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*Clinical Research*

# Normal Lower Extremity Duplex Findings in Patients with Left Ventricular Assist Devices: A Basis for Vascular Laboratory Interpretation

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**Background:** Left ventricular assist devices (LVADs) have been shown to cause changes in carotid artery duplex-derived flow velocity waveforms; however, possible effects on lower extremity arterial duplex (LEAD) findings have not been characterized. We sought to characterize LEAD findings in patients with LVADs to establish a basis for vascular laboratory interpretation of LEAD in patients with LVADs.

**Methods:** Retrospective single institution review of all patients with LEAD performed after LVAD implantation from 2003 to 2014. Peak systolic velocity (PSVs) of common femoral (CFA), superficial femoral (SFA), popliteal, and posterior tibial arteries (PTA) in asymptomatic extremities in patients with LVADs were compared to a control group of patients at our institution without LVADs who underwent LEAD for nonischemic indications. Arterial brachial index (ABIs) and CFA waveform acceleration times (ATs) and end diastolic velocity (EDV) were also measured.

**Results:** There were 248 LVAD patients, 29 had LEAD of at least 1 lower extremity (34 extremities, 22 asymptomatic, and 12 symptomatic) during the study period and 136 control limbs. Mean PSVs (cm/s) in the control CFA, mid SFA, popliteal, and PTA were 137 ± 4.8, 104.2 ± 4.5, 65.2 ± 2.8, and 64.6 ±3.2. Mean PSVs were significantly decreased in the LVAD patients: 49.5 ± 4.9, 40.6 ± 3.7, 27.2 ± 2.2, and 25.5 ± 2.3, $P < 0.001$ for each comparison. Average ABI for control limbs was 0.91 ± 0.05 compared to 1.17 ± 0.35 in LVAD extremities ($P < 0.001$). Mean CFA AT was 97 ms in the controls and 207 ms in LVAD patients, $P < 0.001$. Mean CFA EDV was 14.7 cm/s in the controls and 18.6 cm/s in the LVAD patients, $P = 0.011$.

**Conclusions:** This is the first study characterizing LEAD in lower extremity arteries in LVAD patients. PSV is significantly decreased throughout lower extremity vessels, and common femoral artery acceleration time increased. Results can serve as a basis for identifying normal LEAD findings in LVAD patients.

## INTRODUCTION

Left ventricular assist devices (LVADs) support the failing heart by diverting blood flow through a motorized pump directly into the aorta. The first generation of LVADs replicated cardiac physiology with pulsatile flow, and they were shown to improve long-term survival compared to best medical therapy.[1] Second generation devices use rotary pumps to create continuous axial flow. In addition to being smaller, continuous axial flow devices have superior stroke-free survival and device durability.[2] Continuous axial flow devices are used at

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**Table I.** Demographic characteristics, control versus LVAD patients

| Characteristic | Control *n* (%), *n* = 136 | LVAD *n* (%), *n* = 29 | *P* value |
|---|---|---|---|
| Male | 91 (65) | 22 (76) | 0.385 |
| Age | 60 | 49 | 0.003 |
| DM | 40 (27) | 17 (58) | <0.001 |
| CKD | 22 (15) | 18 (62) | <0.001 |
| Chronic dialysis | 13 (9) | 1 (3) | 0.468 |
| CAD | 60 (41) | 19 (65) | 0.016 |
| HTN | 94 (64) | 19 (66) | 0.941 |
| HLD | 76 (52) | 15 (52) | 0.945 |
| History of TIA/CVA | 13 (0.07) | 7 (25) | 0.019 |
| Smoking (ever) | 95 (65) | 12 (41) | 0.012 |
| Medications | | | |
| Statin | 63 (45) | 22 (78) | 0.001 |
| Beta blocker | 54 (39) | 22 (78) | >0.001 |
| Full anticoagulation | 13 (0.07) | 20 (71) | >0.001 |
| Antiplatelet therapy (aspirin, clopidogrel, or both) | 74 (53) | 24 (86) | 0.001 |

DM, diabetes mellitus; CKD, chronic kidney disease; CAD, coronary artery disease; HTN, hypertension; HLD, hyperlipidemia; TIA, transient ischemic attack; CVA, cerebrovascular accident.

our institution in patients with end-stage heart failure as destination therapy or as a bridge to cardiac transplantation.

In a recent study, carotid waveforms in patients with continuous axial flow LVADs were shown to have decreased peak systolic velocities and prolonged acceleration times.[3] Velocity-based criteria are crucial to interpretation of duplex ultrasonography, and the study suggests normal lower extremity arterial duplex (LEAD) findings in LVAD patients may also differ from those in non-LVAD patients. LEAD may be utilized in patients with LVADs as part of an evaluation before cardiac transplantation as well as for evaluation of possible lower extremity ischemia. However, to date, the effect of LVADs on LEAD findings has not been characterized, and as a result, interpreting examinations as normal or abnormal in patients with LVADs is not based on established criteria for normal LEAD velocity and waveform findings in normal limbs in patients with LVADs. As the prevalence of patients with LVADs grows, there is a need to provide standardized values for LEAD findings in patients with LVADS to foster accurate interpretation of LEAD in patients with LVADs. We therefore sought to characterize normal LEAD findings in patients with LVADs to serve as a basis for vascular laboratory interpretation.

## METHODS

We performed a retrospective, single-center review of all patients with LEAD after left ventricular assist device (LVAD) implantation from 2003 to 2014. The cardiothoracic surgery department at our institution maintains an internal database of all patients in whom LVADs were implanted. From this database, we identified by electronic medical record review all patients who underwent LEAD during the time an LVAD was in place. Patient characteristics gathered included gender, age, smoking status, comorbidities (e.g., presence of diabetes, chronic kidney disease, and coronary artery disease), and medication use (e.g., anticoagulation, antiplatelet use, beta blocker, and statin). Reason for LEAD in LVAD patients was determined from chart review, and all extremities were categorized as symptomatic or asymptomatic for ischemic symptoms. If an LVAD patient received an LEAD for cardiac transplant workup and the patient had no ischemic lower extremity symptoms and normal pulses, both limbs were used in the analysis as normal in the LVAD group. If an LVAD patient received an LEAD for a unilateral diminished or absent pulse, only the asymptomatic leg with normal pulses was used to characterize normal LEAD values in LVAD patients.

Peak systolic velocity (PSV) of common femoral (CFA), superficial femoral artery (SFA), popliteal, and posterior tibial arteries (PTA) in asymptomatic extremities of LVAD patients were recorded and compared to those of patients without LVADs who had received LEAD at our institution for nonischemic indications. CFA end diastolic velocities were also determined and compared in the asymptomatic LVAD limbs versus control limbs.

The control group was derived from patients who underwent LEAD at our institution from 2012 to 2014 without lower extremity ischemia symptoms