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Bridging cardiogenic shock patients with short-term ventricular support at a community hospital to long-term ventricular support at a tertiary hospital

José González-Costello, MD^{a,b}, Jonathan Yang, MD^c, Daniel B. Sims, MD^a, Alexander P. Kossar^c, Lindsay K. Murray, BA^a, Paolo C. Colombo, MD^a, Hiroo Takayama, MD^c, Donna Mancini, MD^a, Yoshifumi Naka, MD, PhD^c, Ulrich P. Jorde, MD^a, Nir Uriel, MD^a

^aDivision of Cardiology, Department of Medicine, Columbia University Medical Center, New York, New York

^bServei de Cardiologia, Hospital Universitari de Bellvitge, L'Hospitalet de Llobregat, Barcelona, Spain

^cDivision of Cardiothoracic Surgery, Department of Surgery, Columbia University Medical Center, New York, New York

Abstract

BACKGROUND—Patients in cardiogenic shock require immediate circulatory support.

Outcomes of patients who underwent short-term ventricular assist device (STVAD) implantation in a community hospital (CH) as a bridge to a long-term VAD (LTVAD) were compared with those who received both implants at the same tertiary hospital (TH).

METHODS—Data were retrospectively reviewed for patients with a STVAD who were bridged to a LTVAD in a TH from 1997 to 2010. We studied outcomes and survival censored for cardiac transplantation.

RESULTS—Thirty-seven patients (73% male) were identified. Mean age was 52 ± 16 years, 30% were diabetic, and 65% had intra-aortic balloon pump support. Reasons for STVAD implantation were an acute myocardial infarction, 38%; post-cardiotomy, 38%, decompensated chronic heart failure, 19%; and others, 5%. A STVAD was implanted in a CH in 20 patients (54%), and they had fewer cardiovascular risk factors than those whose STVAD was implanted at the TH. All patients at the CH were at Interagency Registry for Mechanically Assisted Circulatory Support 1 compared with 71% at the TH ($p = 0.014$). Patients from the CH tended to die sooner after LTVAD implant, although long-term survival was similar. At the 1-year follow-up, 65% from the CH were alive or had received a transplant vs 60% from the TH.

Reprint requests: José González-Costello, MD, Division of Cardiology, Columbia University Medical Center, 630 W 168 St, New York, NY, jgcostello@hotmail.com.

Disclosure statement

Dr Naka reports receiving consulting fees from Thoratec and Terumo Heart. Dr Jorde reports receiving consulting fees from Thoratec and Jarvik Heart. None of the other authors as a financial relationship with a commercial entity that has an interest in the subject of the presented manuscript or other conflicts of interest to disclose.

CONCLUSION—Patients with cardiogenic shock in whom a STVAD was implanted in a CH and then were bridged to a LTVAD in a TH had similar long-term survival as those bridged to LTVAD at the TH.

Keywords

community hospital; tertiary hospital; cardiogenic shock; short-term ventricular assist device; long-term ventricular assist device

Long-term left ventricular assist devices (LTVAD) are increasingly being used for patients with refractory heart failure as a bridge to cardiac transplantation (CT) or as destination therapy. This strategy provides a survival rate of 70% at 1 year with the current continuous-flow LTVADs.^{1,2} However, these trials did not include patients who had received a short-term VAD (STVAD) before the LTVAD. STVAD implantation is needed in patients with cardiogenic shock, defined as an Interagency Registry for Mechanically Assisted Circulatory Support (INTERMACS) profile 1,³ to stabilize their hemodynamics, improve end-organ perfusion, and make the patient suitable for a LTVAD or CT, or both.

LTVAD implantation provides better outcomes in high-volume centers.⁴ However, STVAD implantation can be performed in smaller community hospitals (CHs). This initial stabilization with a STVAD must be followed by transfer to a tertiary hospital (TH) in patients who can be candidates for a LTVAD or CT, or both.

