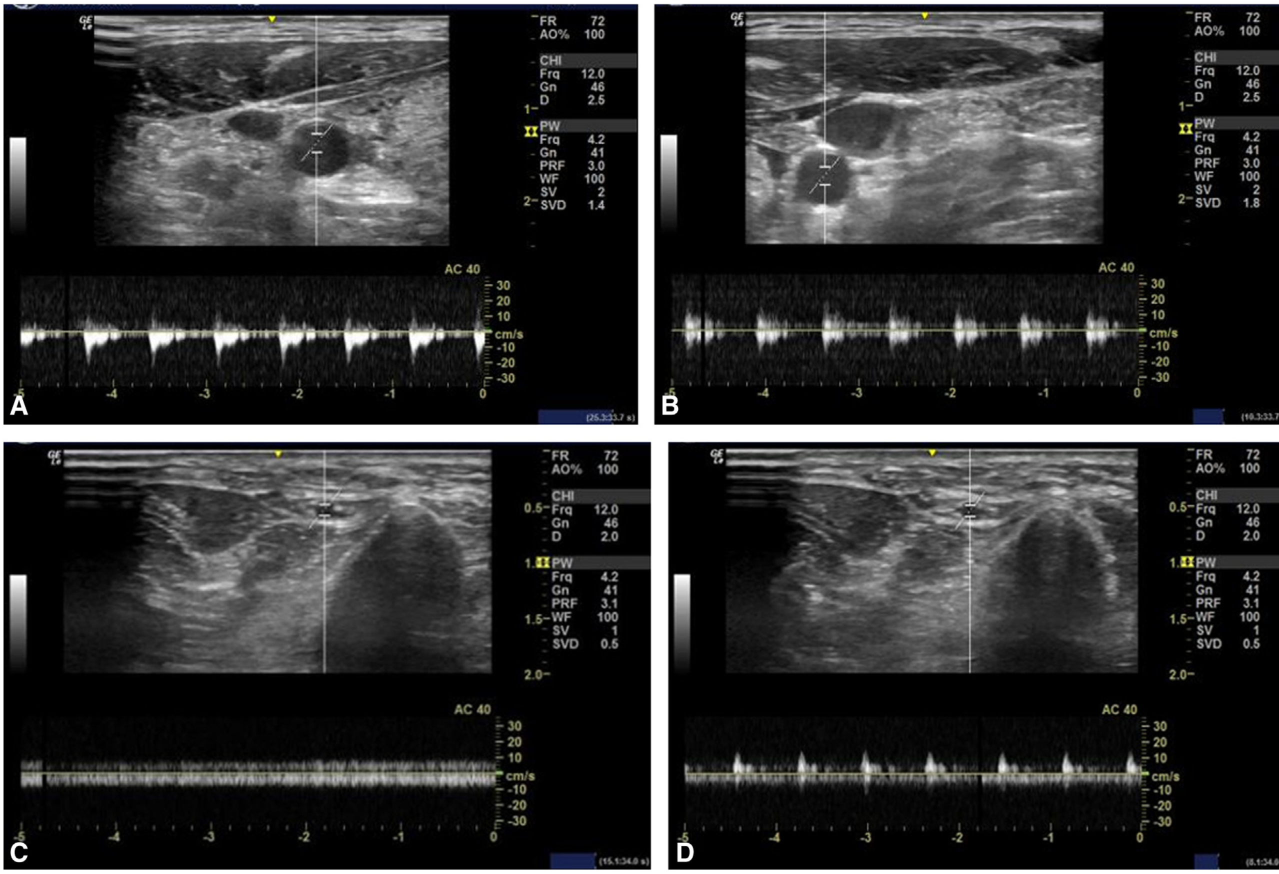

FIGURE E1. The spectral Doppler ultrasound images of common carotid artery and radial artery. A, The spectral Doppler ultrasound of the left common carotid artery showed intermittent high peaks spectrum when extracorporeal membrane oxygenation (ECMO) flow was 3.5 L. B, The spectral Doppler ultrasound of the right common carotid artery showed intermittent high peaks spectrum when ECMO flow was 3.5 L. C, The spectral Doppler ultrasound of the left radial artery showed a flat spectrum when ECMO flow was 3.5 L. D, The spectral Doppler ultrasound of the left radial artery showed intermittent high peaks spectrum when ECMO flow was 2.5 L.

