Interprovincial spoke-to-hub transport using the Impella Recover LP 5.0 left ventricular assist device as a bridge to long-term circulatory support

Mina Guirgis BSc¹, Kanwal Kumar BSc BScMed MD^{1,2}, Shelley Zieroth MD FRCPC³, Roger Philipp MD FRCPC³, Alan H Menkis MD FRCSC², Darren H Freed MD PhD FRCSC^{1,2}

M Guirgis, K Kumar, S Zieroth, R Philipp, AH Menkis, DH Freed. Interprovincial spoke-to-hub transport using the Impella Recover LP 5.0 left ventricular assist device as a bridge to long-term circulatory support. *Can J Cardiol* 2010;26(8):e320-e322.

Current hospital administrative practices categorize health care centres in a network of 'spokes' (primary care centres) and 'hubs' (tertiary care centres). For the treatment of cardiogenic shock, long-term left ventricular assist devices (LVADs) and transplant therapies are only used at a few hub centres nationwide and are, thus, only available to patients living in close proximity to these centres. The relatively lower technical requirements of the Impella Recover LP 5.0 LVAD (ABIOMED Inc, USA) translate into greater use by spoke centres for the short-term treatment of cardiogenic shock, and facilitate appropriate stabilization and subsequent transportation to a suitable hub centre. Based on a review of the literature, the present report describes the first case demonstrating successful use of the Impella Recover LP 5.0 LVAD, implanted under local anesthetic, for the purposes of interprovincial spoke-to-hub transport in a bridge-to-bridge-to-transplant procedure. By providing an economical and technically straightforward alternative to traditional extracorporeal membrane oxygenation, the present case demonstrates that less invasive LVADs are valuable to the spoke-and-hub model for delivery of specialized cardiac care.

Key Words: *Cardiogenic shock; Impella Recover; Interprovincial spoke-to-hub transport; Ventricular assist device*

Current hospital administrative practices categorize health care centres in a network of spokes and hubs (1). The 'spokes' are primary care centres that offer immediate yet temporary life-sustaining therapies, and channel the most severe cases to centres or 'hubs' that can provide the long-term treatment not available at the spoke sites. In the setting of mechanical circulatory support, long-term left ventricular assist devices (LVADs) and transplant therapies are only used at a few hub centres. The relatively lower technical requirements of the Impella Recover LP 5.0 LVAD (ABIOMED Inc, USA) translate into greater utilization by spoke centres for the treatment of cardiogenic shock (2,3). Based on a literature review, we report the first case demonstrating successful use of the Impella Recover LP 5.0 LVAD, implanted under local anesthetic, for the purpose of interprovincial spoke-to-hub transport in a bridge-to-bridge-to-transplant procedure.

CASE PRESENTATION

Mr S is a 54-year-old man with a greater than 10-year history of nonischemic dilated cardiomyopathy and symptomatic congestive heart failure managed medically. Following a sudden onset of angina, he presented to his local rural hospital and was diagnosed with an anterior ST elevation myocardial infarction complicated by

Le transport interprovincial d'un centre de soins primaires à un centre de soins tertiaires grâce au dispositif d'assistance ventriculaire gauche de marque Impella Recover LP 5.0, en attendant un soutien ventilatoire à long terme

D'après les pratiques d'administration hospitalière actuelles, les centres de santé sont classés en un réseau de centres de soins primaires (CSP) et de centres de soins tertiaires (CST). Pour traiter un choc cardiogène, seuls quelques CST utilisent les dispositifs d'assistance ventriculaire gauche (DAVG) à long terme et les transplantations. Les exigences techniques relativement moins importantes du DAVG de marque Impella Recover LP 5.0 (ABIOMED Inc., É.-U.) en favorisent une utilisation plus généralisée dans les CST pour le traitement à court terme du choc cardiogène et facilitent la stabilisation pertinente du patient ainsi que son transport subséquent vers un CST adapté. D'après une analyse bibliographique, le présent rapport décrit le premier cas démontrant l'utilisation réussie d'un DAVG de marque Impella Recover LP 5.0 implanté sous anesthésie locale en vue du transport interprovincial d'un CSP à un CST dans le cadre de deux interventions provisoires en attendant une transplantation. Grâce à une solution économique et techniquement simple pour remplacer l'oxygénation extracorporelle classique, le présent cas démontre que les DAVG moins effrayants sont précieux dans le cadre du modèle de dispensation de soins cardiaques spécialisés de CSP à CST.

