Cost-Effectiveness Analysis of Continuous Flow Left Ventricular Assist Devices as Destination Therapy

Rogers et al: Value of Mechanical Circulatory Support

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Abstract

Background—Continuous flow left ventricular assist devices (LVADs) have become the dominant devices for mechanical circulatory support, but their cost-effectiveness is undetermined. This study assessed the cost-effectiveness of continuous flow devices for destination therapy versus optimal medical management in advanced heart failure and compared the results to previous estimates for pulsatile devices.

Methods and Results—A Markov model was developed to assess cost-effectiveness. Survival, hospitalization rates, quality of life and cost data were obtained for advanced heart failure patients treated medically or with a continuous flow LVAD. Rates of clinical outcomes for all patients were obtained from clinical trial databases. Medicare prospective payments were used to estimate the cost of heart failure admissions. The cost of LVAD implantation was obtained prospectively from hospital claims within a clinical trial. Compared to medically managed patients, continuous flow LVAD patients had higher five-year costs ($360,407 vs. $62,856), quality-adjusted life years (1.87 vs. 0.37), and life years (2.42 vs. 0.64). The incremental cost-effectiveness ratio (ICER) of the continuous flow device was $198,184 per quality-adjusted life year and $167,208 per life year. This equates to a 75% reduction in ICER compared to the $802,700 per quality-adjusted life year for the pulsatile-flow device. The results were most sensitive to the cost of device implantation, long-term survival, cost per rehospitalization, and utility associated with patients’ functional status.

Conclusions—The cost-effectiveness associated with continuous flow LVADs for destination therapy has improved significantly relative to the pulsatile flow devices. This change is explained by significant improvements in survival, functional status and reduction in implantation costs.

Key Words: cost-effectiveness, heart failure, heart-assist device
The burden of advanced heart failure is characterized by excessive morbidity and mortality, poor quality of life, high treatment costs, and limited treatment options. Nearly 6 million Americans have heart failure and approximately 10% have advanced disease.\textsuperscript{1,2} The estimated total annual cost for heart failure in the US is $39 billion in 2010 with the advanced heart failure population consuming a disproportionate amount of these healthcare resources.\textsuperscript{1,3} After failing evidence-based medical and electrical therapies, these patients have extremely limited treatment options. Heart transplant is considered epidemiologically insignificant as most patients are ineligible for transplant or are unlikely to receive a donor heart resulting from the shortage of suitable organs. Technologic innovations and the clinical application of alternative therapies such as mechanical circulatory support devices, including left ventricular assist devices (LVADs) may help bridge this gap of available and effective therapy.

Several studies have evaluated the long-term outcomes and costs associated with LVAD therapy. Nearly 10 years ago, the Randomized Evaluation of Mechanical Assistance for the Treatment of Congestive Heart Failure (REMATCH) randomized patients ineligible for transplant to treatment with an LVAD or optimal medical management (OMM). The LVAD patients had survival rates of 52\% at one year and 23\% at two years compared to 25\% and 8\% in the OMM arm.\textsuperscript{4} The mean cost for the implant-related hospitalization was $210,187.\textsuperscript{5} A follow-up cost-effectiveness analysis based on the REMATCH trial published in 2004 concluded that the incremental cost effectiveness ratio (ICER) was $802,700 per quality-adjusted life year (QALY).\textsuperscript{6} As centers gained more experience with patient selection, device implantation and post-operative management, costs for the initial implant hospitalization decreased. Miller and colleagues presented cost data from a cohort of patients implanted with a pulsatile flow LVAD
after completion of the REMATCH trial in select high-volume centers and demonstrated that the mean cost for implantation decreased to $128,048. In a contemporary review of six pulsatile LVAD studies, Clegg reported a cost per quality-adjusted life year of $341,573 and cited a potential improvement in LVAD cost effectiveness with the introduction of continuous flow devices.

The HeartMate II Destination Therapy trial randomized patients with advanced heart failure to receive the older pulsatile LVAD used in REMATCH or a new generation continuous flow LVAD. Patients who received the continuous flow device had 1- and 2-year survival rates of 68% and 58% compared to 55% and 24% with the pulsatile device. The continuous flow LVAD patients experienced similar long-term improvements in quality of life, exercise performance and end-organ function to patients supported with pulsatile flow devices. Furthermore, fewer continuous flow devices required replacement for mechanical failure.