In 1999, our group showed the feasibility of this approach in patients with failed cardiectomy using regional networks centered around a bridge-to-transplant TH with an aggressive approach to implanting LTVADs.⁵ Given the scarcity of literature regarding this bridge-to-bridge strategy in a “spoke-to-hub” network, aside from experiences with extracorporeal membrane oxygenation (ECMO)^{6–8} and case reports,⁹ we aimed to compare outcomes of patients whose STVAD was implanted in a CH who were transferred to our TH for implant of a LTVAD vs those who received both implants at our TH.

Methods

This study was approved by the Columbia University Medical Center (CUMC) Institutional Review Board.

Patient population

We performed a retrospective review of the medical records of all patients who received a STVAD before being bridged to a LTVAD at CUMC from August 1997 to May 2010. The patients were divided in 2 groups according to whether the STVAD had been implanted in a CH or at CUMC. Baseline clinical characteristics, laboratory parameters, medications, intra-operative data, and outcomes were obtained by reviewing the electronic medical record, medical records, and operative notes. Data regarding the implant of the STVAD in the CH was obtained from the admission and operative notes at our center. Adverse events were defined as stated in previous LTVAD studies.²

Patient management strategy

The STVAD was implanted in patients considered to be in refractory cardiogenic shock, defined as a cardiac index below 2 liters/min/m², with signs of end-organ dysfunction despite maximal inotropic and intra-aortic balloon pump support. In patients in whom the STVAD had been implanted in a CH, our goal was to decide, as soon as possible, the suitability of the patient for transfer to our center. We followed the protocol used at CUMC for transfer of failed cardiectomy,⁵ which is synthesized in Table 1. Once the patient was at our center, the LTVAD was implanted if the possibilities of myocardial recovery were low: long standing low ejection fraction, late revascularization after a myocardial infarction, or absence of viable myocardium in imaging studies.

Bridge to CT directly from STVADs was attempted in patients with expected short time to CT (blood type B or AB, small body habitus) and in patients who needed biventricular support. During the first years of the study, the LTVAD was implanted during the first few days after the STVAD implant, once basic neurologic status was considered to be present.⁵ During more recent years and coinciding with the introduction of the Centrimag STVAD (Levitronix LLC, Waltham, MA), which can provide flows of up to 10 liters/min, has prolonged durability, increased ease of implantation, and less need for anticoagulation,¹⁰ timing of the LTVAD implant has been deferred to achieve normalization of end-organ perfusion and to better assess neurologic function, including imaging studies.

After 1 to 2 weeks of STVAD support, the following weaning protocol is performed in patients in whom recovery can be expected: acute lymphocytic myocarditis, revascularized viable myocardium, and preserved ejection fraction pre-cardiotomy. With minimal or no inotropic support and a partial thromboplastin time ratio exceeding 2, the right STVAD flow is gradually reduced to 2 liters/min under echocardiographic and hemodynamic monitoring. If over the next 30 minutes the central venous pressure remains below 16 mm Hg, the right ventricle does not dilate, and left STVAD flow does not drop, the right STVAD would no longer be needed. After weaning of the right STVAD is successful, the left STVAD flow is gradually reduced to 2 liters/min. If over the next 30 minutes the left ventricular ejection fraction remains above 45%, the pulmonary capillary pressure remains below 18 mm Hg, and the central venous oxygen saturation remains stable, withdrawal of the left STVAD is also attempted.

Statistical analysis

Normally distributed continuous variables are expressed as mean $\pm$ standard deviation and non-normally distributed continuous variables are expressed as median and interquartile range. Categorical variables are expressed as number and percentage. The comparison of quantitative variables between the 2 groups was done using Student's *t*-test for normally distributed variables and the Mann-Whitney *U* test for non-normally distributed variables. The chi-square test was used for categorical variables with Fisher's correction when appropriate. We studied survival curves censored for CT using the Kaplan-Meier method and compared groups using the log-rank test. Significance was set at $p < 0.05$ (2-tailed). All statistical evaluations were performed with SPSS 18 software (spss Inc, Chicago, IL).

