Left Ventricular Assist Device Inflow Angle and Pump Positional Change Over Time Adverse Impact on Left Ventricular Assist Device Function

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Background. **This study investigates the impact of left ventricular assist device (LVAD) inflow cannula angulation, pump positional change over time, and the incidence of thrombotic pump dysfunction in a large cohort of HeartMate II (HM2) patients.**

Methods. **Patients (n = 326) who received primary HM2 LVAD between January 2008 and December 2013 at a single institution were retrospectively reviewed. Patients who underwent pump exchange (PE) for pump dysfunction, patients who had pump dysfunction (PD) but did not require pump exchange, and patients with normal LVAD pump dysfunction (NL) were compared. Pump positional change and angle of the inflow cannula with respect to the angle between inflow cannula and the LVAD body (IL angle) were measured from routine chest radiograph at postoperation, before discharge, and follow-up. Pump positional change was assessed based on pump positional differences between discharge and follow-up. Patients were also grouped by IL acute angulation (less than 65 degrees) and pump positional change.**

Results. **There were 21, 15, and 290 patients in the PE group, PD group, and NL group, respectively. There were significant differences in IL angle between PE and NL at all timepoints: postoperation (PD 63.6 ± 12.5, NL 70.6 ± 12.3; $p = 0.018$), before discharge (PD 64.4 ± 12.8, NL 69.5 ± 10.5; $p = 0.039$), and follow-up (PD 62.6 ± 14.2, NL 67.9 ± 11.2; $p = 0.002$). However, the IL angle was insignificant between PE and PD groups and between PD and NL groups. Sixty-seven percent of the PE group had pump positional change as opposed to 36% of the NL group ($p = 0.019$). Eighty-four of 101 patients with pump positional change and 75 of 91 patients with acute angulation at postoperation did not have pump dysfunction.**

Conclusions. **Pump positional change may contribute to LVAD dysfunction or failure, but it does not entirely account for observed pump dysfunction or failure.**

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Thrombotic left ventricular assist device (LVAD) dysfunction can have devastating complications despite pump exchange [1, 2]. Pump thrombosis is one of the serious complications after LVAD placement [3–6]. The incidence of pump thrombosis is 2.2% to 8.4%, with observed mortality of 48.2% for patients not undergoing heart transplant or pump exchange [3]. Although recent series of pump exchange in the setting of LVAD thrombosis have reported good results [4, 7, 8], the incidence of early HeartMate II (HM2; Thoratec, Pleasanton, CA) [9] thrombosis warrants examination because of suboptimal survival after pump exchange [10]. Furthermore, a second surgical procedure risks additional blood product transfusion, which may potentially contribute to allosensitization and subsequently worsen heart transplant outcome [11].

The purpose of this study is to investigate the impact of pump position on pump thrombosis, as assessed by chest radiograph and defined by inflow cannula to pump body angle and position of the LVAD body relative to the diaphragm.

Patients and Methods

We retrospectively reviewed 326 of 347 primary HM2 implants between January 2008 and December 2013

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Abbreviations and Acronyms

CT	= computed tomography
HM2	= HeartMate II
IL	= angle of inflow cannula to left ventricular assist device
LV	= left ventricle
LVAD	= left ventricular assist device
NL	= normal left ventricular assist device function
PD	= pump dysfunction
PE	= pump exchange

performed at Barnes-Jewish Hospital (with Institutional Review Board approval). Twenty-one patients who died during the admission were excluded from the study. Only patients with more than one chest radiograph during the January 2008 to December 2013 period were included in the study. Patients with pump dysfunction leading to pump exchange (PE) were compared with patients who had pump dysfunction (PD) but did not require pump exchange and with patients who had normal LVAD (NL) function. The coring position of the left ventricle (LV) was performed in uniform manner, at the apex, 1 to 2 cm anterolateral to the LV apex dimple. The cannula position was confirmed by intraoperative transesophageal echocardiography. Patient demographics, chest radiographs, and clinical laboratory values were retrospectively analyzed between groups. Standard anticoagulation therapy consisted of aspirin 325 mg and coumadin, with a targeted international normalized ratio between 2 and 3 and bridging with intravenous unfractionated heparin. Pump thrombosis was defined by hemolysis (highest lactate dehydrogenase level more than 2.5 times normal value).

