From bench to bedside: Can the improvements in left ventricular assist device design mitigate adverse events and increase survival?

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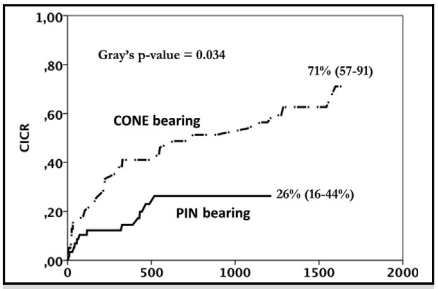
ABSTRACT

Objective: In vitro tests demonstrated that the new cone-bearing configuration of the Jarvik 2000 (Jarvik Heart Inc, New York, NY) left ventricular assist device exhibits better hydraulic efficiency than the previous pin-bearing design. We investigated the long-term outcomes of patients who received the Jarvik 2000 left ventricular assist device, depending on bearing design.

Methods: A retrospective review of prospectively collected data from 18 centers included in the Italian Registry was performed. From May 2008 to September 2013, 99 patients with end-stage heart failure were enrolled. Patients were divided into 2 groups according to their Jarvik 2000 suspending mechanism: Group pin included patients with pin bearings (May 2008 to June 2010), and group cone included patients with newer cone bearings (July 2010 to September 2013). The 2 groups did not differ significantly in terms of baseline characteristics.

Results: A total of 30 of 39 patients (group pin) and 46 of 60 patients (group cone) were discharged. During follow-up, 6 patients underwent transplantation, and in 1 patient the left ventricular assist device was explanted. The cumulative incidence competing risk of the entire cohort for noncardiovascular-related death was 28% (20%-40%); the cumulative incidence competing risk for cardiovascular-related death was 56% (42%-73%): 71% in group pin versus 26% in group cone ($P = .034$). The multivariate analyses confirmed that the pin-bearing design was a risk factor for cardiovascular death, along with Interagency Registry for Mechanically Assisted Circulatory Support class. Right ventricular failures and ischemic and hemorrhagic strokes were significantly higher in group pin.

Conclusions: Patients with the new pump configuration showed a better freedom from cardiovascular death and lower incidence of fatal stroke and right ventricular failure. Further studies are needed to prove the favorable impact of pump-enhanced fluid dynamics on long-term results. (J Thorac Cardiovasc Surg 2016;151:213-7)



The CICR for CV death by bearing design: pin versus cone.

Central Message

Patients with the newer configuration of the Jarvik 2000 (Jarvik Heart Inc, New York, NY) LVAD showed a better freedom from CV death, stroke, and RV failure.

Perspective

In vitro tests demonstrated that the new cone-bearing configuration of the Jarvik 2000 LVAD exhibits better hydraulic efficiency than the previous pin-bearing design. We investigated in vivo the long-term outcomes of 99 patients with the Jarvik device who were enrolled in the Italian Registry. The new pump configuration was associated with less CV deaths and reduced complications.

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In vitro experimental research is of vital importance because it allows new hypotheses to be piloted without experimentation on patients. Translational research is the step between promising in vitro results and their application to clinical practice. However, results determined in vitro often do not maintain their relevance when tested in real patients.

In the field of ventricular assist device technology, despite rapid progress in recent years, the search for the ideal device continues.[1] An ideal device should have excellent hemodynamic performance, a low risk of thrombosis, a low risk of infection, and cause minimal patient inconvenience and discomfort. Because these are complex mechanical systems, much experimentation of new designs occurs in vitro before testing in the clinical setting.

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Abbreviations and Acronyms

CICR = cumulative incidence competing risk
CV = cardiovascular
LVAD = left ventricular assist device
RV = right ventricular

The Jarvik 2000 (Jarvik Heart Inc, New York, NY) is an axial flow ventricular assist device with an impeller pump supported by contact bearings. The original design of the Jarvik 2000 pump featured pin bearings to mount the impeller, but these were replaced with cone bearings in the latest design.[2] The cone-bearing mechanism was developed for the pediatric model and tested in an animal model demonstrating a reduction in thrombus formation.[3,4] Therefore, it was introduced to the adult pump. Stanfield and Selzman[5] demonstrated an improvement in hydrodynamic performance of the Jarvik 2000 because of this change in design when tested in vitro. However, at this stage there are only case reports comparing the 2 different suspension mechanisms in human patients.[6]

We set out to investigate the impact of this modification on midterm outcomes in patients who underwent Jarvik 2000 implantation and were included in the Italian prospective multicenter national registry.

