Review Article on Left Ventricular Assist Devices

Blood pressure management in mechanical circulatory support

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Abstract: Durable mechanical support has become widely available for end stage heart failure as destination therapy and as bridge to transplantation. The accurate measurement of blood pressure (BP) as well as the recognition and management of hypertension in patients with continuous flow left ventricular assist devices (CF-VADs) is an essential component of optimal clinical care. Strategies for the control of BP in CF-VAD patients are increasingly important as there is an evolving understanding of the connection between hypertension, pump output, and adverse outcomes. As clinical experience grows, optimal BP targets, as well as methods to measure BP in CF-VAD patients have been further defined.

Keywords: Blood pressure (BP); mechanical circulatory support; continuous flow left ventricular assist device (CF-VAD); mean arterial pressure (MAP)

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Introduction

The number of patients supported by left ventricular assist device (LVAD) is increasing as durable mechanical support has become widely available for end stage heart failure as destination therapy and as bridge to transplantation. Patients with LVADs are now living longer as a result of significant advances in pump technology, candidate selection, and clinical management. Continuous flow LVADs (CF-VADs) have largely replaced pulsatile LVADs as the predominant LVAD type due to their improved durability.

The accurate measurement of blood pressure (BP) as well as the recognition and management of hypertension in patients with LVADs is an essential component of optimal clinical care. Hypertension is an established long-term risk factor for cardiovascular disease. Given the improved outcomes and extended support times for many LVAD patients, long-term management strategies for the control of BP are increasingly important. There is increasing evidence that links hypertension in LVAD patients to adverse outcomes (1). A multicenter review of CF-VAD patients from 2006 to 2013 examined the association between BP and adverse events and showed that higher BP was significantly associated with a composite of adverse outcomes including hemorrhagic stroke, aortic insufficiency, and thromboembolic events (2). This study was the first to show an association between poorly controlled BP and adverse events in the CF-VAD population. In a separate study of 96 LVAD patients stratified by the number of antihypertensive medications there were prescribed to achieve a target mean arterial pressure (MAP) of less than 80 mmHg, LVAD patients not on any antihypertensive medications experienced higher rates of neurologic events (3).

Impact on pump output

BP control for patients with continuous flow pumps is essential to maximize pump output and ensure adequate decompression of the left ventricle. Effective BP control is particularly important in the setting of CF-VADs, since

these types of devices are more sensitive to afterload than the previous generation of pulsatile flow LVADs. An understanding of the physiology of CF-VADs highlights several factors that may contribute to device dysfunction and device related complications in the setting of poorly controlled hypertension. Pump output at a given speed is greatly dependent on afterload. Among continuous flow devices, centrifugal pumps such as HeartWare's Ventricular Assist System are even more sensitive to afterload than axial flow pumps such as Thoratec's HeartMate II (4). Increased afterload, in the form of systemic hypertension, results in decreased flow, decreased cardiac output, and less effective ventricular unloading. Decreased LVAD flow in the setting of high systemic vascular resistance may also increase stasis and contribute to the risk of device thrombosis. Poorly controlled BP in LVAD patients may acutely affect clinical outcomes and worsen heart failure symptoms by reducing LVAD ventricular unloading, inducing sub endocardial ischemia, and precipitating ventricular arrhythmias.

Impact on stroke risk

Stroke is one of the most devastating outcomes related to the treatment of end stage heart failure with long term LVAD support. In the original randomized controlled trial of CF-VADs, the incidence of both hemorrhagic and ischemic stroke was 18% at 2 years (5). Despite advances in LVAD technology, the stroke rate has remained relatively constant. Recent data from the Interagency Registry for Mechanically Assisted Circulatory Support (INTERMACS) found a 17% 2-year incidence of stroke (6).

In the general population, hypertension is the most significant risk factor for stroke. The risk of stroke in patients with hypertension is one and a half times that of patients with BP within normal reference ranges. In fact, patients with severe hypertension, as defined by a systolic BP (SBP) greater than 160 mmHg, have a relative risk of stroke that is nearly four times that of normotensive patients (7). The role of typical cardiovascular disease comorbidities such as hypertension in stroke risk in LVAD populations has not been well established. However, data is emerging that links poorly controlled BP to an increased risk of stroke in LVAD patients.

Nassif and colleagues recently examined BP at the time of LVAD implantation as a novel risk factor for stroke. In a large cohort of 275 CF-VAD patients, elevated SBP on discharge after LVAD implant was independently associated with a greater risk of subsequent stroke (8). It is not clear if the elevated pre-discharge BP reflects the extent of hypertension prior to device implant, or is an indicator of poorly controlled BP during the period of LVAD support. It is possible that both scenarios could be associated with an increased stroke risk. Nevertheless, these results indicate that careful management of hypertension in LVAD patients is a potential modifiable risk factor for reducing the incidence of stroke in patients supported by CF-VAD. Further studies are needed to define the optimal target BP range.