Given the improvement in survival, the reduced need for device replacement, improved quality of life and a decrease in hospitalization costs associated with newer devices, the cost-effectiveness of LVAD therapy would reasonably be expected to improve. The objective of the current study was to perform a cost-effectiveness analysis of continuous flow LVADs for destination therapy versus OMM from a third-party payer perspective based on the latest clinical and cost data available and to compare these data to previous estimates of the ICER for pulsatile LVADs.
Methods

Data Sources

Clinical outcomes and costs for this analysis were obtained from several sources. Clinical outcomes for optimal medical therapy were derived from the REMATCH trial (n=61, 1998-2001)\textsuperscript{4} and the clinical outcomes of continuous flow LVADs (n=134, 2005-2007) were obtained from the HeartMate II Destination Therapy Trial.\textsuperscript{9}

Enrollment criteria in these trials distinguished a high risk patient population. Patients had predominantly New York Heart Association (NYHA) functional class IV symptoms and a left ventricular ejection fraction of \( \leq 25\% \). They also had a peak oxygen consumption of \(<14\, \text{ml/kg/min}\) or required treatment with continuous infusion of positive inotropic agents. These patients were ineligible for heart transplantation because of advanced age or co-morbidities that were thought by the investigative site to preclude successful transplant.

The current analysis captured patient-specific clinical events and costs from the time of randomization in a clinical trial through a maximum of five years. In REMATCH, the two-year survival rate was 0.08 for patients receiving OMM and 0.25 for the pulsatile LVAD.\textsuperscript{4} In the HeartMate II Destination Therapy trial, the two-year survival rate was 0.58 for patients receiving the continuous flow device.\textsuperscript{9} An indirect comparison of OMM and continuous flow LVAD outcomes was required using data from REMATCH and the HeartMate II Destination Therapy trial since no trial has directly compared these treatments. Treatment strategies and protocols for OMM and LVAD destination therapy have been described previously.\textsuperscript{4,9} Baseline patient characteristics were similar between the OMM and continuous flow LVAD treatment groups except that those in the continuous flow LVAD group were on average 6 years younger and 25\%
were classified by investigators as NYHA functional class III while all OMM patients had NYHA class IV disease.4,9

Cost data were obtained from multiple sources, including prospectively collected hospital billing data, Medicare payments for professional services related to LVAD implantation, and Medicare prospective payments for rehospitalizations. A detailed description for each source is provided in later sections.

Model Design and Structure

A decision analytic model was adapted from the Blue Cross Blue Shield (BCBS) Technology Evaluation Center assessment.6 After receiving an LVAD for destination therapy or being assigned to OMM, patients were evaluated through a Markov process containing two health states: alive or dead. Patients in the OMM and LVAD arms followed the same Markov process with monthly probabilities of transition between health states specific to each treatment group (Figure 1). Costs, QALYs, and life years (LYs) accrued during a patient’s model-based lifetime were based on assumptions relating to monthly hospitalization rates and costs, outpatient costs, and the distribution of NYHA Functional Classification (I-IV) health states over time. These parameters and the monthly transition probabilities were informed using data from the REMATCH and HeartMate II Destination Therapy Trials, as described below.

Calculation of QALYs and LYs

Cycle-specific survival probabilities were estimated from the Kaplan-Meier survival curves for the OMM cohort in the REMATCH trial and for the continuous flow LVAD cohort in the HeartMate II Destination Therapy trial. Follow-up in both trials was completed at 24 months
thus requiring survival assumptions beyond this time point. In REMATCH, the survival probability of the OMM cohort at 24 months was 8%. Extrapolation of survival past 24 months was based on an exponential survival curve using the constant hazard rate observed within 24 months (0.105 per month). For the LVAD treated patients, three different methods for survival extrapolation beyond 24 months were used. For the base case analysis, an exponential survival curve was fit to the 24 month data (0.023 per month) from the model. In the sensitivity analysis, the methods of stop and drop (i.e., assuming that all patients surviving to 24 months die immediately thereafter) and a linear extrapolation between the observed survival at 24 months of 58% and 40% at 60 months were used (Figure 2).

