Neuroendovascular Interventions for Acute Ischemic Strokes in Patients Supported with Left Ventricular Assist Devices: A Single-Center Case Series and Review of the Literature

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BACKGROUND: **With the shortage of donor hearts, increasingly more patients with end-stage heart failure are implanted with left ventricular assist devices (LVADs). LVADs are associated with a significant risk of developing acute ischemic strokes (AISs). Very little is known on about the management of AIS in patients with LVAD, especially with regard to the safety and efficacy of neuroendovascular techniques.**

METHODS: **We identified 5 patients with heart failure and LVAD implants who developed AIS and underwent neuroendovascular interventions at Columbia University Medical Center. Their cases were reviewed for the safety, efficacy of the interventions, and potential complications.**

RESULTS: **There were no significant complications from the interventions. In all 5 cases, there was at least a 4-point improvement in the National Institutes of Health Stroke scale and none of the cases developed symptomatic hemorrhage. Two patients had substantial improvement and received cardiac transplantations.**

CONCLUSIONS: **Neuroendovascular intervention is safe and feasible in patients with LVAD and may potentially contribute to improving the outcome of a disease that has a poor natural history. Further study is recommended.**

INTRODUCTION

Chronic heart failure affects approximately 5.7 million Americans and is one of the leading causes of hospitalization, morbidity, and mortality worldwide.[1] With the shortage of donor hearts, cardiac transplantation is limited to only a fraction of patients with end-stage heart failure.[2,3] Patients with end-stage heart failure have an option to undergo left ventricular assist device (LVAD) implantation either as a bridge to transplant or destination therapy. Widespread use of LVAD is limited by multiple complications, notably stroke.

The development of acute ischemic strokes (AISs) in this patient population complicates management significantly and adds to the already relatively high morbidity and mortality.

Despite accumulating evidence regarding the benefits of neurointerventional procedures in the patient with undifferentiated stroke,[4-8] the adoption of this therapy in patients with LVADs has been limited due to concern of futility.[9] Two case series[10,11] were identified in the literature describing AIS in patients with LVADs, and neither describes any patients treated with endovascular therapy. Furthermore, those patients have been systematically excluded from clinical trials of neurointerventional procedures, as they often meet exclusion criteria of anticoagulant use or significant medical comorbidities.[6,12] The literature is restricted to rare case reports, contributing to the perception of futility of intervention in these patients.[13] Because the presence of "irreversible neurological disorder" is a relative contraindication to cardiac transplantation,[14] aggressive treatment of AIS may make the critical difference in allowing some patients to advance to

Key words
- Ischemic stroke
- Left ventricular assist device
- mechanical thrombectomy

Abbreviations and Acronyms
AIS: Acute ischemic stroke
CT: Computerized tomography
CTA: Computed Topographic Angiography
INR: International normalized ratio
LVAD: Left ventricular assist device
MAP: Mean arterial pressure
mRS: Modified Rankin scale
NIHSS: National Institutes of Health Stroke scale
r-tPA: Recombinant tissue plasminogen activator
TICI: Modified Thrombolysis in Cerebral Infarction

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transplantation. Treatment with intravenous recombinant tissue plasminogen activator (r-tPA) in this subgroup is not an ideal option due to underlying acquired von Willebrand disease and anticoagulant use.[15]

In the present article we report the cases of 5 patients with LVADs who developed AIS and underwent neuroendovascular interventions to re-establish cerebral blood flow.

METHODS

Study Population

This single center case series examined 5 consecutively treated patients supported with LVAD who underwent mechanical thrombectomy for AIS. Patients were admitted to the Neurological Intensive Care Unit of Columbia University Medical Center (New York, NY) between June 2009 and April 2014. The study was approved by the Columbia University Medical Center Institutional Review Board.

Clinical Management

Clinical management conformed to the American Heart Association/American Stroke Association guidelines and our institutional protocol for the management of AIS.[15,16]

Data Collection

Demographics, past medical history, baseline clinical status, National Institutes of Health Stroke scale (NIHSS), imaging results, as well as treatment and complications during hospitalization were recorded prospectively. Patients who survive the hospitalization were followed up for routine care at Columbia University Medical Center and examinations were documented.

