The Texas Heart Institute® Journal

Perioperative Mechanical Circulatory Support Symposium

Management of Vasoplegic Shock in Left Ventricular Assist Device Insertion Procedures

Subhasis Chatterjee, MD[1,2]

[1]Michael E. DeBakey Department of Surgery, Baylor College of Medicine, Houston, Texas
[2]Department of Cardiovascular Surgery, The Texas Heart Institute, Houston, Texas

Keywords: shock; ventricle assist device; perioperative care; vasopressor agents

Introduction

Vasoplegic shock (VS) after left ventricular assist device (LVAD) implantation is characterized by high cardiac output; low systemic vascular resistance; and refractory hypotension, with the need for higher-dose vasopressors. There is considerable heterogeneity in how VS is defined; as a result, its incidence can vary widely in published series and ranges from 10% to 45% after LVAD implantation.[1-4]

Current Limitations

Much of what the medical community understands about the pathophysiology of VS is derived from its understanding of distributive shock in sepsis and after cardiopulmonary bypass. The body's normally adaptive response to preserve normotension by constricting blood vessels is dysregulated, which results in a maladaptive loss of vasomotor tone in resistance vessels and VS. Adverse outcomes (acute kidney injury) and mortality (5%-40%) are increased in VS after LVAD implantation.[1,3,4] Prevention, early recognition, and a systematic approach to VS management may help mitigate its deleterious consequences. Longer duration of VS after LVAD implantation is associated with worse outcomes; therefore, early intervention may provide a therapeutic window of opportunity to improve outcomes.[2]

Patients at higher risk of developing VS include those with chronic kidney disease, previous cardiac surgery, and a higher acuity of presentation as well as those undergoing longer operations with prolonged cardiopulmonary bypass times and the need for multiple transfusions.[1,4,5] Although there is some controversy regarding the role of angiotensin-converting enzyme inhibitors and angiotensin II receptor blockers, general practice has been to discontinue those and other antihypertensive agents or goal-directed heart failure medical therapy before surgery.

During surgery, efforts to reduce cardiopulmonary bypass time and minimize transfusions are worthwhile. Common agents in the early perioperative period (milrinone and propofol) may exacerbate VS, and alternatives should be considered. It is also important to recognize that shock in LVAD recipients may be explained by hypovolemia, hemorrhage, right ventricular dysfunction, low cardiac output from inadequate pump speed, cardiac tamponade, or vasoplegia. These processes are dynamic and not mutually exclusive. As a result, astute clinicians should constantly reassesses patients with hypotension with these potential conditions in mind, using a combination of invasive hemodynamic, echocardiographic, laboratory, and bedside clinical evaluation tools.[6,7]

Citation: Chatterjee S. Management of vasoplegic shock in left ventricular assist device insertion procedures. *Tex Heart Inst J*. 2023;50(4):e238172. doi:10.14503/THIJ-23-8172
Corresponding author: Subhasis Chatterjee, MD, Department of Surgery, Baylor College of Medicine, One Baylor Plaza, MS: BCM 390, Houston, TX 77030-3411 (subhasis.chatterjee@bcm.edu)

Recent Developments

The need for vasopressors to sustain an acceptable mean arterial pressure and the role of pharmacologic adjuncts in mitigating the inflammatory processes inciting VS are apparent. The rationale behind using multiple vasopressors is that the physiologic response to maintaining blood pressure is conceptually a 3-legged stool[8] that consists of the sympathetic (norepinephrine), the vasopressin, and the renin-angiotensin (angiotensin II) systems. The combination of norepinephrine and vasopressin is associated with improved mortality and less atrial fibrillation compared with norepinephrine monotherapy.[9] Vasopressin also has minimal effect on pulmonary vascular resistance, whereas norepinephrine is associated with a small increase; in patients with severe right ventricular dysfunction, vasopressin may be a better choice. Meanwhile, it has been demonstrated that angiotensin II can help patients achieve a higher mean arterial pressure with less use of concurrent vasopressors.[10] It is important to recognize that some patients do not respond to vasopressin or angiotensin II; consequently, the need to use alternative agents and strategies is critical. As a result, our current approach to vasopressor use consists of norepinephrine followed by vasopressin, then angiotensin II.[11]

In cases of refractory VS, patient-specific adjuncts, such as methylene blue and hydroxocobalamin, are used because of their effects on nitric oxide metabolism; corticosteroids, thiamine, and vitamin C are used as anti-inflammatory interventions. A list of adjunctive approaches is given in Table I. The use of these agents should be individualized based on patient-specific needs and institutional experience.

Abbreviations and Acronyms

LVAD	left ventricular assist device
VS	vasoplegic shock

Future Directions

Conceptually, there is increasing recognition that the current model's focus on a stepwise escalation from each of these 3 vasopressors may need to be modified to an approach more similar to the current approach to sepsis—namely, initiate treatment with all 3 vasopressors simultaneously at a certain trigger point, wait for a satisfactory blood pressure, and then deescalate based on clinical response. Upcoming clinical trials will aim to explore this and other options to help guide clinicians in caring for these high-risk patients. Increasingly personalized approaches, such as administering angiotensin II to patients with high plasma renin, who respond more favorably to this treatment than those with low plasma renin, may be used in the future.[12] The development of point-of-care plasma renin assays may offer clinicians the ability to rapidly determine better and more appropriate therapies for patients.