For both the OMM and LVAD cohorts, QALYs were estimated based on survival adjusted for the cohort's average utility (i.e., the preference that an individual or a society places on health outcomes, usually ranging from 0 to 1) in each cycle. Utility measurements were not collected in the HeartMate II Destination Therapy study or the REMATCH trial, so utility estimates were derived from health states based on NYHA classes. The probability of belonging to a specific NYHA class varied over time. Monthly estimates of these probabilities were obtained from the REMATCH and HeartMate II Destination Therapy trials for the OMM and LVAD arms, respectively (Table 1). When the NYHA classes were not reported, data were interpolated from the immediately preceding month and the month after. The distribution at 24 months was used to estimate NYHA classes beyond 24 months. For the OMM cohort, only the distribution of patients in NYHA classes I/II or classes III/IV were available. Patients were predominantly classified as classes III/IV during the 24-month trial period, so we assumed that 25% of those had class III and 75% had class IV heart failure. For the small number of patients classified into classes I/II at 3 (3%) and 6 months (9%), they were all assumed to have class II
At the 24 month assessment in REMATCH, 1 of the 3 patients who remained alive in the OMM cohort reported NYHA class I/II symptoms. For the purposes of this analysis, the number of OMM patients with NYHA class I/II symptoms at ≥24 months was considered to be 0% to be consistent with the observed rates throughout the entire REMATCH trial. A mean utility value of 0.855, 0.771, 0.673, and 0.532 were assigned to NYHA classes I, II, III, and IV, respectively, suggesting that patients with NYHA classes I heart failure were willing to trade, on average, 15% of their remaining years in return for perfect health and those with NYHA classes IV disease were willing to trade 47% of their remaining life. It was assumed that the utilities for NYHA categories did not differ between the LVAD and OMM patients.

The total LYs and QALYs for the OMM and LVAD cohort in the study period were calculated as the sum of LYs and QALYs accumulated in each cycle and were discounted at 3% per year per recommendation from the Panel on Cost-Effectiveness in Health and Medicine.

Calculation of Costs

Costs were assessed from the perspective of a third-party payer. Three main categories of costs were included: LVAD implantation and replacement costs, rehospitalization costs, and outpatient costs. Implantation and replacement costs applied only to LVAD recipients, while rehospitalization costs and outpatient costs applied to all patients.

LVAD implantation costs included hospital and professional service costs. Hospital costs encompassed the entire hospitalization from implantation to discharge, including the cost of the device, intensive care days, medical/surgical days, operating room, diagnostics, laboratory tests, blood products, drugs, and miscellaneous services. Although patients may incur costs during the pre-implantation phase of the hospitalization for heart failure therapy or management of their
comorbidities, these costs were not included. Hospital costs were estimated from hospital claims data collected from a subset of patients (83 out of 134) who were representative of all patients receiving a continuous flow device in the HeartMate II trial. The costs of professional services were obtained from an analysis of Medicare claims submitted by physicians for patients selected from a random sample of Medicare beneficiaries who underwent an LVAD implantation procedure in 2008. The costs included the surgical procedure and follow-up evaluation and management from cardiologists and other physicians in the same quarter that the LVAD was implanted.