Results

During the study period, 140 patients had been managed at CUMC after the implantation of a STVAD. The STVAD had been implanted at CUMC in 114 patients and in a CH in 26. Figure 1 shows the outcomes of these patients. Twenty-two patients were bridged to CT directly from STVAD, without transition to LTVAD. Patients with STVADs were sent to CUMC from 15 different CHs from the New York and New Jersey areas: 2 CHs sent 3 patients, 2 CHs sent 2 patients each, and the other 11 CHs sent 1 patient each. The name of the referring hospital was not available for 5 patients. Figure 2 shows the number of patients referred from the CHs according to different time periods.

We included in the study 37 patients with a STVAD who were bridged to a LTVAD. Of these, 17 received their STVAD at CUMC, and 20 received the implant at a CH. Table 2 reports the baseline characteristics in both groups. Patients from the CH had undergone more previous cardiac surgery, mainly coronary revascularization.

Status before STVAD

The entire cohort was in critical condition: 66% of patients were supported with an intra-aortic balloon pump and 72% were receiving vasopressors. There were no major differences in drug therapy between the groups before STVAD implant, except for a lower use of dobutamine in the CUMC group that may be explained by the more frequent use of milrinone in our center. Seven patients from the CUMC group and 4 from the CH group had received clopidogrel in the 5 days before their SVAD implant.

Implant of STVAD

Figure 3 shows the reasons for implanting a STVAD. More patients underwent STVAD implant after a previous cardiectomy in the CH than at CUMC (55% vs 18%; $p = 0.03$). The STVADs used are reported in Table 3. The 2 patients in whom venoarterial ECMO was used at the CH were bridged at CUMC with a Levitronix Centrimag Biventricular VAD and then to a LTVAD. The Abiomed BVS 5000 (Abiomed Inc, Danvers, MA) was used predominantly at the CH and the Levitronix Centrimag at CUMC (Table 3). There were no significant differences between the use of biventricular and only left ventricular support between both groups. The time from STVAD implant at the CH to transfer to CUMC was 38 ± 25 hours.

Implant of LTVAD

Time of support with the STVAD until implant of the LTVAD is reported in Table 5 and was shorter in patients transferred from a CH. The LTVADs implanted were 25 Heartmate I, 9 Heartmate II, 1 Thoratec PVAD, and 1 Thoratec Biventricular IVAD (Thoratec Corp, Pleasanton, CA). Concomitant procedures performed during the STVAD or LTVAD implant included 5 closures of the foramen ovale, 3 tricuspid valve repairs, 2 aortic valve repairs (Park's stitch¹¹), and 1 mitral valve repair.

Complications during hospital stay

Right heart failure, defined as the need for right STVAD after implant of the LTVAD or maintenance of the previous right STVAD in the case of biventricular support, was seen in 9 patients (45%) from the CH and in 6 (35%) from CUMC. Two patients from the CH and 1 from CUMC died with the right STVAD in place. In the rest, the right STVAD could be explanted, except in the case of the Thoratec Biventricular IVAD.

The in-hospital complications are reported in Table 4. All strokes were ischemic and were detected after LTVAD implant, with the exception of 2 patients in whom the strokes were detected while they were on STVAD support. Five occurred in the TH group and 3 in the CH. There were 4 peripheral embolic events in the CH implants and none in the TH. Three required surgical intervention. All cases occurred once the LTVAD (3 Heartmate I and 1 Heartmate II) was in place except in 1 patient. In 1 ECMO case, surgical fasciectomy was required after the femoral cannulas were removed. Continuous venovenous hemodialysis was performed in more than 50% of the patients after LTVAD implant but could be discontinued after recovery of kidney function in 45% in the CH group and in 55% in the CUMC group. The others died on hemodialysis.

Outcomes after LTVAD

Time of support with the LTVAD was longer in the CUMC population, but all of the patients in this group came from a later period (2004–2010). Patients from the CH were seen from 1997 to 2010. CT occurred in 11 patients (55%) from the CH and 7 (41%) from CUMC, and median time to CT was 4 months in both groups. The LTVAD was explanted in 1 patient in each group. One patient recovered ventricular function and is alive at 8 years after explant. The LTVAD in the other was explanted due to pocket infection, and surgical revascularization was performed during that procedure. The patient was not a candidate for CT and died 1 year after explant.