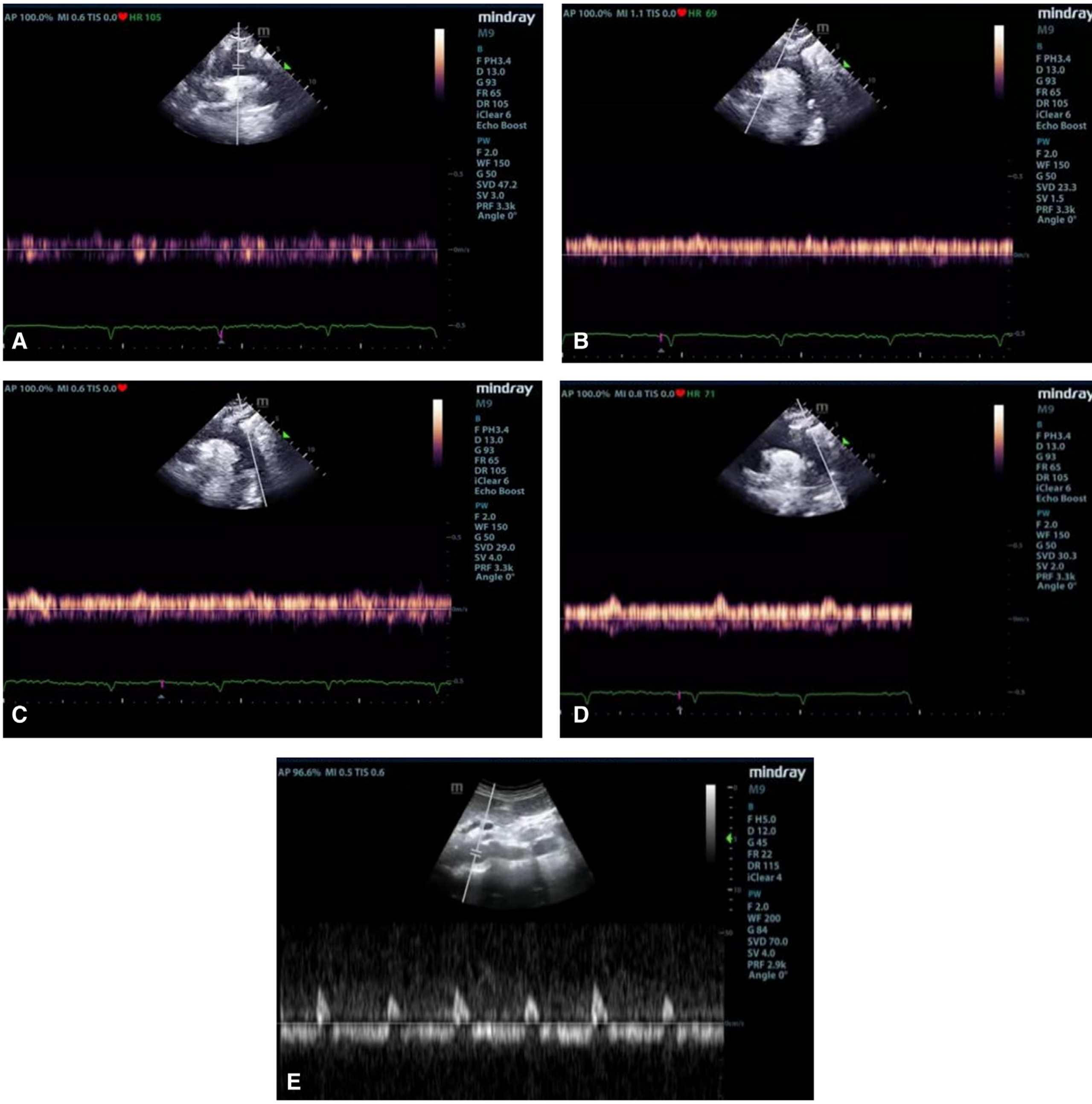

FIGURE E2. The spectral Doppler ultrasound images of the aortic arch and abdominal aorta. A, The spectral Doppler ultrasound of the arch of aorta showed a flat spectrum after extracorporeal membrane oxygenation (ECMO) initiation. B, The spectral Doppler ultrasound of the left common carotid artery showed a flat spectrum after ECMO initiation. C, The spectral Doppler ultrasound of left subclavian artery showed a flat spectrum after ECMO initiation. D, The spectral Doppler ultrasound of left subclavian artery showed intermittent high peaks spectrum before ECMO weaning. E, The spectral Doppler ultrasound of abdominal aorta showed intermittent high peaks spectrum before ECMO weaning.