The frequency of rehospitalizations for the LVAD cohort was based on data from the HeartMate II Destination Therapy trial in which an annual rehospitalization (including LVAD pump replacement) rate of 2.64 per person and LVAD replacement rate of 0.06 per person was reported. As hospitalizations for LVAD replacement versus a typical heart failure management are associated with markedly different payments, rates for these hospitalizations were estimated separately. A monthly rehospitalization rate, excluding rehospitalization for LVAD replacement, was estimated at 0.215 per person and a monthly LVAD replacement rate was estimated at 0.005 per person. For the OMM cohort, the readmission rate in the base case analysis was based on the COMPANION Trial which compared patients with advanced heart failure that received cardiac resynchronization therapy to patients that received optimal pharmacological therapy. In this study, the patients were all in NYHA Class III or IV and the average age was 66 years. For the OMM group, 65% of patients were hospitalized during follow-up and the average number of hospital admissions per patient-year of follow-up was 1.59. In terms of admissions per month, this equates to 0.1325. The sensitivity analysis tested the assumption based on the 30-day rehospitalization rates for a cohort of medically-managed HF patients in the Medicare fee-for-
service program. The cost per rehospitalization was estimated from the average Medicare reimbursement rates for medical severity diagnosis-related group (MS-DRG) 291 (heart failure & shock with major complications and comorbidities) and MS-DRG 292 (heart failure & shock with complications and comorbidities). The cost for LVAD replacement was estimated from the average Medicare reimbursement rates for MS-DRG 1 (heart transplant or implant of heart assist system with major complications and comorbidities). The cost per rehospitalization was assumed to be the same for patients with an LVAD and those receiving OMM, consistent with the prior cost-effectiveness analysis of LVADs. For patients who died, a one-time end-of-life cost was added, which was based on the cost of medical management for patients with end-stage HF during the last quarter of their lives.

Outpatient costs included professional services, laboratory tests, and drugs. In a study of bridge-to-transplant patients, the average weekly outpatient cost was $352, yielding a monthly cost of $1,531 (1995 $US). This amount was revalued in 2009 $US using the consumer price index for medical care services. Consistent with the prior cost-effectiveness analysis of LVADs, outpatient costs were assumed to be the same for LVAD and OMM patients. Although these costs were based on a small cohort of bridge-to-transplant patients who were treated more than a decade ago, as these costs were a small fraction of the costs for initial implantation and subsequent hospitalizations, this estimate was unlikely to impact the cost-effectiveness findings.

All costs were in 2009 US dollars. Costs incurred beyond the first year were discounted at 3% per year. Detailed cost parameter values used in the base-case analysis are presented in Table 2.
**Base-Case Analysis**

The costs and outcomes for the OMM and LVAD cohorts were forecasted over five years. The incremental cost-effectiveness ratio (ICER) was calculated comparing the difference in average total costs and the difference in average QALYs or LYs between the OMM and LVAD cohorts. The model was constructed with TreeAge Pro 2006 Software (TreeAge Software, Inc. Williamstown, MA).

**Sensitivity analysis**

The BCBS technology assessment, which used data from the REMATCH study, suggested that the model results were more sensitive to the cost of LVAD implantation and variations in utility for NYHA classes than other parameters. The same model structure was applied in our analysis and the parameters driving the results remained the same. In addition, alternative assumptions for rehospitalization costs and long-term survival for the LVAD cohort were tested. Alternative costs of rehospitalizations for both LVAD and OMM patients were estimated from the average cost per rehospitalization for the pulsatile device cohort in the REMATCH trial. Alternative assumptions for long-term survival extrapolation for LVAD patients, such as stop and drop and a linear survival curve were included in the sensitivity analysis.
Results

Baseline Results

Using the values described for all parameters, at 5 years patients in the LVAD arm gained on average 1.87 QALYs, or 2.42 LYs, at a total cost of $360,407. Medically treated patients gained 0.37 QALYs or 0.64 LYs at a cost of $62,856 (Table 3). The ICER for the continuous flow LVAD compared to OMM was $198,184 per QALY and $167,208 per LY.

The baseline results suggested a substantial improvement of continuous-flow devices compared to the previous cost-effectiveness analysis for pulsatile devices, where the total costs were estimated at $391,906 (2002 US$), total QALY at 0.76, and an ICER of $802,674 (2002 US$).6

Sensitivity Analyses

Results were most sensitive to variations in long-term survival probabilities associated with the LVAD, the cost of LVAD implantation, cost per rehospitalization, and utility for NYHA class I and II (Figure 3). However, ICERs of $300,000 or more depended on the improbable assumption that all patients implanted with an LVAD who survived 24 months would die immediately thereafter. In other scenarios where a wide range of values for the selected parameters were tested, the ICERs for LVAD relative to OMM remained below $300,000 per QALY.
Discussion

This study demonstrates a meaningful improvement in the cost effectiveness of mechanical circulatory support in the recent era. These favorable outcomes are largely related to improved survival with continuous flow LVADs coupled with reductions in implant costs and a persistent improvement in functional abilities in patients treated with mechanically supported circulation. The relative 75% reduction in cost/QALY during the past decade suggests that LVAD therapy continues to evolve in to a mainstream therapy for advanced heart failure.