high-grade atrioventricular block. Following stabilization with dopamine (5 µg/kg/min to 15 µg/kg/min) and insertion of a transvenous pacing wire, the patient was transferred to a tertiary care centre with cardiac surgery onsite, approximately 2 h away. On arrival, the patient had a blood pressure of 86/69 mmHg, a heart rate of approximately 70 beats/min (paced), a respiratory rate of 18 breaths/min and a hemoglobin saturation of 95% on 5 L supplemental oxygen. He had an increased jugular venous pressure of approximately 5 cm to 6 cm, with cool and clammy extremities. The electrocardiogram demonstrated third-degree atrioventricular block with increasing frequency of nonsustained ventricular tachycardia. He underwent emergent percutaneous coronary catheterization and thrombectomy of his proximal left anterior descending artery, with the remaining coronary arteries essentially unremarkable. The culprit lesion was not stented due to the patient's severe acetylsalicylic acid allergy and the potential need for heart transplantation. Despite restoration of Thrombolysis in Myocardial Infarction 3 flow following the procedure, the patient required increasing circulatory support, at which time an intra-aortic balloon pump (IABP) was inserted. The documented left ventricular end-diastolic pressure at this time was 39 mmHg. In the hours following, despite the use of inotropic

¹Institute of Cardiovascular Sciences, St Boniface Hospital Research Centre; ²Department of Surgery, Section of Cardiac Surgery; ³Department of Internal Medicine, Section of Cardiology, University of Manitoba, St Boniface General Hospital Cardiac Sciences Program, Winnipeg, Manitoba

Correspondence: Dr Darren H Freed, Surgical Heart Failure Program, Cardiac Sciences Program, St Boniface General Hospital, CR3030 Asper Clinical Research Building, 369 Tache Avenue, Winnipeg, Manitoba R2H 2A6. Telephone 204-258-1031, fax 204-231-4624, e-mail dfreed@sbg.h.mb.ca

Received for publication October 5, 2009. Accepted March 9, 2010

Figure 1 A Long-axis transthoracic echocardiographic view following the insertion of the Impella Recover LP 5.0 (ABIOMED Inc, USA) device approximately 75 mm below the aortic valve into the left ventricular (LV) cavity. B Anteroposterior chest x-ray postimplantation demonstrating both the Impella device (red) and the transvenous pacing wire (blue) within the LV and right ventricular (RV) cavities, respectively. Ao Aorta; LA Left atrium

agents and an IABP in place, the patient continued to experience signs and symptoms of cardiogenic shock (pulmonary capillary wedge pressure 35 mmHg) with end organ failure (mixed venous hemoglobin saturation at approximately 60% with a 24 h urine output of approximately 100 mL). An echocardiogram demonstrated cardiomegaly (left ventricular end-diastolic diameter of 8.0 cm) with a left ventricular ejection fraction of less than 10%.

In addition to a transplant workup being initiated, given the low likelihood of recovery and the inability to use long-term mechanical circulatory support at the tertiary care centre, it was decided to insert an Impella Recover LP 5.0 LVAD to facilitate safe long-distance air transport on high-level support to a hub centre. The patient underwent implantation of the Impella Recover LP 5.0 LVAD using fluoroscopic guidance and transthoracic echocardiography. At the time of insertion, the patient had pulmonary artery pressures of approximately 55/25 mmHg. After consultation with the cardiologist and the cardiac anesthetist, the procedure was performed under conscious sedation and local anesthetic. Because the patient's respiratory condition continued to remain stable with routine diuretic and heart failure therapies, there were no immediate indications for mechanical respiratory support. The patient had a right femoral cut-down via the pre-existing IABP site. Following the removal of the balloon pump, the Impella Recover LP 5.0 LVAD was inserted over a wire exchange (Figure 1). The procedure was otherwise uncomplicated, with an estimated blood loss of approximately 250 mL. The device gave the patient an additional 4.3 L/min of flow and, with infusions of inotropes, stabilized his hemodynamics sufficiently to enable safe long-distance transfer to the hub centre.

The following day, a team consisting of a cardiac specialist, a perfusionist and a senior intensive care nurse accompanied the patient during air transport from Winnipeg (Manitoba) to Ottawa (Ontario), where he was further assessed for cardiac transplantation. Two days later, due to the anticipated prolonged wait for a suitable blood type O donor heart, the patient underwent successful implantation of a HeartMate II (HM-II; Thoratec Corporation, USA) ventricular assist device. Following transport back to the spoke centre, the patient's condition on the HM-II continued to improve. Approximately three months after his HM-II implantation, the patient underwent successful cardiac transplantation at the original hub centre. The patient was successfully discharged from the spoke centre approximately 21 weeks following his initial presentation, and continues to do well on follow-up visits.