Vasoplegic shock after LVAD implantation is a common perioperative problem. A systematic approach to management offers an opportunity to reduce adverse outcomes.

TABLE I. Adjunctive Strategies Used in the Treatment of Vasoplegic Shock

Drug	Mechanism and benefits	Typical dosage	Adverse effects and limitations
Methylene blue	Inhibits guanylyl cyclase and nitric oxide synthase, suppresses nitric oxide–mediated vasodilation	1-2 mg/kg bolus, 1-2 mg/kg/h continuous infusion	Serotonin syndrome, methemoglobinemia, interference with oximetry measurements; avoid in patients with glucose-6-phosphate dehydrogenase deficiency
Hydroxocobalamin	Direct nitric oxide scavenger, binds hydrogen sulfide, suppresses nitric oxide–mediated vasodilation	5 g IV bolus over 15 min or 6 h	Chromaturia, intermittent dialysis false-blood leak alarm, interference with colorimetric assays
Thiamine	Cofactor for pyruvate dehydrogenase to produce acetyl-CoA, facilitates lactate clearance	200 mg IV every 12 h	Flushing, nausea, restlessness
Ascorbic acid	Cofactor for catecholamine synthesis, improves microcirculation	1500 mg IV every 6 h	Oxalate nephropathy; avoid in patients with glucose-6-phosphate dehydrogenase deficiency

IV, intravenous.

Published: 11 August 2023

Author Contributions: Subhasis Chatterjee is responsible for the entire manuscript.

Conflict of Interest Disclosure: Subhasis Chatterjee has served on advisory boards for Edwards Lifesciences, La Jolla Pharmaceutical Company, Eagle Pharmaceuticals, and Baxter Pharmaceuticals.

Funding/Support: None.

Section Editors: José L. Diaz-Gómez, MD, MAS; James M. Anton, MD.

Meeting Presentation: Presented at: the 1st Annual Perioperative Mechanical Circulatory Support Symposium & Cutting-Edge Critical Care Echo Workshop; February 24-25, 2023; Houston, Texas.

References

1. de Waal EEC, van Zaane B, van der Schoot MM, et al. Vasoplegia after implantation of a continuous flow left ventricular assist device: incidence, outcomes and predictors. *BMC Anesthesiol.* 2018;18(1):185. doi:10.1186/s12871-018-0645-y
2. Kim M, Lamba H, Miller R, et al. Predictors and impact of vasoplegia after continuous-flow left ventricular assist device implantation. *J Heart Lung Transplant.* 2019;38(4 suppl):S126-S127. doi:10.1016/j.healun.2019.01.297
3. Swan JT, Iso T, Rizk E, et al. Defining vasoplegia following durable, continuous flow left ventricular assist device implantation. *ASAIO J.* 2022;68(1):46-55. doi:10.1097/MAT.0000000000001419
4. Tecson KM, Lima B, Lee AY, et al. Determinants and outcomes of vasoplegia following left ventricular assist device implantation. *J Am Heart Assoc.* 2018;7(11):e008377. doi:10.1161/JAHA.117.008377
5. Dayan V, Cal R, Giangrossi F. Risk factors for vasoplegia after cardiac surgery: a meta-analysis. *Interact Cardiovasc Thorac Surg.* 2019;28(6):838-844. doi:10.1093/icvts/ivy352
6. Pek JH, Teo LYL. Point-of-care ultrasound in the evaluation of patients with left ventricular assist devices at the emergency department. *J Emerg Med.* 2022;62(3):348-355. doi:10.1016/j.jemermed.2021.10.018
7. Ltaief Z, Ben-Hamouda N, Rancati V, et al. Vasoplegic syndrome after cardiopulmonary bypass in cardiovascular surgery: pathophysiology and management in critical care. *J Clin Med.* 2022;11(21):6407. doi:10.3390/jcm11216407
8. Busse LW, Barker N, Petersen C. Vasoplegic syndrome following cardiothoracic surgery—review of pathophysiology and update of treatment options. *Crit Care.* 2020;24(1):36. doi:10.1186/s13054-020-2743-8
9. McIntyre WF, Um KJ, Alhazzani W, et al. Association of vasopressin plus catecholamine vasopressors vs catecholamines alone with atrial fibrillation in patients with distributive shock: a systematic review and meta-analysis. *JAMA.* 2018;319(18):1889-1900. doi:10.1001/jama.2018.4528
10. Klijian A, Khanna AK, Reddy VS, et al. Treatment with angiotensin II Is associated with rapid blood pressure response and vasopressor sparing in patients with vasoplegia after cardiac surgery: a post-hoc analysis of Angiotensin II for the Treatment of High-Output Shock (ATHOS-3) Study. *J Cardiothorac Vasc Anesth.* 2021;35(1):51-58. doi:10.1053/j.jvca.2020.08.001
11. Chatterjee S. Profound vasoplegia after coronary artery bypass grafting. *JoSH.* 2022;1(2):1-4. doi:10.57905/josh/e2022129
12. Bellomo R, Forni LG, Busse LW, et al. Renin and survival in patients given angiotensin II for catecholamine-resistant vasodilatory shock: a clinical trial. *Am J Respir Crit Care Med.* 2020;202(9):1253-1261. doi:10.1164/rccm.201911-2172OC