Impact on aortic regurgitation

Aortic regurgitation is a recognized complication of CF-VAD support that can affect survival and quality of life (9). Poorly controlled BP after LVAD implant can worsen preexisting aortic insufficiency or lead to *de novo* aortic insufficiency, particularly in the setting of a closed aortic valve or one that rarely opens. Cowger and colleagues looked at the development of aortic insufficiency following LVAD implant in a 2010 study that included both continuous flow and pulsatile LVADs. They concluded that aortic insufficiency progresses over time in LVAD support patients, and the patients supported with CF-VADs appeared to develop more aortic insufficiency than those with pulsatile LVADs (10). A more recent study identified an association between BP control and the development of aortic regurgitation in patients with CF-VADs. In a cohort of 119 CF-VAD patients, elevated BP as early as 3 months post implant was identified as a predisposing factor for the development of aortic insufficiency (11). Collectively, these data suggest that early and aggressive control of BP can protect against the development or progression of aortic insufficiency following CF-VAD implantation.

Impact on device thrombosis

Pump thrombosis is another major complication of CF-VAD support that is likely related to hypertension. Najjar and colleagues identified an association between pump thrombosis and BP in LVAD patients. They analyzed pump thrombus events in 382 patients who underwent centrifugal CF-VAD implant as a bridge to transplant. A multivariable analysis revealed that a MAP greater than 90 mmHg was a significant risk factor for pump thrombosis (12). Further studies are needed to elucidate the pathophysiology that underlies the association between hypertension and pump thrombosis.

BP goals in CF-VAD patients

In the management of patients with LVADs, various BP target ranges have been proposed. There is recognition that BP control is important and guidelines for BP control in LVADs exist. However, there is a paucity of evidence to support current recommendations. The INTERMACS has defined a hypertension adverse event as new onset SBP >140 mmHg, or diastolic BP >90 mmHg for pulsatile pumps and a mean BP >110 mmHg for continuous flow pumps. As evidence about the adverse effects of hypertension in LVAD patients grows, expert opinion over the years has progressively recommended lower goals for BP. In a 2009 review, Wilson and colleagues suggested a MAP goal of 70-90 mmHg (13). Clinical management guidelines by Slaughter *et al*. in 2010 recommend a goal MAP range of 70-80 mmHg (4). The current ISHLT guidelines advise a target MAP less than 80 mmHg provided that the adverse effects of low BP can be avoided, and acknowledge that there is no strong evidence base for BP targets with CF-VADs. Current guidelines also recommend the titration of standard heart failure pharmacotherapy with beta blocker, ace inhibitor or angiotensin receptor blockers (ARBs) in order to achieve optimal BP control.

Challenges in BP measurement in CF-VAD patients

The measurement of BP and the management of hypertension in patients with CF-VADs can present unique challenges. Patients with CF-VADs often do not have a palpable pulse, and therefore traditional BP measurement by auscultation or automated cuff is less reliable. The arterial line is the gold standard, but is an invasive procedure and not practical for routine outpatient use. Bennett *et al*. measured BP by various methods in CF-VAD patients with arterial lines in the immediate post-operative period. A Doppler probe, compared to automatic cuff, palpation, and auscultation, can detect a pressure in almost all patents that is accurate and correlates with arterial catheter mean BP (14).

Efforts are underway to identify an easier and more reliable method to measure BP. A recent group examined sphygmomanometry combined with finger pulse oximetry as a novel method to non-invasively measure BP in CF-VAD patients. As pulse oximetry is widely available in healthcare settings, this technique may warrant further consideration (15).

In another recent study, a slow cuff deflation device was compared to four other methods of BP measurement including standard automated BP cuff, and Doppler, and arterial line, in a cohort of 60 patients supported with HeartMate II. The slow cuff deflation device was more reliable than the standard automated device and was accurate when compared to arterial line. The device was successful in 88% of BP measurement attempts compared with 71% for the standard automated cuff device. This study also exposed the possible limitations of the Doppler method. In non-pulsatile patients, the Doppler method underestimated SBP by 4 mmHg and overestimated MAP by 9 mmHg. Their data suggest that Doppler more closely reflects the SBP more than the MAP. The limitations of Doppler method were particularly evident with increasing pulse pressure. The authors concluded that the slow cuff deflation device was successful, reliable, and valid when compared to arterial line, and offers a significant advantage over Doppler in that it is inexpensive and can be used in the home setting (16).