DISCUSSION

Conventional treatment options for refractory cardiogenic shock focus primarily on medical management, with the more severe cases requiring implantation of ventricular assist devices and/or cardiac transplantation. Due to resource allocation, these specialized interventions have traditionally been offered exclusively at hub centres, limiting the scope of care that can be delivered at peripheral spoke institutions. The use of devices such as the Impella Recover LP 5.0 LVAD, known to significantly reduce morbidity and mortality, is a viable option for spoke centres with limited cardiac resources (4). The present case is notable because it demonstrates the successful organizational framework of the hub-and-spoke model, the first use of the Impella Recover LP 5.0 LVAD for the purposes of interprovincial air transport, and the first implantation of the device under conscious sedation and local anesthetic.

Originally developed by the airline industry, the hub-and-spoke system has been adopted by the health care field as a means to deliver specialized care in an efficient manner (5). Due to the limited availability of donor hearts and the significant resources required for an effective transplant program, the spoke-and-hub framework for delivery of higher acuity cardiac care is ideal for the Canadian public health care system. Nonetheless, for this arrangement to succeed, patients presenting to spoke centres need to be appropriately stabilized and subsequently transported to the hub facility in a timely fashion. Furthermore, to ensure reasonable throughput at the hub centre, spoke facilities must be able to repatriate patients and deliver the necessary long-term care. From onset to resolution, the patient's treatment required travel back and forth between at least three different hospital sites, demonstrating the multilevel approach required for acute heart failure. This collaboration is vital because every medical centre cannot offer the same degree of heart failure treatment that was required in the present case. Due to our tertiary institution's central location, we have the ability to function both as a hub centre for smaller community hospitals without advanced cardiac care, and as a spoke facility to transfer patients to any one of the several national hub centres offering definitive heart failure therapy.

While the Impella Recover LP 5.0 LVAD has been used as a bridging measure in the past, we report the first successful use of the percutaneous device for the purposes of interprovincial spoke-to-hub transport (2,3). With the ability to offer up to 5 L of cardiac support, the device is able to provide superior and longer duration of hemodynamic stability compared with standard IABP therapy (6). Furthermore,

the device requires relatively less resources and experience than traditional extracorporeal membrane oxygenation (ECMO) and implantable LVADs, thereby simplifying the management and troubleshooting by spoke centres. Additionally, complications associated with peripheral ECMO and implantable LVADs, such as left-heart distention, lower limb ischemia, hemolysis, bleeding and strokes, are reduced or avoided (7-9). In addition, transport with the device (particularly air transport) is more comparable with a streamlined IABP transfer than with an involved ECMO or LVAD transfer in terms of equipment, electrical requirements and personnel required. Finally, although more expensive up-front than ECMO, ease of implantation, use and transport makes this device a viable alternative to implantable LVADs.

As with all mechanical circulatory support devices, the Impella Recover is not without limitations and potential complications. Theoretically, although the Impella Recover LP 5.0 is able to deliver 5 L of cardiac support, a patient entirely dependent on this level of support with little to no reserve may not be an ideal candidate for such a device. Complications associated with the device remain uncommon and variable depending on the reported series. A recent randomized comparison between the standard IABP (n=13) and the Impella device (n=13) found no device-related technical failures, major bleeding or ischemia. The Impella device was associated with a higher level of hemolysis and one case of lower-limb ischemia following explantation (6). Other documented complications include sensor failure, functional mitral stenosis and displacement/repositioning (10-12).

The potential need to reposition the device during air transport remains a concern, which may limit its use. On the whole, repositioning remains poorly examined. Siegenthaler et al (11), reviewing their experience with the Impella device, found that four of 24 patients (approximately 17%) required device repositioning. It is unknown from the published report whether this was echocardiographically guided. As mentioned previously, transport with the device is more comparable with an IABP transfer than an ECMO transfer, which can be fraught with potential in-flight complications (13,14). Air transport of patients with an IABP in place has been successfully performed for the past 20 years (15). Similar preflight precautions with the Impella device need to be adhered to. Confirmation of placement, proper securing of the device to the patient, and a standardized preflight transfer protocol remain fundamental. Additionally, if the patient's neurological and

respiratory status are equivocal, sedation with or without securing the airway may be required to prevent in-flight problems that may lead to displacement of the device. Our patient was alert and responsive with a stable respiratory status, thereby eliminating the need for mechanical ventilation. Patients who are highly dependent on the device may not be ideal candidates for air transport. Our patient's cardiac status on the device was relatively stable before transport. As with ECMO transfers, a physician thoroughly experienced with the device and potential complications should accompany the patient to the destination centre. Unlike air transport with an IABP, pressure changes during flight are less of a concern. Finally, the destination site should follow a similar protocol before and after receiving a patient with an Impella device in place. Any change in the patient's hemodynamics or requirement for inotropic/pressor support should alert the attending physician that there may be an issue, and displacement could be the cause. Following a review algorithm, if displacement is suspected, it should be communicated to the referral and destination sites, with the implementation of a predetermined alternative plan. For the most part, appropriate patient selection, strict preventive measures and appropriate preflight planning should avoid most cases of displacement during the usual 3 h to 4 h site-to-site transfer.

