

Use of extracorporeal membranous oxygenator in transcatheter aortic valve replacement

George Makdisi¹, Peter B. Makdisi², I-Wen Wang³

¹Gulf Coast Cardiothoracic Surgery Institute, Tampa General Hospital, Tampa, FL, USA; ²Division of Gynecologic Surgery, Mayo Clinic College of Medicine, Rochester, MN, USA; ³Division of Cardiothoracic Surgery, Indiana University School of Medicine, Indiana University Health, Methodist Hospital, Indianapolis, IN, USA

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Correspondence to: I-Wen Wang, MD, PhD. Division of Cardiothoracic Surgery, Indiana University School of Medicine, Indiana University Health, Methodist Hospital, Indianapolis, IN 46202, USA. Email: IWang@iuhealth.org.

Abstract: The superiority of transcatheter aortic valve replacement (TAVR) compared with medical therapy for patients with aortic stenosis (AS) who are not suitable candidates for surgery had been proven. Cardiopulmonary bypass (CPB) is rarely used in TAVR. Reports of early use of extracorporeal membranous oxygenator (ECMO) have promising outcomes. ECMO offers the option of cardiac support rescue in case of intraoperative hemodynamic instability and can be instituted in advance when hemodynamic instability is expected. Here we review the English literature about the use of ECMO in TAVR procedures, and discuss the indications and rationale for its use as well as its advantages.

Keywords: Transcatheter aortic valve replacement (TAVR); TAVI; extracorporeal membranous oxygenator (ECMO); aortic stenosis (AS)

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Introduction

Aortic stenosis (AS) is the most common form of valvular heart disease that predominantly affects elderly patients. Its prevalence is estimated at 4.6% in patients greater than 75 years of age (1). Patients with severe AS who develop symptoms have a very poor prognosis with significant decrease in survival and a 50% mortality within 2 years without treatment (2). The operative risk is elevated during conventional aortic valve replacement with a mortality ranging up to 30% in patients with advanced heart failure (3-6). After the introduction of transcatheter aortic valve replacement (TAVR) by Cribier *et al.* (7) in 2002, the superiority of TAVR compared with medical therapy for patients considered too high risk for surgery has been established. TAVR has become more attractive as the appropriate alternative for elderly patients with very

high surgical risk (4,5,8-11). Considering the prognosis of patients who are not candidates for TAVR nor conventional aortic valve replacement have mortality rate at 6 months is 31.8% and at 2 years 53.4% (6,12), Leon *et al.* and Reiss *et al.* (13,14) concluded in the PARTNER trial that “TAVR should be the new standard of care for patients with AS who are not suitable candidates for surgery”. Nowadays, TAVR continues to grow beyond those populations originally studied, to include those with severe left ventricular dysfunction and those with failing surgical homografts (valve-in-valve TAVR) (15,16). Although, TAVR expands the options for patients with severe AS and is less-invasive alternative in high-risk frail and decompensated patients, it remains a complex procedure that may result in serious complications (e.g., severe aortic regurgitation, major bleeding, device embolization, coronary occlusion, and aortic dissection). While these complications are

uncommon, they may precipitate sudden hemodynamic collapse necessitating cardiopulmonary bypass (CPB) or other mechanical support (17,18).

Use of CPB in TAVR procedures

Mechanical circulatory support (MCS) devices were used in nearly 10.6% of the patients who underwent TAVR procedures, among these CPB was used between 1.2% to 6.6% of TAVR cases (8,18,19). Drews *et al.* (20), however, reported increase of the CPB use to 13% of these very high-risk patients during valve implantation. It also has been shown that using MCS in TAVR procedures was associated with significantly high rates of mortality, complications, and increased length and cost of hospitalization (8). The use of MCS was also identified as an independent predictor of increased early and late mortality (21). Furthermore, it was also reported that CPB recipients had the highest 1-year mortality rate compared to patients who required intra-aortic balloon pump (IABP) and no support at all: 1-year mortality rate was 52.8% in those who received MCS emergently versus planned MCS of 40.3% versus no MCS of 21.6% (19).

Not all patients electively put on CPB during the procedure need the support. However, elective CPB should be considered in patients with severe cardiogenic shock, poor left ventricular function, or enlarged right ventricle with severe pulmonary hypertension (20). Its elective use will increase the safety in critically ill patients in order to maintain hemodynamic stability during the phases of rapid pacing and to eliminate manual cardiopulmonary resuscitation as the postoperative course of these patients is unfavorable (20).

CPB is also used as an intraoperative emergent method to rescue patients from myocardial collapse as a consequence of the most severe TAVR complications and allows time to perform a thorough diagnostic evaluation and facilitate a safe definitive treatment of the complication (18). Intraoperative emergent complications needing CPB might include severe paravalvular leak in patients with depressed left ventricular function, severe diastolic dysfunction, or significant mitral regurgitation. The ability of these patients to compensate for acute severe aortic insufficiency may be compromised (22-25). The use of CPB allows time for a full assessment of the leak and either re-ballooning of the prosthesis or preparation of a second device for valve-in-valve treatment. CPB also can be used in cases of coronary malperfusion, or severe bleeding at the apex of the left ventricle which

allows decompression of the ventricle to facilitate a safe primary repair. The hemodynamic support provided by CPB is not without potential harm as it is well documented in the literature that CPB is associated with undesirable side effects, e.g., activation of inflammatory mediators, increased pulmonary vascular resistance, platelet activation, coagulopathy and impaired renal function (26-29).