MATERIALS AND METHODS

Patients and Groups

A retrospective review of data concerning Jarvik 2000 implantation prospectively collected from 18 centers and included in the Italian Registry was performed. Written informed consent was obtained for all patients, and the study was approved by local institutional review boards.

From May 2008 to September 2013, 104 consecutive patients with end-stage heart failure were enrolled. Of these patients, 99 were adults and 5 were children, and the latter were excluded from the analysis. Patients were divided into 2 groups based on the design of their Jarvik 2000 suspension mechanism: Group pin included patients with pin bearings, implanted between May 2008 and June 2010; group cone included patients with newer cone bearings, implanted between July 2010 and September 2013. All patients were provided with the intermittent low-speed controller. Baseline demographic data for the 2 groups are shown in Table 1. The patients in the 2 groups did not differ significantly in terms of baseline characteristics, although a tendency toward lower Interagency Registry for Mechanically Assisted Circulatory Support profile in group cone was observed.

Surgical Technique

The surgical technique used to implant the Jarvik 2000 device has been reported.[7,8] In our series, surgical access was via left thoracotomy, sternotomy, and ministernotomy plus minithoracotomy in 71, 20, and 8 cases, respectively. In 62 patients, device implantation was performed off-pump, and in 35 cases cardiopulmonary bypass was used. The only differences found between groups were a higher rate of patients receiving the Jarvik 2000 device via median sternotomy (18 vs 2) or minimally invasive incision (8 vs 0) in the cone group.

Follow-up and Outcome

All discharged patients were closely followed up in outpatient clinics. The anticoagulation regimen was the same among centers, consisting of unfractionated heparin in the immediate postoperative period, followed by warfarin. The follow-up ended in December of 2013. The median interval time was 424 days (25th-75th percentiles: 220-777), with longer follow-up in group pin than in group cone (737 ± 506 days vs 402 ± 304 days, $P < .001$). The primary end point was the difference regarding cardiovascular (CV)-related deaths. The secondary outcomes were pump thrombosis, thrombotic and hemorrhagic cerebral and gastrointestinal deaths, and right ventricular (RV) failure.

Statistical Analysis

Differences between groups in independent, normally distributed, continuous variables were evaluated using the *t* test. Variables that were not normally distributed were evaluated using the nonparametric Mann–Whitney *U* test. Differences in categoric variables were evaluated using the Fisher exact test or Pearson's chi-square test for more than 2 groups. Cumulative incidence competing risk (CICR) was used to assess late outcome (deaths non-CV related; deaths CV related, transplants or explants). Difference between groups was assessed with Gray's test.[9] The results are reported as CICR and 95% confidence interval. Hazard-proportional Cox analysis was performed to identify independent variables for lower freedom from CV deaths but undergoing transplantation or explantation. All the variables reported in Table 1 were initially included in the univariate analyses along with pin/cone-bearing pump design. In the initial multivariate models, we included all variables with a *P* value less than .2 at univariate analysis. Center and cohort effects have been included in the model via a Gamma frailty.[10] The internal validation of the model was performed using 1000 bootstrap samples. Finally, the model with the highest Harrell's C-index was reported.[11] All comparisons were 2-sided. We used the Statistical Package for the Social Sciences (IBM, Armonk, NY) and the R System.

RESULTS

In-Hospital Mortality

In-hospital mortality was 23% (23 cases); no difference between the 2 groups was found (9 [23%] in group pin vs 14 [23%] in group cone, $P = .976$). Multiorgan failure was the main cause of death (10/23, 43%). Respiratory failure occurred in 4 patients (17%), a hemorrhagic event occurred in 4 patients (17%), and sepsis occurred in 3 patients (13%); ischemic stroke and intestinal infarction occurred in 1 patient each.

Survival

Seventy-six patients were successfully discharged from the hospital, 30 with pin bearings and 46 with cone bearings. The baseline characteristics of the 2 groups are compared in Table 1. Among discharged patients, during follow-up 60 patients died of any cause (32 in group pin and 28 in group cone). A CV event was the cause of death in 37 of them (25 in group pin and 12 in group cone). There were 6 transplant recipients (5 in group cone vs 1 in group pin). In 1 case, the left ventricular assist device (LVAD) was explanted (group cone).

The CICR of the entire cohort for non–CV-related deaths was 28% (20%-40%). The CICR for CV-related deaths was 56% (42%-73%). The differences between groups