Patients from the CH tended to die sooner after LTVAD implant, although long-term survival censored for CT was similar (Figure 4). At 1 month, 80% from the CH were alive or had received allografts vs 100% from CUMC. At 1 year, 65% from the CH were alive or had received allografts vs 60% from CUMC. Median follow-up was 15 months. Three patients from CUMC and 1 from CH remain on LTVAD support awaiting CT.

Death in the CH group occurred during the initial hospital stay in 35%, and the cause of death was multiorgan system failure in 5, sepsis in 1, and sepsis and disabling stroke in another. All of the patients who died came from CHs that had only sent us 1 patient, whereas the patients who came from CHs that had referred us 2 or more patients with a STVAD had a favorable outcome. Death in the CUMC group occurred in 24% of patients during the initial hospital stay due to multiorgan system failure in 3 and to sepsis and right heart failure in 1. Two more patients from this group died after hospital discharge, both 8 months after implant, one after a stroke and the other, for whom the cause of death is unknown, after admission to another hospital.

Discussion

The main finding of our study is that in a population of patients with acute cardiogenic shock, implant of a STVAD in a CH and then bridge to LTVAD at a TH provided similar long-term survival as those who received both implants at a TH.

Feasibility of a “spoke-to-hub” network

Cardiogenic shock complicates acute myocardial infarction (AMI) in up to 8% of patients¹² and has a mortality of up to 50% at 6 months, despite early revascularization.¹³ Post-cardiotomy shock occurs after 3% to 4% of all cardiac surgeries,¹⁴ and mortality remains around 40% despite the advent of VADs.¹⁵ The implantation of a STVAD⁵ or ECMO¹⁶ as a bridge to CT or to LTVAD can improve survival in patients in INTERMACS class 1, who otherwise have a higher mortality rate when implanted with a LTVAD.¹⁷

Figure 1 shows that patients in whom a STVAD was implanted at CUMC implied a mortality of 45%. The relatively low mortality of patients from the CH probably implies a selection of transferred patients. Therefore, the implementation of a “spoke-to-hub” network may provide similar outcomes to those achieved in a TH to a higher number of patients and expand its use to all patients with cardiogenic shock and not only to those after a failed cardiotomy.⁵ Good candidate selection, timing of transport, and fluid communication between the “spoke” and “hub” centers is critical to achieve good outcomes. Although the numbers are low, that more experienced CHs had better outcomes could imply that a more focused approach from the “hub” center toward these selected “spoke” centers may increase the number of patients that benefit from STVAD implant with good final outcomes and improve competence in STVAD support at the CH. No serious complications during transport were reported, although given the retrospective nature of our study, we would not have detected unsuccessful transfers. All transfers were performed by ambulance and none by air transport.

STVAD for cardiogenic shock

Our patients were in critical condition, and half of them had suffered a cardiac arrest. This was the reason a STVAD was implanted, because the risk of implanting a LTVAD at that moment was deemed too high.¹⁷ The survival curves of both groups show that all of the deaths in the CH group occurred early after implant of the LTVAD. This could be attributed to a higher percentage of post-cardiotomy shock after AMI¹⁸ and a higher use of the Abiomed STVAD in the CH. The Abiomed BVS-5000 is a less durable device that needs higher anticoagulation and therefore requires a faster transfer to LTVAD. This coupled, with the fact that the Abiomed provides lower flows than the Levitronix, also means that the CH patients probably underwent LTVAD surgery with end-organ recovery that was not as complete, resulting in higher earlier mortality. Our current practice is to wait longer with a STVAD to achieve good end-organ recovery, extubate, start physical therapy, and evaluate the possibility of recovery. This is more attainable with the newer continuous-flow STVADs such as the Levitronix Centrimag.¹⁰ Implantation of these smaller STVADs in the CH with the support of a TH before transfer may be the next step toward improving outcomes.