Use of extracorporeal membranous oxygenator (ECMO) as an alternative to CPB in TAVR procedures

The advances in ECMO technology and the improvement of commercially available percutaneous cannulas of different sizes and lengths in the complete implantation sets make ECMO at present day a more powerful resuscitation tool (30,31). It is also relatively less expensive than some forms of MCS (32). Additionally, it is easier to transport the patient with ECMO support or to use it bedside if necessary. Miniaturized ECMO systems can be highly effective and safe for the initiation of emergency ECMO while performing cardiopulmonary resuscitation (e-CPR) in the cardiac catheterization laboratories. Especially for patients in need of cardiac surgery, transfer to extracorporeal assistance can be more easily processed by using miniaturized ECMO systems (30). Furthermore, ECMO provides both cardiac and pulmonary support for patients for some duration until they recover from the complications or a decision is made for definite operative plans. The unit can also provide mild hypothermia for cerebral protection in the event of complete prolonged hemodynamic collapse (33).

Use of ECMO as emergency rescue

Along with some case reports regarding using ECMO as emergency rescue (34-36), there are four papers (22-24,30) reporting series of multiple patients these are listed in *Table 1* (1), in these series the using of ECMO permitted to procedure completion in 44-66%, support to surgery in 33-56% and survival to discharge in 44-75% of cases. Over all in the cohort study published by Husser *et al.* (22): the veno-arterial extracorporeal membrane oxygenation (VA-ECMO) cohort was significantly higher risk (median logistic EuroSCORE 26% vs. 15%). They concluded that emergent implantation of VA-ECMO for circulatory support appears to be safe and feasible to stabilize the patient for further treatment (22). Both Seco *et al.* and Husser *et al.* concluded that VA-ECMO may potentially minimize the effect of

Table 1 Emergency use of ECMO

Study	All TAVR cases included	Emergency/rescue ECMO	Procedure completion	Support to surgery	Survival to discharge (%)
Husser <i>et al.</i> (22)	131	9 (7%)	4 (44%)	5 (56%)	44
Seco <i>et al.</i> (23)	100	3	2 (66%)	1 (33%)	66
Banjac <i>et al.</i> (24)	230	10 (4.3%)	–	5 (50%)	70
Arlt <i>et al.</i> (30)		4	2 (50%)	2 (50%)	75

ECMO, extracorporeal membranous oxygenator; TAVR, transcatheter aortic valve replacement.

Table 2 Prophylactic use of ECMO

Study	All TAVR cases included	Prophylactic ECMO	Procedure completion	Support to surgery	Survival to discharge (%)
Husser <i>et al.</i> (22)	131	9 (7%)	9 (100%)	0	100
Seco <i>et al.</i> (23)	100	8 (8%)	8 (100%)	0	100

ECMO, extracorporeal membranous oxygenator; TAVR, transcatheter aortic valve replacement.

TAVR complications (22,23). Most common reasons for emergent peri-procedural initiation of ECMO were: (I) ventricular perforation; (II) hemodynamic instability; (III) refractory cardiogenic shock; and (IV) hemodynamic deterioration due to ventricular arrhythmia.

These outcomes are comparable to the literature about using CPB for emergency support of intraoperative TAVR complication. Eggebrecht *et al.* (37) reported 12 patients (4%) of their series required emergent CPB; all 4 needed surgical conversion with a resulting 30-day survival of 52%. Roselli *et al.* (18) also reported a single-centre series, 12 (4%) of 303 patients undergoing TAVR required emergency CPB following complications resulting in hemodynamic collapse. In three patients a period of resuscitation with CPB was sufficient for recovery, while nine required complication-specific procedures (e.g., valve-in-valve TAVR, conversion to open procedure and SAVR). Seven patients required additional circulatory support, five via IABP, and two via VA-ECMO. Thirty-day mortality was 16% with only 45% survival at 12 months. This is far lower survival than in TAVR patients not requiring emergency CPB (19).

Use of ECMO as prophylactic measure

There is little in the literature reported about using prophylactic support with VA-ECMO with only two papers (22,23) reporting series of multiple patients. These are

listed in *Table 2*. In a cohort study about ECMO use in nine TAVR patients, the authors noted that preemptive use of ECMO in selected high risk patients was associated with improved procedural success (100%) and 30-day survival to discharge of 100%. They concluded that prophylactic strategy may be suitable in the following scenario: severely impaired left ventricular function, slow recovery from rapid left ventricular pacing during testing of a pacemaker, high vasopressor requirements during general anesthesia or concomitant high risk PCI (22). Seco *et al.* (23) reported the same results in their series of eight patients. These outcomes are also comparable to the published data about using CPB in patients of very high risk (logistic EuroSCORE 59%, STS 35%). Overall technical success (94%) and peri-procedural complications were comparable to the standard TAVR cohort, suggesting planned ECMO may be a feasible adjunct in high-risk cases that may otherwise have been declined TAVR (20).

Given that TAVR patients are often frail and decompensated, early signs of hemodynamic instability during anesthetic induction may be predictive of subsequent problems and dictate additional measures to be initiated for stabilization (38).

Conclusions

The outcomes of using ECMO as prophylactic are

comparable with conventional TAVR patients, whereas requirement for emergency VA-ECMO was associated with significantly lower procedural success and survival. Using of ECMO could replace CPB used as prophylaxis in high risk patients undergoing TAVR insertion and would be used to stabilize patients in cases of hemodynamic instability with or without ischemic changes, with comparable results to CPB use.

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Footnote

Conflicts of Interest: The authors have no conflicts of interest to declare.

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