ELSEVIER

Carotid Duplex Ultrasound Changes Associated with Left Ventricular Assist Devices

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Background: Carotid duplex ultrasound (CDUS) is often used as a screening test in cardiac patients. Significant cardiac dysfunction may affect the accuracy of CDUS because of alterations in the cardiac cycle. Left ventricular assist devices (LVADs) are frequently implanted as a bridge to cardiac transplant. A review of CDUS in patients with LVADs was performed to assess their influence on arterial waveforms and velocities.

Methods: Patients with LVADs undergoing carotid duplex in our Intersocietal Commission for the Accreditation of Vascular Laboratories (ICAVL)-accredited vascular laboratory were identified. The carotid waveforms were analyzed qualitatively and quantitatively. Common carotid artery (CCA) and internal carotid artery (ICA) peak-systolic and end-diastolic velocities (PSV and EDV) were recorded as ICA/CCA velocity ratios. In patients with prior CDUS, the changes between these values were analyzed before and after LVAD placement.

Results: Of the 14 patients with LVADs treated in our institution over the past 2 years, 4 had CDUS (8 ICAs). Mean age was 57 years, and 3 of the 4 patients were men. All patients were free of cerebrovascular symptoms. Qualitatively, there was significant blunting of the CCA and ICA waveforms noted in all 8 ICAs. The degree of stenosis was reported as $\leq$15% in 7 ICAs and 15–45% in 1 ICA. The mean ICA PSV was 61.8 cm/sec. Two patients (4 ICAs) had CDUS before and after LVAD placement. Comparing pre- and post-LVAD values, the mean ICA PSV decreased by 42% (54 cm/sec; $P = 0.04$) and EDV increased by 51% (17 cm/sec; $P = 0.3$). The PSV and EDV ratios were unchanged. Overall assessment of category of stenosis was unchanged in 2 ICAs ($\leq$15%), one decreased from moderate to mild (45–70% to 15–45%), and one ICA changed from 45–70% to $\leq$15% based on the decreased ICA PSV.

Conclusions: The presence of an LVAD has a significant influence on CDUS findings. There is a qualitative change in the ICA with blunting of the waveform, and a quantitative change with a decreased PSV and an increased EDV. Compared with pre-LVAD placement, there is a significant decrease in PSV which may affect the accuracy of CDUS using velocity-based criteria. Further study into the accuracy of CDUS in patients with LVADs is necessary.

INTRODUCTION

Carotid duplex ultrasound (CDUS) has emerged as the diagnostic test of choice for the evaluation of carotid artery disease. This noninvasive modality evaluates the arterial waveforms, systolic, and end-diastolic velocities of blood flow through the extracranial cerebrovascular system. Based on these velocities, the determination of stenosis secondary to atherosclerosis is made. This velocity-based criterion is known to be of critical importance in the

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diagnosis of symptomatic and asymptotic carotid artery disease.[1–3]

CDUS is often used as a screening test in patients with cardiac disease before surgical interventions as these patients are at risk for cerebrovascular disease.[4] A subset of cardiac patients with advanced heart failure refractory to medical management require the use of left ventricular assist devices (LVADs) as a means of recovery after significant myocardial insult, as a bridge to cardiac transplantation, or as definitive therapy for patients who are poor surgical candidates.[5,6] Various complications after LVAD implantation have been documented in the literature including neurologic sequelae ranging from transient ischemic attacks to hemorrhagic and ischemic strokes.[7]

In general, LVAD systems consist of a small implantable pump which is connected via an external cable to a monitoring/controller system and an external power source that includes options for rechargeable batteries or a fixed power source. These systems are usually implanted via an incision in the left upper quadrant of the abdomen and connected in parallel to the circulatory system. The pumps are attached via conduits to the apex of the left ventricle and the ascending aorta. Designed for long-term use, these small implantable pumps are intended for use inside and outside of the hospital.

Currently, at our institution, the only LVAD used is a continuous axial flow device that diverts blood from the left ventricle and drives it into the aorta via an outflow graft.[8] This mechanism is distinct from previous generation LVADs which were volume displacement devices designed to have cyclic flow to closely resemble normal cardiac physiology. With the use of continuous axial flow LVADs, blood flow from the left ventricle to the aorta has a tendency to lose its pulsatile nature with lower systolic flow and increased diastolic flow.[9]

The alteration in normal circulatory physiology after LVAD implantation makes the evaluation of the extracranial cerebrovascular system considerably more problematic. We performed a review of CDUS in patients with LVADs from our institution to assess the influences of LVADs on carotid duplex-derived arterial waveforms and velocities.

MATERIAL AND METHODS

A database compiled by the department of cardiothoracic surgery comprising all patients with implanted LVADs from June 2010 to November 2012 was reviewed. Patients with LVADs who underwent postimplantation CDUS in our Intersocietal Commission for the Accreditation of Vascular Laboratories (ICAVL)-accredited vascular laboratory were identified.[10] All CDUS studies were obtained by the department of cardiothoracic surgery as part of their preoperative protocol for LVAD patients who were being evaluated for cardiac transplant candidacy. None of the patients identified had computed topography angiography (CTA) of the neck or magnetic resonance angiography (MRA) of the neck for comparison. A retrospective review of all CDUS findings was then completed by 2 of the authors independently (AC and AMA).

All the CDUS studies were performed at our institution by experienced vascular sonographers. The common carotid artery (CCA), internal carotid artery (ICA), external carotid artery (ECA) and vertebral artery were examined. Standard views were obtained with grayscale, color, and spectral Doppler settings.[11] The determination for degree of stenosis was made using the velocity-based criteria listed in Table I. These criteria have been previously internally validated in our ICAVL-accredited vascular laboratory and also take into consideration the 2003 Ultrasound Consensus Conference recommendations for carotid artery stenosis.[12]

The carotid waveforms were analyzed qualitatively and quantitatively. CCA and ICA peak-systolic and end-diastolic velocities (PSV and EDV) were recorded as ICA/CCA velocity ratios. In patients with CDUS before LVAD placement, the changes between these values were analyzed before and after LVAD placement. Differences were analyzed using SAS software (SAS Institute, Cary, NC). P values <0.5 were considered significant. The study was approved by the Investigation Review Board of Loma Linda University Medical Center.

RESULTS

Of the 15 patients treated with LVADs in the past 2 years at our institution, 4 had CDUS studies completed after LVAD implantation (8 ICAs). Mean age was 57 years, and 3 of the 4 patients were men. None of the patients evaluated after LVAD implantation had cerebrovascular symptoms. CDUS studies were obtained from 2 to 11 months after LVAD placement (Table II).

Qualitatively, there was significant blunting of the CCA and ICA waveforms noted in all 8 ICAs (Fig. 1). Quantitatively, the degree of stenosis was reported as $\leq$15% in 7 ICAs and 15–45% in 1 ICA. The mean ICA PSV was 61.8 cm/sec.

Two patients (4 ICAs) had CDUS both before and after LVAD implantation. The study interval