Clinical and Radiologic Variables

The Columbia University team includes a dedicated vascular neurologist who consults on all patients with LVADs who develop a neurological complication. The diagnosis of AIS was established by an initial noncontrast spiral computerized tomography (CT) of the head followed by CT angiography (CTA). In this case series all of the patients underwent digital subtraction angiography to confirm and/or determine the presence, size, and location of the occluded vessel. The decision of whether to use mechanical thrombectomy and/or intra-arterial r-tPA, as well as the choice of device used for mechanical thrombectomy was left to the operator's discretion.

The degree of vessel occlusion before and after treatment was defined by the modified Thrombolysis in Cerebral Infarction (TICI) classification and adjudicated by the operator.

Successful recanalization was defined as a TICI score $\geq$2b after treatment. Procedure time was defined as the time from groin access to achieving recanalization.[17]

Neurological improvement of $\geq$4 points on the NIHSS or a score of 0 24 hours after the intervention in association with a recanalization score of TICI score $\geq$2b after treatment was considered successful.[18]

Symptomatic intracerebral hemorrhage was defined as the presence of hemorrhage after treatment, with worsening of clinical examination by $\geq$4 points on the NIHSS.[17]

Outcome Assessment

The primary clinical outcome was improvement in the NIHSS, and the primary radiologic outcome measure was reestablishment of intracranial flow. Discharge examination was documented using the 7-point version of the modified Rankin scale (mRS) rated from death to symptom-free full recovery (0). Poor outcome was defined as death or moderate-to-severe disability (unable to walk or tend to bodily needs, mRS score 4–6).[19] Patients who survive the hospitalization were followed up at the Columbia University Medical Center outpatient clinic and examinations were documented.

RESULTS

A total of 5 patients were enrolled (1 woman and 4 men; mean age, 61 years [range, 21–65 years]). Mean admission NIHSS was 18.6 (range, 17–22) and mean time from symptom onset to intervention was 4 hours 18 minutes. Two patients developed AIS despite being adequately anticoagulated (**Table 1**). All patients had intracranial internal cerebral artery and/or middle cerebral artery occlusion confirmed by CTA and digital subtraction angiography. The mean recanalization time was 100 minutes (range, 60–120 minutes). None of our patients demonstrated an increase in their before procedural NIHSS. There was no hemorrhagic transformation in any of the cases and none of the patient required decompressive craniectomy for mass effect. The mean after procedural NIHSS score was 8.4 (range, 1–13). The outcomes from intervention varied significantly. Two patients had a TICI score of 3, 1 patient had a TICI score of 2A. Two patients had substantial clinical improvement that was sustained at 3 and 6 months (**Table 2**). Of note both patients proceeded to receive cardiac transplantations. In 1 case where the patient was septic, we were unable to gain access to the vessel of interest due to the patient's tortuous anatomy, hence the patient's TICI score was 0 and the patient subsequently passed away. There was no definite difference in the character of the clot extracted from patients with LVADs compared with that in the general population, neither subjectively during the procedure nor under histopathologic evaluation.

DISCUSSION

Management of AIS in the setting of LVADs is challenging. Due to concern for higher risk of complications, this cohort of patients has been excluded from clinical trials. A review of the literature revealed that little is known about the management of AIS in patients with LVADs and that data on short-term and long-term outcomes are scant, especially with regard to the efficacy of neuroendovascular techniques and the functional prognosis of patients with LVADs after AIS.

Herein we present the largest case series to date describing thromboembolectomy in patients with LVADs who suffered AIS. In all of our cases, there was at least a 4-point improvement in the NIHSS and none of the cases developed symptomatic hemorrhage. Two patients in particular had a good outcome after intervention. After presenting with NIHSS scores of 22 and 19, and then undergoing reperfusion therapy with TICI scores of 2A and 3, respectively, both had substantial clinical improvement (mRS of 1 at 6 months) and were able to proceed to receive cardiac