Conclusions

The number of people with durable mechanical circulatory support continue to grow. Hypertension is now an established risk factor for adverse outcomes in patients with CF-VADs. Increasingly, evidence suggests that more stringent BP goals may be protective against the device complications of stroke, pump thrombosis, and aortic insufficiency. In the long term management of LVAD patients, MAP should be maintained between 70-80 mmHg, striking a balance between tight BP control and the avoidance of the side effects of low BP. Fortunately, the same pharmacotherapy regimen that can be utilized to lower BP in LVAD patients may have additional benefits in terms of the management of heart failure, and the establishment of favorable environment for potential myocardial recovery. Doppler measurement of BP is currently the standard of care, however this method it is not without its limitations. While it is now generally accepted that Doppler pressure is the most reliable and consistent method to obtain a BP in the setting of continuous flow, there is less consensus on whether the obtained Doppler pressure represents MAP or SBP. In patients with significant pulsatility, the Doppler pressure may more closely measure the SBP. Efforts are underway to develop easier, more accessible noninvasive methods to measure BP in the setting of continuous flow.

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Footnote

Conflicts of Interest: The authors have no conflicts of interest to declare.

References

1. Wasson LT, Yuzefpolskaya M, Wakabayashi M, et al. Hypertension: an unstudied potential risk factor for adverse outcomes during continuous flow ventricular assist device support. Heart Fail Rev 2015;20:317-22.
2. Saeed O, Jermyn R, Kargoli F, et al. Blood pressure and adverse events during continuous flow left ventricular assist device support. Circ Heart Fail 2015;8:551-6.
3. Lampert BC, Eckert C, Weaver S, et al. Blood pressure control in continuous flow left ventricular assist devices: efficacy and impact on adverse events. Ann Thorac Surg 2014;97:139-46.
4. Slaughter MS, Pagani FD, Rogers JG, et al. Clinical management of continuous-flow left ventricular assist devices in advanced heart failure. J Heart Lung Transplant 2010;29:S1-39.
5. Slaughter MS, Rogers JG, Milano CA, et al. Advanced heart failure treated with continuous-flow left ventricular assist device. N Engl J Med 2009;361:2241-51.
6. Kirklin JK, Naftel DC, Pagani FD, et al. Sixth INTERMACS annual report: a 10,000-patient database. J Heart Lung Transplant 2014;33:555-64.
7. Gorelick PB, Sacco RL, Smith DB, et al. Prevention of a first stroke: a review of guidelines and a multidisciplinary consensus statement from the National Stroke Association. JAMA 1999;281:1112-20.
8. Nassif ME, Tibrewala A, Raymer DS, et al. Systolic blood pressure on discharge after left ventricular assist device insertion is associated with subsequent stroke. J Heart Lung Transplant 2015;34:503-8.
9. Jorde UP, Uriel N, Nahumi N, et al. Prevalence, significance, and management of aortic insufficiency in continuous flow left ventricular assist device recipients. Circ Heart Fail 2014;7:310-9.
10. Cowger J, Pagani FD, Haft JW, et al. The development of aortic insufficiency in left ventricular assist device-supported patients. Circ Heart Fail 2010;3:668-74.
11. Patil NP, Mohite PN, Sabashnikov A, et al. Does postoperative blood pressure influence development of aortic regurgitation following continuous-flow left ventricular assist device implantation? Eur J Cardiothorac Surg 2015. [Epub ahead of print].
12. Najjar SS, Slaughter MS, Pagani FD, et al. An analysis of pump thrombus events in patients in the HeartWare ADVANCE bridge to transplant and continued access protocol trial. J Heart Lung Transplant 2014;33:23-34.
13. Wilson SR, Givertz MM, Stewart GC, et al. Ventricular assist devices the challenges of outpatient management. J Am Coll Cardiol 2009;54:1647-59.
14. Bennett MK, Roberts CA, Dordunoo D, et al. Ideal methodology to assess systemic blood pressure in patients with continuous-flow left ventricular assist devices. J Heart Lung Transplant 2010;29:593-4.
15. Woldendorp K, Gupta S, Lai J, et al. A novel method of blood pressure measurement in patients with continuous-flow left ventricular assist devices. J Heart Lung Transplant 2014;33:1183-6.
16. Lanier GM, Orlanes K, Hayashi Y, et al. Validity and reliability of a novel slow cuff-deflation system for noninvasive blood pressure monitoring in patients with continuous-flow left ventricular assist device. Circ Heart Fail 2013;6:1005-12.

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