Advanced heart failure is associated with high residual mortality. For those patients that meet indications, heart transplant remains the gold standard and preferred therapy. However, the shortage of suitable donor organs has limited this option to fewer than 2,500 patients each year. A durable and cost-effective mechanical circulatory support treatment option could narrow the chasm that exists between the number of patients with advanced heart failure and the scarce resource of transplantation.

Mechanical circulatory support devices were initially designed as pulsatile pumps requiring sufficient size to hold a normal cardiac stroke volume and a complex mechanism to propel the blood that included multiple moving parts. Although hemodynamically successful, device size and durability as well as significant adverse events limited their clinical applicability. Newer pump designs based on continuous flow have permitted miniaturization and design simplification which has resulted in improved durability and less surgical trauma for implantation. Improved patient-centric care has accompanied these engineering advances. In the latest randomized trial of continuous flow versus pulsatile LVADs for destination therapy, there was a significant improvement in two year survival and reduction in adverse events.23 Left ventricular assist devices are emerging as the treatment of choice for patients with advanced...
heart failure who are ineligible for heart transplantation. However, the relatively high cost of this therapy raises the lingering issue of cost effectiveness.

In the Medicare population ineligible for transplant, the average cost for treating advanced heart failure with optimal medical management is approximately $180,000 with the majority being spent in the last six months of life.\(^3\) In the initial evaluation of costs for pulsatile LVADs, the average cost of LVAD implantation was $210,187 and an independent tech assessment determined an ICER of $802,700.\(^5,6\) In comparison to the pulsatile devices, the hospital costs for continuous flow device implantation decreased by 50%.\(^14\) Despite the increased survival and quality of life improvements, high treatment costs restricted the adoption of LVAD therapy to a highly selected, extremely sick patient population. Our current cost analysis of patients treated with the new continuous flow LVADs reveal a significant reduction in the ICER/QALY from $802,700 to $198,184. This ICER/QALY is still significantly higher than the traditionally-used threshold of $50,000 when considering therapies to be cost-effective, but the incremental cost reduction in a relatively short time period is encouraging.

ICERs, as calculated in cost-effectiveness analyses, represent the opportunity cost of resources at margin. However, when applied to orphan disease or other end of life treatments, ICERs can be challenged as the evaluation does not consider the innovative nature of medicine or availability of alternative treatment.\(^24\) Although the notion of an ICER threshold value as a guiding principle for resource allocation is subject to debate, cost effectiveness guided by ICERs continues to be the most commonly used tool in the evaluation of health care practices and new medical technologies. ICERs less than $50,000 per QALY are considered cost-effective and those between $50,000 and $100,000 are regarded as acceptable. Thus, the use of LVADs for the treatment of advanced heart failure has not yet achieved the currently accepted benchmark.
Ongoing improvements in patient survival, reduction in long term complications and readmission rates, and a focus on inpatient and outpatient processes of care would reasonably be expected to result in further declines in the ICER with the goal of ultimately achieving the current “standard” for cost effectiveness.

