Case Series

VADoscopy: A Novel Intraoperative Technique to Evaluate HeartMate II Left Ventricular Assist Device Inflow Obstruction and Thrombosis

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With HeartMate II (HMII) implants increasing so has the frequency of device exchange. However, identifying inflow cannula obstruction, pump thrombosis, or outflow obstruction as the mechanism of pump dysfunction can be difficult. Echocardiography, CT angiogram, and cardiac catheterization are not definitive in determining the location of pump failure. Therefore, intraoperative examination is often necessary to confirm a diagnosis, requiring extensive dissection to visualize the entire system. We hypothesized a novel intraoperative technique, VADoscopy, to evaluate the inflow cannula for thrombus or pannus formation, and can help guide decision on which portion(s) of the HMII require replacement. Visualization of the inflow cannula can determine if either the pump itself or the pump along with the inflow cannula requires replacement, potentially limiting unnecessary dissection around the left ventricular apex and inflow cannula. A subxiphoid or subcostal incision exposes the pump. Patients are placed on cardiopulmonary bypass using the femoral vein and artery, after the outflow cannula is clamped. Once the pump is removed from the pocket, a 22 French 80 cm (Edwards Life Science, Irvine, CA) Fogarty balloon is advanced through the inflow cannula into the left ventricle and inflated to limit blood flow from the heart. A 5 French 30 cm flexible endoscope (Karl Starz Flex-X, Germany) is then placed into the inflow cannula and left ventricle to evaluate for the presence of thrombus, pannus, or debris. Six patients had HMII exchange with VADoscopy. In all patients, VADoscopy demonstrated no inflow cannula pannus or thrombus as the cause of pump dysfunction. Postoperatively there were no embolic events or evidence of reoccurring pump dysfunction suggesting an inflow cannula obstruction was not missed. VADoscopy is a novel and effective operative diagnostic modality to evaluate the inflow cannula within the HMII left ventricular assist device, limiting the amount of dissection, and potentially reducing the morbidity associated with HMII pump exchange. ASAIO Journal 2013; 59:671–674.

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Device-related thrombus generation and thromboembolic events remain one of the main complications with the use of left ventricular assist devices (LVADs). Traditionally, echocardiography, CT angiogram, cardiac catheterization, heart failure symptoms, and hemolysis laboratory results have been used to assist in the evaluation of a thrombus laden pump. However, intraoperative examination and LVAD exchange are often necessary for making the definite diagnosis and determining the location of the thrombus. In particular, the HeartMate II (HMII) inflow cannula with its metallic characteristic, none of the preoperative imaging modalities are definitive in determining the existence of thrombus or obstruction within the inflow bend relief and conduit. However, dissecting the HMII inflow cannula during pump exchange can be challenging, particularly after extensive scarring from the previous operation, and in the presence of a dilated right ventricle. Furthermore, dissection of the left ventricular apex and inflow conduit to conclusively eliminate the presence of inflow obstruction can potentially increase the morbidity of the procedure. New nonsternotomy surgical approaches, for example, subcostal and subxiphoid incision, demonstrate good results to avoid redo-median sternotomy. Intraoperatively, via these incisions, the HMII pump can be examined for thrombus by detaching it from the inflow and outflow conduits. However, in order to examine the inflow conduit, extensive dissection is needed around the left ventricular apex and inflow graft. In this report, we describe our experiences with a new intraoperative technique: VADoscopy, to evaluate the HMII inflow cannula for thrombus and/or pannus formation, graft kinking or obstruction and to avoid unnecessary dissection of the left ventricular apex or unwanted injury.

Operative Technique

The patient is taken to the operating room and placed in the supine position. After adequate induction of general endotracheal anesthesia, the chest, abdomen, and lower extremities are prepped and draped in the usual sterile manner. The groin is incised, and the common femoral artery and vein are dissected. A subcostal or extended subxiphoid incision exposes the HMII

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in the preperitoneal space. The dissection can be facilitated with a Rultract retractor (Rultract Inc., Cleveland, OH) if necessary to expose the pump to the inflow conduit and bend relief. The outflow cannula is dissected free so that it can be clamped. The patient is then systemically heparinized, and cardiopulmonary bypass is initiated after discontinuing ventricular assist device support and clamping the outflow conduit. The HMII pump is then detached from the inflow and outflow conduits by disconnecting the screw ring connectors on both sides of the pump housing (Figure 1). The HMII driveline is divided. The pump is then explanted and examined for thrombus and defect as shown in Figure 2. The outflow conduit is then examined for thrombus and obstruction. Back bleeding of the outflow graft upon unclamping for a brief period determines whether the outflow conduit is obstructed with thrombus.

To begin evaluating the inflow conduit, a 20 French Fogarty catheter is inserted into the left ventricle via the inflow bend relief, and the balloon is inflated to prevent the backflow of blood. A 5 French 30cm flexible ureteroscope (Karl Storz Flex-X, Germany), with continuous irrigation, is passed into the left ventricle via the inflow bend relief while imaging the inflow cannula and graft for any thrombosis, pannus, kinking, or obstruction (Figure 3). If the inflow conduit appears to be widely patent, a new HMII pump is prepared in the usual manner on the back table and no further dissection is needed. The pump is then connected to the previous inflow conduit, and

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**Figure 1.** Picture of the Heartmate II pump, which during exchange, the inflow and outflow conduits are detached by disconnecting the screw ring connectors on both sides of the pump housing.