Outcomes after bridge to LTVAD

Death occurred in the CUMC group at a later stage and may reflect the higher prevalence of comorbidities in this group. As a whole, the strategy of bridging from STVAD to LTVAD and then to CT in our population provided similar survival to those patients bridged to CT with continuous-flow LTVADs,¹ although the patients from our cohort are selected in the sense that they would not have received a LTVAD unless they did well on the STVAD. This strategy may be able to rescue patients in critical cardiogenic shock, but it comes at a price of an increased need for temporary right STVAD, continuous venovenous hemodialysis, and a higher incidence of stroke or embolic events than if only a LTVAD had been needed.¹ Therefore, if the STVAD could have been avoided, these outcomes might have been improved and the aforementioned costs reduced. This may be achieved by the implantation of a LTVAD at an earlier stage. Also, early primary percutaneous coronary intervention with intra-aortic balloon pump may abort or reverse cardiogenic shock after AMI and avoid the need for STVADs.^{12,13,19}

An important limitation is that we do not know how many STVADs were implanted in the CHs. Also, STVADs are used less often and sometimes belatedly in CHs due to less experience, and thus, our study could be showing only the tip of the iceberg of patients in need of a STVAD.^{20,21} We did not have laboratory data of these patients before STVAD implant, and we, therefore, only show the first values once the patient arrived at CUMC. The STVADs were different in both groups, which is a limitation for comparison purposes; however, given our results, it also proves that what is important is restoring the hemodynamics, regardless of how this is accomplished.

In conclusion, outcomes of patients receiving a STVAD at a CH who are successfully transferred to a TH for LTVAD are similar to those who received STVADs at the TH and were then bridged to LTVAD. This suggests that despite the differences in patient populations, once a patient from the CH makes it through to the TH, the outcomes with LTVAD reflect the experience of the TH rather than the patient population.

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Figure 1.

Flow-chart shows the outcomes of patients with a short-term ventricular assist device (VAD) managed at Columbia University Medical Center. CT, cardiac transplantation; LTVAD, long-term ventricular assist device.

Figure 2.
Number of patients with short-term ventricular assist devices implanted at a community hospital and referred to Columbia University Medical Center according to 3 periods of time.

Figure 3.

Causes of a short-term ventricular assist device implant at Columbia University Medical Center (dark gray) and at a community hospital (light gray). Others were 1 myocarditis at Columbia and 1 non-explained acute heart failure at the community hospital. AMI, acute myocardial infarction; CABG, coronary artery bypass graft; CHF, decompensated chronic heart failure; PCI, percutaneous coronary intervention.

Figure 4. Kaplan-Meier survival curves censored for cardiac transplant according to where the short-term ventricular assist device was placed.

Table 1

Evaluation of Patients with a Short-term Ventricular Assist Device at a Community Hospital Before Transfer to a Tertiary Hospital

Parameters evaluated	Objective
Type of STVAD and cannulation	Ensure adequate decompression of LV
Invasive hemodynamics	Evaluate adequate LVAD support and/or need for BiVAD
Mixed venous oxygen saturation	
Arterial oxygen saturation	Screen for ARDS. PO ₂ < 100 mm Hg on 100% oxygen would be a contraindication for transfer
Echocardiogram, ECG, cardiac enzymes	Evaluate potential for myocardial recovery
Hepatic and renal function (urine output)	Evaluate end-organ function
Basic neurologic function	Considered present if patient moved all extremities
On-going post-operative bleeding	Would delay transfer until chest tube drainage < 100 ml/hour

ARDS, adult respiratory distress syndrome; BiVAD, biventricular assist device; ECG, electrocardiogram; LV, left ventricle; LVAD, left ventricular assist device; PO₂, partial pressure of oxygen; STVAD, short-term ventricular assist device.