A number of potential limitations of this study are worth noting. The clinical and economic data for LVADs and OMM were obtained based on reports from various time periods. Survival data for OMM were based on REMATCH performed nearly 10 years ago whereas the continuous flow LVAD data was based upon the recently completed HeartMate II Destination Therapy trial. Similar to the progress seen with LVADs, one would expect advances in medical management and its outcomes, for example, earlier referral to hospice may have reduced the hospitalization costs which may lead to a reduction in the overall costs. Furthermore, patients randomized to the OMM arm in REMATCH OMM were older than those treated with continuous flow LVADs in HeartMate II Destination Therapy trial. If the data on a more recent OMM cohort with a similar age distribution were used, one may anticipate a better survival than currently estimated for the OMM patients. However, given the marked difference in survival and the lack of novel treatments demonstrated to improve the outcomes of patients with this severity of illness, it is reasonable to believe that the results would have been similar if more recent data for OMM were used. Another consideration in the interpretation of this study is the anticipation that long-term mechanical circulatory support will be applied in an older patient population than studied in the HeartMate II Destination Therapy trial. The overall impact of VADs on survival, functionality, hospital days and cost in the elderly may negatively impact the cost effectiveness of mechanically assisted circulation and should be systematically evaluated. Secondly, costs of rehospitalizations were not collected in the HeartMate II Destination Therapy trial and were
derived by estimation from other sources. The Medicare inpatient prospective payment system uses diagnostic related groups (DRGs), which are linked to payment rates for an acute hospital stay based on a patient’s clinical condition and treatment strategy, and these were used in this study. As the causes for hospital admissions were unavailable, the analysis only included the payment for a typical episode of heart failure related admission during which medical management is provided. Using MS-DRG payments for heart failure & shock may have overstated the re-hospitalization costs for the OMM cohort. It may also have under- or overstated the costs for the LVAD cohort. Although it is reasonable to believe that most admissions would fall under heart failure related MS-DRGs, a recent report from the Interagency Registry for Mechanically Assisted Circulatory Support (INTERMACS) showed that most readmissions were for non-heart failure reasons. This current estimate for the readmission ($6,850) is substantially lower than the average readmission cost ($30,627) in the REMATCH trial. REMATCH was conducted 10 years ago when the clinical experience with the LVADs remained extremely limited. With the growing clinical experience and the improvement of the device, the implantation cost and the adverse event rates were dramatically reduced. It is reasonable to believe a similar trend for the rehospitalization cost. Furthermore, the REMATCH costing cohort included only 34 patients and most of them died within 2 years. If we assume most costs are incurred during the last 6 months of a patient’s life, the higher mortality would lead to a higher estimate of average cost per hospitalization.

Utility estimates in the study were not validated for an LVAD population and LVAD-specific utility estimates are currently not available from the literature. The use of functional class as a surrogate for utility has been used in other clinical heart failure trials and was utilized in the original cost effectiveness assessment of LVAD therapy. Analysis of functional and
quality of life outcomes from the HeartMate II clinical trials program demonstrated early and sustained improvements in 6 minute walk distance as well as Minnesota Living with Heart Failure and Kansas City Cardiomyopathy scores. Thus, it may be anticipated that substitution of another functional or quality of life metric would have yielded similar utility to that observed with New York Heart Association Functional Class. The INTERMACS registry is collecting the EQ-5D data for the LVAD population; the single-index utility estimates derived from the EQ-5D data when available can be used to validate the NYHA class–based utility estimates in this study.

**Conclusion**

Using similar methods as the original BCBS tech assessment, we have demonstrated a significant improvement in the ICER for LVADs used to treat advanced heart failure in patients that are not eligible for heart transplantation. Based on this assessment, it is anticipated that continued refinement of patient selection criteria, technological advances, and improvements in management strategies will converge and result in the demonstration of LVADs as an economically effective treatment option for patients with advanced heart failure.
Sources of Funding

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Disclosures

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References


18. Medicare Program; Changes to the Hospital Inpatient Prospective Payment Systems and Fiscal Year 2009 Rates; Payments for Graduate Medical Education in Certain Emergency Situations; Changes to Disclosure of Physician Ownership in Hospitals and Physician Self-Referral Rules; Updates to the Long-Term Care Prospective Payment System; Updates to Certain IPPS-Excluded Hospitals; and Collection of Information Regarding Financial Relationships Between Hospitals; Final Rule. Federal Register 73. 8-19-2008.


Table 1. Probability of being in NYHA Classes I – IV

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<th>OMM#</th>
<th>Class I</th>
<th>Class II</th>
<th>Class III</th>
<th>Class IV</th>
<th>LVAD ¶⁹</th>
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<tr>
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<td>Class I</td>
<td>Class II</td>
<td>Class III</td>
<td>Class IV</td>
<td>Class I</td>
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<td>0%</td>
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<td>NR</td>
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<td>24%</td>
<td>73%</td>
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<td>42%</td>
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<td>23%</td>
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<td>75%</td>
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<td>75%</td>
<td>42%</td>
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<td>75%*</td>
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# In the REMATCH trial, only the percentage of OMM cohort in NYHA classes I/II or classes III/IV were reported. In the model, the percentage of patients in classes I/II was assigned to class II and 25% of those in classes III/IV were assumed in class III and 75% were assumed in class IV.