**Figure 2.** Thrombus formation within the bend relief (A) and the HeartMate II pump (B).

**Figure 3.** A: Intraoperative photo demonstrating the utilization of an ureteroscope (Karl Storz Flex-X, Germany) and Fogarty catheter in examination of the HeartMate II inflow conduit via a subcostal incision. B: Ureteroscopy images revealed no thrombus, graft kinking or obstruction in the HeartMate II inflow conduit.
the driveline is externalized through the right upper abdominal quadrant. Multiple deairing maneuvers are performed including sumping off the HMII pump and creating 22 gauge needle holes in the outflow graft. The clamp on the outflow graft is removed, cardiopulmonary bypass is weaned, and the HMII pump is started to achieve optimal hemodynamics. Transesophageal echocardiography is used to examine the left ventricular dimension, septum position, LVAD flow, and aortic and mitral valve opening and closing.

Results

This technique was utilized in six patients. The presentation for all patients included red heart alarming of the HMII VAD in addition to clinical symptoms of hemolysis and heart failure. In all patients, VADoscopy demonstrated no inflow cannula pannus or thrombosis as the cause of pump dysfunction, and the HMII pump was easily replaced without further dissection around the left ventricular apex and inflow cannulae. Postoperatively there were no patients who developed emboli or redeveloped pump dysfunction suggesting an inflow cannulae obstruction was missed. No patient required take back for bleeding, and none develops wound infection or complication postoperatively.

Discussion

Previous clinical studies on the HMII LVAD have shown a significant improved quality of life and functional capacity in a broader heart failure patient population. The use of HMII has become routine practice at many centers across the country. Despite its improved design, device-related thrombus generation and thromboembolic events remain one of the main complications that require device replacement. Thromboembolic events can occur in 2% to 3% of patients receiving the HMII LVAD.1–3 With the continuous flow design of HMII, patients might be predisposed pump thrombosis, and hence anticoagulation with warfarin is currently recommended.1

Identifying inflow thrombosis and obstruction can be difficult, and unfortunately, preoperative echocardiography, CT angiogram, and cardiac catheterization are not definitive and can only potentially examine the outflow graft and left ventricle for thrombus formation \(\text{Figure 4}\). Therefore, intraoperative examination is often necessary to confirm a diagnosis requiring extensive dissection to properly visualize the inflow cannulae. With extensive scarring from the previous operations, and in many patients a dilated right ventricle, this dissection can be challenging and risky.

Unfortunately, our technique described here was developed after one of our previous experience in replacing a thrombosed HMII pump and missed an inflow cannula kinking/obstruction \(\text{Figure 5}\). Therefore, we developed this new intraoperative technique to evaluate for HMII inflow obstruction during

\[\text{Figure 4. CT angiogram (CTA) of a patient with HeartMate II showing the areas that can and cannot be (dashed-line box) imaged with preoperative echocardiogram (ECHO), CT angiogram and cardiac catheterization (LV gram).} \]

\[\text{Figure 5. Autopsy photo of an obstructed HeartMate II inflow cannula.} \]
pump exchange for thrombosis and kinking via an endoscopic approach, that is, VADoscopy, in order to accurately image the inflow cannula and to avoid unnecessary dissection around the left ventricular apex and inflow conduit and to limit any unwanted injuries, bleeding, and the extent of operation.

At our center, we have utilized VADoscopy in six patients. With the use of the Fogarty catheter to prevent backflow of blood (especially in patients with aortic insufficiency), a flexible ureteroscope with continuous irrigation, clear images (Figure 3B) have been obtained for the evaluation of the inflow conduit. New surgical approaches, for example, subcostal incision,4,5 have developed with great results to avoid redo-median sternotomy. We used the subcostal incision in our early experiences. However, recently we have utilized the subxipoid incision. The extended subxipoid incision can provide good exposure of the HMII pump, the proximal outflow graft and the inflow bend relief. It also allows extension of the incision, if a sternotomy is needed. If dissection of the left ventricular apex is needed, a subcostal incision can be used in addition. VADoscopy has helped minimize the incision and to avoid unnecessary dissection around the left ventricular apex and inflow conduit if no pathology is found. Postoperatively no patients developed emboli, or redeveloped pump dysfunction suggesting that an inflow cannulae obstruction was missed. Furthermore, with VADoscopy, none of the patients require take back for bleeding, and none of them re-present with infection possibly secondary to shorter operating time and less transfusion requirement.

Conclusion

Despite device improvements and progressively newer generations of VADs, with the increase in HMII implants, the need for LVAD exchange because of device failure or thrombosis is, and will be, a practicality. This report provides an example of a simple technique to evaluate the inflow cannulae and left ventricle during device exchange for pump thrombosis or obstruction, avoiding unnecessary and risky dissection around the dilated right ventricular and scarred left ventricular apex. Future studies are still needed to ensure the sensitivity of VADoscopy in a larger cohort of patients. In conclusion, VADoscopy is a novel and effective intraoperative diagnostic modality to evaluate the inflow cannulae within the HMII LVAD, limiting the amount of dissection, and potentially reducing the morbidity associated with HMII pump exchange.

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References