CONCLUSION

With the increasing use of percutaneous LVADs such as the Impella Recover, spoke centres now have a greater ability to care for patients in cardiogenic shock who would otherwise not benefit from conventional paracorporeal pulsatile ventricular assist devices (2). We report the first successful use of the Impella Recover LP 5.0 LVAD for the purpose of interprovincial spoke-to-hub transport in a bridge-to-bridge-to-transplant procedure. Implanted under local anesthetic, the Impella LVAD facilitated appropriate stabilization and subsequent air transportation of a patient in refractory cardiogenic shock. By providing an economical and technically straightforward alternative to traditional ECMO, our case demonstrates that percutaneous LVADs are valuable to the spoke-and-hub model for delivery of specialized cardiac care, thereby delivering definitive care sooner, and reducing overall morbidity and mortality (4).

DISCLOSURES: The authors have no pertinent disclosures.

REFERENCES

1. Kherani AR, Cheema FH, Oz MC, et al. Implantation of a left ventricular assist device and the hub-and-spoke system in treating acute cardiogenic shock: Who survives? *J Thorac Cardiovasc Surg* 2003;126:1634-5.
2. Samoukovic G, Rosu C, Giannetti N, Cecere R. The Impella LP 5.0 as a bridge to long-term circulatory support. *Interact Cardiovasc Thorac Surg* 2009;8:682-3.
3. LaRocca GM, Shimbo D, Rodriguez CJ, et al. The Impella Recover LP 5.0 left ventricular assist device: A bridge to coronary artery bypass grafting and cardiac transplantation. *J Am Soc Echocardiogr* 2006;19:468e5-7.
4. Granfeldt H, Hellgren L, Dellgren G, et al. Experience with the Impella recovery axial-flow system for acute heart failure at three cardiothoracic centers in Sweden. *Scand Cardiovasc J* 2009;43:233-9.
5. Safford SD, Hayward TZ, Safford KM, Georgiade GS, Rice HE, Skinner MA. A cost and outcomes comparison of a novel integrated pediatric air and ground transportation system. *J Am Coll Surg* 2002;195:790-5.
6. Seyfarth M, Sibbing D, Bauer I, et al. A randomized clinical trial to evaluate the safety and efficacy of a percutaneous left ventricular assist device versus intra-aortic balloon pumping for treatment of cardiogenic shock caused by myocardial infarction. *J Am Coll Cardiol* 2008;52:1584-8.
7. Aiyagari RM, Rocchini AP, Remenapp RT, Graziano JN. Decompression of the left atrium during extracorporeal membrane oxygenation using a transeptal cannula incorporated into the circuit. *Crit Care Med* 2006;34:2603-6.
8. Vanzetto G, Akret C, Bach V, et al. [Percutaneous extracorporeal life support in acute severe hemodynamic collapses: Single centre experience in 100 consecutive patients.] *Can J Cardiol* 2009;25:e179-86.
9. John R, Kamdar F, Liao K, Colvin-Adams M, Boyle A, Joyce L. Improved survival and decreasing incidence of adverse events with the HeartMate II left ventricular assist device as bridge-to-transplant therapy. *Ann Thorac Surg* 2008;86:1227-34; discussion 34-5.
10. Burzotta F, Paloscia L, Trani C, et al. Feasibility and long-term safety of elective Impella-assisted high-risk percutaneous coronary intervention: A pilot two-centre study. *J Cardiovasc Med (Hagerstown)* 2008;9:1004-10.
11. Siegenthaler MP, Brehm K, Strecker T, et al. The Impella Recover microaxial left ventricular assist device reduces mortality for postcardiotomy failure: A three-center experience. *J Thorac Cardiovasc Surg* 2004;127:812-22.
12. Toggweiler S, Jamshidi P, Erne P. Functional mitral stenosis: A rare complication of the Impella assist device. *Eur J Echocardiogr* 2008;9:412-3.
13. Foley DS, Pranikoff T, Younger JG, et al. A review of 100 patients transported on extracorporeal life support. *ASAIO J* 2002;48:612-9.
14. Coppola CP, Tyree M, Larry K, DiGeronimo R. A 22-year experience in global transport extracorporeal membrane oxygenation. *J Pediatr Surg* 2008;43:46-52.
15. Mertlich G, Quaal SJ. Air transport of the patient requiring intra-aortic balloon pumping. *Crit Care Nurs Clin North Am* 1989;1:443-58.