¶ For months with missing data, linear interpolation was used in the model.

* In the REMATCH trial, 33% and 67% of OMM cohort reported NYHA classes I/II and III/IV, respectively. Due to the small sample size (N=3) for OMM patients at 24 months, the data were reset to 0% and 100% in the model.

Abbreviations: NR: not reported; NYHA, New York Heart Association; OMM, optimal medical management; LVAD, left ventricular assist device
Table 2. Model parameters, values, and data sources in the base case and sensitivity analysis

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<th>Base case</th>
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<tr>
<td>24-month survival for OMM(^4)</td>
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<td>LVAD implantation professional service cost(^{15})</td>
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<td>LVAD replacement cost(^{18})</td>
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<td>End-of-life cost(^{19})</td>
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<td>0.578 – 0.964</td>
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<td>0.505 – 0.841</td>
</tr>
<tr>
<td>Utility for NYHA Class IV(^{12})</td>
<td>0.532</td>
<td>0.399 – 0.665</td>
</tr>
</tbody>
</table>

\(^{*}\)One standard deviation from the mean cost ($193,812)

Abbreviations: LVAD, left ventricular assist device; KM: Kaplan Meier; OMM, optimal medical management; CMS, Centers for Medicare & Medicaid Services; SAF, Standard Analytic Files
Table 3. Costs, QALYs, and Life Year Results for the Base Case Analysis

<table>
<thead>
<tr>
<th>Parameters</th>
<th>OMM</th>
<th>LVAD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Cost ($)</td>
<td>$62,856</td>
<td>$360,407</td>
</tr>
<tr>
<td>Total QALYs (year)</td>
<td>0.37</td>
<td>1.87</td>
</tr>
<tr>
<td>Total LYS (year)</td>
<td>0.64</td>
<td>2.42</td>
</tr>
</tbody>
</table>

Abbreviations: LVAD: left ventricular assist device; LY: life year; OMM: optimal medical management; QALY: quality-adjusted life year
Figure Legends

**Figure 1. Health State Transition Model.** This model included only two health states, Alive and Dead, with a time-dependent probability of transitioning from Alive to Dead.

**Figure 2. Survival Curves for Base Case and Sensitivity Analyses.** The survival curves for the base case analysis and the two sensitivity analyses – stop and drop and linear extrapolation – from 24 months to 60 months are shown.

**Figure 3. Results of the One-way Sensitivity Analyses.** In the LVAD arm, the methods of stop and drop (assuming that all patients surviving to 24 months die immediately thereafter) and a linear extrapolation (assuming a 60-month survival rate of 40%) are used. Utility values for patients with NYHA I-IV heart failure were ranged by plus or minus 25% of the base case estimates. The initial hospital cost of LVAD implantation is varied by one standard deviation below or above the mean. The cost per rehospitalization for patients receiving an LVAD from the REMATCH trial ($30,267) is used in the LVAD and OMM arms. The monthly re-hospitalization rate for the OMM arm is assumed to be between the rate for the LVAD arm (0.215) and 0.1325.

LVAD, left ventricular assist device; NYHA, New York Heart Association; OMM, optimal medical management.
Incremental Cost Effectiveness Ratio per Quality Adjusted Life Year

LVAD survival extrapolation  
Hospital cost of LVAD implantation ($122,785)  
Cost per rehospitalization ($6,850)  
Utility for NYHA Class I (1.0)  
Utility for NYHA Class II (0.964)  
Utility for NYHA Class III (0.673)  
Utility for NYHA Class IV (0.399)  
Monthly rehospitalization rate for OMM (0.26)  

Cost/QALY

< base case
> base case
Cost-Effectiveness Analysis of Continuous Flow Left Ventricular Assist Devices as Destination Therapy
Joseph G. Rogers, Robin R. Bostic, Kuo B. Tong, Rob Adamson, Mark Russo and Mark S. Slaughter

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