Chest radiographs were selected based on the image quality, the position of the sternal wires, and the ability to assess all LVAD positions, including the entire pump body. Only chest radiographs with sternal wires overlying the vertebrae were analyzed. Chest radiographs with rotation greater than 2 mm were discarded. Radiographs with significant atelectasis and effusions were also excluded. Analysts were blinded to outcome. A validation set was also performed with a subset of patients who underwent more than one chest computed tomography (CT) scan for clinical management. Setup error and rotation to anthropomorphic measurements were corrected. The subtracted appropriate coronal sections of thoracic CT scans were done to the same measurement being performed on chest radiograph. These measurements were compared with those obtained by chest radiograph using Pearson correlation test (*R* value 0.80) [12].

The angle between the inflow cannula and the LVAD body (IL angle) and the inflow cannula direction to mitral valve (broad angulation) or septum (acute angulation) were determined by drawing a line through the mid portion of the inflow cannula and the LVAD body on each radiograph (Fig 1). Pump pocket depth was also analyzed based on the inflow cannula position relative to the diaphragm. The rationale was to see whether heart remodeling or pump pocket constriction and depth of inflow cannula have any impact on the angle of the inflow cannula. If more than one third the length of the inflow cannula was below the diaphragm, we categorized it as subdiaphragmatic; if as much as one third of the inflow cannula was above the diaphragm, it was categorized as on the diaphragm; and if more than one third of the inflow cannula was above the diaphragm, we categorized it as intrathoracic. Data were collected and analyzed at three timepoints: (1) immediately postoperative; (2) before discharge; and (3) at follow-up for pump positional change. Percentages were calculated based on the number of measurements acquired at each timepoint.

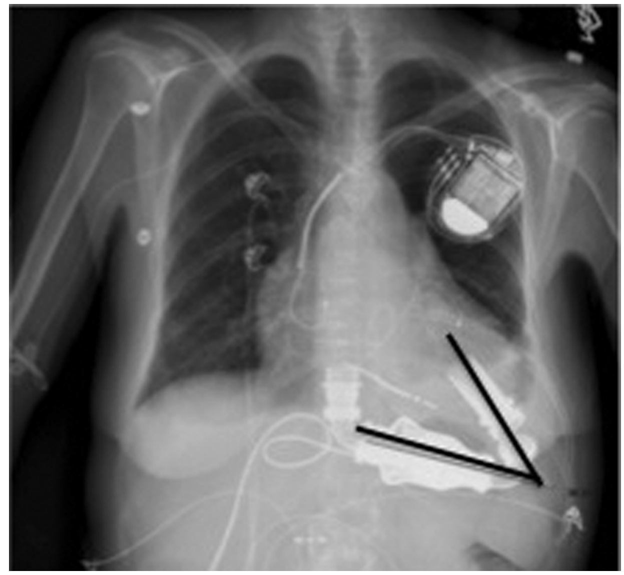

Fig 1. Left ventricular assist device (LVAD) inflow cannula and pump body angle: the lines are made through the mid portion of inflow cannula and LVAD pump body. The angle made by these two lines was measured.

We determined pump positional change by comparing diaphragmatic and LVAD inflow cannula position at discharge and follow-up (Fig 2). An LVAD inflow cannula less than 65 degrees was considered an acute angulation. The changes of inflow cannula angle at follow-up between positive pump positional change and negative pump positional change in the PE group was also compared. The presence of pump positional change or acute angulation was analyzed to determine the impact of pump position on LVAD dysfunction.

Groups were compared by independent samples Student's *t* test and χ^2 analysis. These univariate analyses were used for multivariate analysis using Systat Statistical Software (San Jose, CA) with an alpha level of 0.05. To ensure uniform radiographic evaluation, we excluded