Table 2

Baseline Characteristics

Baseline variables ^a	STVAD		<i>p</i> -value
	At CUMC (<i>n</i> = 17)	At CH (<i>n</i> = 20)	
Age, years	53 ± 21	52 ± 11	0.701
Male sex	12 (70)	15 (75)	0.763
Cardiovascular risk factors			
Coronary heart disease	12 (71)	15 (75)	>0.99
Diabetes mellitus	8 (47)	3 (15)	0.033
Smoking history	12 (71)	6 (30)	0.014
Hypertension	9 (53)	5 (25)	0.085
Previous cardiac surgery	6 (35)	12 (60)	0.136
LVEF before STVAD, %	20 (9–25)	20 (11–24)	0.975
Inotropes			
Milrinone	17 (100)	13 (65)	0.022
Dobutamine	6 (35)	14 (70)	0.021
Dopamine	5 (29)	3 (15)	0.369
Vasopressors			
Norepinephrine	7 (47)	13 (65)	0.175
Epinephrine	4 (25)	6 (30)	0.943
Vasopressin	6 (35)	10 (50)	0.23
Intra-aortic balloon pump	11 (65)	13 (65)	0.985
Mechanical ventilation	10 (59)	14 (70)	0.55
CVVHD	1 (6)	1 (5)	0.871
Cardiac arrest	9 (56)	9 (45)	0.6
INTERMACS profile 1	12 (71)	20 (100)	0.014

CH, community hospital; CUMC, Columbia University Medical Center; CVVHD, continuous venovenous hemodialysis; INTERMACS, Interagency Registry for Mechanically Assisted Circulatory Support; LVEF, Left ventricular ejection fraction; STVAD, short-term ventricular assist device.

^aValues for quantitative variables are expressed as mean ± standard deviation for normally distributed variables and as median (interquartile range) for those not normally distributed. Values for qualitative variables are expressed as number (%).

Table 3

Types of Short-term Ventricular Assist Device Used

Device	STVAD, No. (%)	
	At CUMC (<i>n</i> = 17)	At CH (<i>n</i> = 20)
VA ECMO	2 (12)	2 (10)
Biomedicus	0	2 (10)
Abiomed BVS 5000		
LVAD	0	8 (40)
BiVAD	0	8 (40)
Levitronix Centrimag		
BiVAD	9 (52)	0
LVAD	3 (18)	0
Impella 5.0	2 (12)	0
Tandem Heart	1 (6)	0

BiVAD, biventricular assist device; CH, community hospital; CUMC, Columbia University Medical Center; LVAD, left ventricular assist device; STVAD, short-term ventricular assist device; VA ECMO, venoarterial extracorporeal membrane oxygenation.

Table 4**Outcomes After Surgery**

Outcomes^a	STVAD		p-value
	At CUMC (n = 17)	At CH (n = 20)	
Support duration, days			
STVAD	12 (5.5–24)	3.5 (1–7.5)	0.031
LTVAD	146 (69–185)	56 (18–107)	0.015
RVAD if needed	12 (9.5–22.5)	6.5 (3–11)	0.067
Adverse events			
Sepsis	7 (41)	8 (40)	0.79
Ischemic stroke	5 (29)	3 (15)	0.288
Other embolic event	0	4 (20)	0.155
CVVHD	9 (53)	11 (55)	0.9
Bleeding requiring surgery	6 (35)	9 (45)	0.676
LTVAD pocket infection	4 (25)	1 (5)	0.245
Length of stay, days			
Intensive care unit	30 (13–52)	26 (12–40)	0.437
Hospital	75 (44–96)	54 (28–79)	0.562
CT	7 (41)	11 (55)	0.402
Alive or CT at last follow-up	10 (60)	13 (65)	0.699

CH, community hospital; CT, cardiac transplant; CUMC, Columbia University Medical Center; CVVHD, continuous venovenous hemodialysis; LTVAD, long-term ventricular assist device; RVAD, right ventricular assist device; STVAD, short-term ventricular assist device.

^aValues for quantitative variables are expressed as median (interquartile range), and values for qualitative variables are expressed as number (%).