# Evaluation of Left Ventricular Overload and Use of Unloading Techniques in Venoarterial Extracorporeal Life Support: A Nationwide Survey

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Cardiogenic shock (CS) and cardiac arrest (CA) are among the most lethal complications of acute cardiovascular disease, affected by high in-hospital mortality rates. Venoarterial extracorporeal life support (VA ECLS) is increasingly used either in adults or children with acutely impaired cardiac function refractory to conventional medical therapy. One of the most important concerns in VA ECLS is the increased left ventricular (LV) afterload due to retrograde aortic perfusion, depending on the configuration mode. This could slow myocardial

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**Table 1. Center Information, VA ECLS Information, and LV Unloading Strategy From 18 Italian Tertiary Cardiac Surgical Centers**

| | |
|---|---|
| Overall centers | 18 (100) |
| Center information | |
| Type of center | |
| Non-surgical center, n (%) | 0 (0) |
| Surgical center, n (%) | 11 (61.1) |
| Transplant center, n (%) | 7 (38.9) |
| Type of ECLS center | |
| Cardiac, n (%) | 3 (16.7) |
| Both cardiac and respiratory, n (%) | 15 (83.3) |
| Age groups treated | |
| Adult only, n (%) | 11 (61.1) |
| Adult and pediatric, n (%) | 3 (16.7) |
| Adult, pediatric, and neonatal, n (%) | 4 (22.2) |
| VA ECLS information | |
| VA ECLS runs per year | |
| <20, n (%) | 7 (38.9) |
| 21–40, n (%) | 7 (38.9) |
| 41–100, n (%) | 4 (22.2) |
| Use of PAC in VA ECLS patients | |
| <25%, n (%) | 4 (22.2) |
| 25–50%, n (%) | 4 (22.2) |
| 51–75%, n (%) | 3 (16.7) |
| >75%, n (%) | 7 (38.9) |
| LV overload information | |
| Absence of overload definition, n (%) | 10 (55.5) |
| Daily check for an overload condition, n (%) | 16 (88.8) |
| LV unloading information | |
| Presence of an institutional unloading strategy, n (%) | 8 (44.4) |
| Type of unloading when indicated | |
| Conservative unloading, n (%) | 15 (83.3) |
| <25%, n (%) | 3 (20.0) |
| 26–50%, n (%) | 5 (33.3) |
| 51–75%, n (%) | 2 (13.3) |
| >75%, n (%) | 4 (26.7) |
| Active interventional, n (%) | 18 (100) |
| <25%, n (%) | 2 (11.2) |
| 26–50%, n (%) | 3 (16.7) |
| 51–75%, n (%) | 8 (44.4) |
| >75%, n (%) | 5 (27.7) |
| Timing of active interventional unloading | |
| Prophylactical (at the same time of VA ECLS), n (%) | 10 (55.5) |
| IABP | 8 (80.0) |
| Impella | 1 (10.0) |
| Other | 1 (10.0) |
| Early (within 6 hours from VA ECLS), n (%) | 11 (61.1) |
| Setting of active interventional unloading | |
| Figure in charge of interventional unloading | |
| Intensivist/anesthesiologist, n (%) | 9 (50) |
| Interventional cardiologist, n (%) | 1 (5.6) |
| Cardiac surgeons, n (%) | 7 (38.8) |
| Heart team, n (%) | 1 (5.6) |
| Location of interventional unloading | |
| ICU-bed, n (%) | 8 (44.4) |
| Cath-lab, n (%) | 6 (33.3) |
| Operating theater, n (%) | 4 (22.3) |
| Unloading considered in specific etiology, n (%) | 8 (44.4) |
| Postcardiotomy, n (%) | 3 (37.5) |
| Cardiac arrest (ECPR), n (%) | 0 (0) |
| Cardiogenic shock (nonpost cardiotomy, non-ECPR), n (%) | 5 (62.5) |

ECLS, extracorporeal life supports; ECPR, extracorporeal pulmonary resuscitation; IABP, intra-aortic balloon pump; ICU, intensive care unit; LV, left ventricular; PAC, pulmonary artery catheter; VA, venoarterial.

recovery or further damage the myocardium and negatively affect survival. Currently, several different approaches have been proposed aiming at preventing or treating LV overload during VA ECLS.[1] However, the definition of LV overload and the practice of LV unloading are still poorly characterized and often based on local expertise with a great deal of variability.[2] We thus launched a nationwide survey among 18 tertiary cardio-surgery Italian centers to assess center-based LV overload identification and the actual use of LV unloading strategies.

Treatment heterogenicity was strongly confirmed in our national survey (Table 1 and Figure 1). As a matter of fact, when indicated, active interventional LV unloading techniques were applied by all enrolled centers in our survey with 72% of centers declaring their use in more than 50% of VA ECLS cases. A total of 83% of the centers chose a noninvasive LV unloading approach with only six out of 15 centers (40%) declaring their use in more than half of their cases. Among the available noninvasive strategies, inotropes, and avoidance of fluid overload, either with diuretics or continuous renal replacement therapy, were the most commonly used. Surprisingly, VA ECLS flow modulation was not widely applied (Supplemental figure, Supplemental Digital Content, http://links.lww.com/ASAIO/B173, http://links.lww.com/ASAIO/B174).

Intra-aortic balloon pump (IABP) was frequently implemented by all centers and was considered the first choice in those practicing prophylactical unloading (at the same time of VA ECLS start), despite its controversial role in this setting. As an early, first step approach, IABP seems to be an effective and indirect strategy to prevent or treat mild LV overload.[3,4]

Besides IABP, Impella is widely used to actively and directly unload the LV. The effectiveness of this transaortic microaxial pump is well-known either in preclinical[5] or clinical settings.[6] By directly drawing blood from the LV, Impella significantly decreases myocardial end-diastolic pressure and volume, reducing LV work and myocardial oxygen consumption as compared with other unloading techniques. Furthermore, this strategy may allow to better manage the weaning process from VA ECLS, possibly leading to a higher chance of recovery or to bridge the patient to durable LV assist devices or heart transplantation.[7] Surprisingly, Impella was not applied by almost one-third of the enrolled centers and only 10% implemented Impella in more than half of their VA ECLS patients. The common need of public health care systems to meet cost-containment objectives may partially explain this finding.

Overall, the surgical techniques for LV unloading were rarely used. Among them, direct LV surgical vent is the most applied strategy for achieving a satisfactory LV unloading. In addition, atrial septostomy and percutaneous LV catheter are barely implemented. Yet, more than half of the centers did not use either direct pulmonary artery (PA) surgical vent, LA cannula, or percutaneous PA drainage.

Besides the heterogenicity emerging from the literature and further confirmed by this nationwide survey, the lack of common indications represents the most crucial dilemma. On one hand, this issue does not allow any comparison between centers strategies. On the other hand, the reliability of the results reported by the recent multicentric studies might have been highly affected. Both the absence of an institutional overload definition and of an unloading strategy in more than half of the enrolled centers further highlighted the issue.

The findings from our national survey underlined the central role of echocardiography as the key-tool to detect LV overload during VA ECLS. Both transthoracic or transesophageal echocardiography are bedside, noninvasive or mild invasive techniques, and provide crucial information which ultimately drives the decision-making process. Most of the centers enrolled in the survey identified the aortic valve (AV) opening impairment

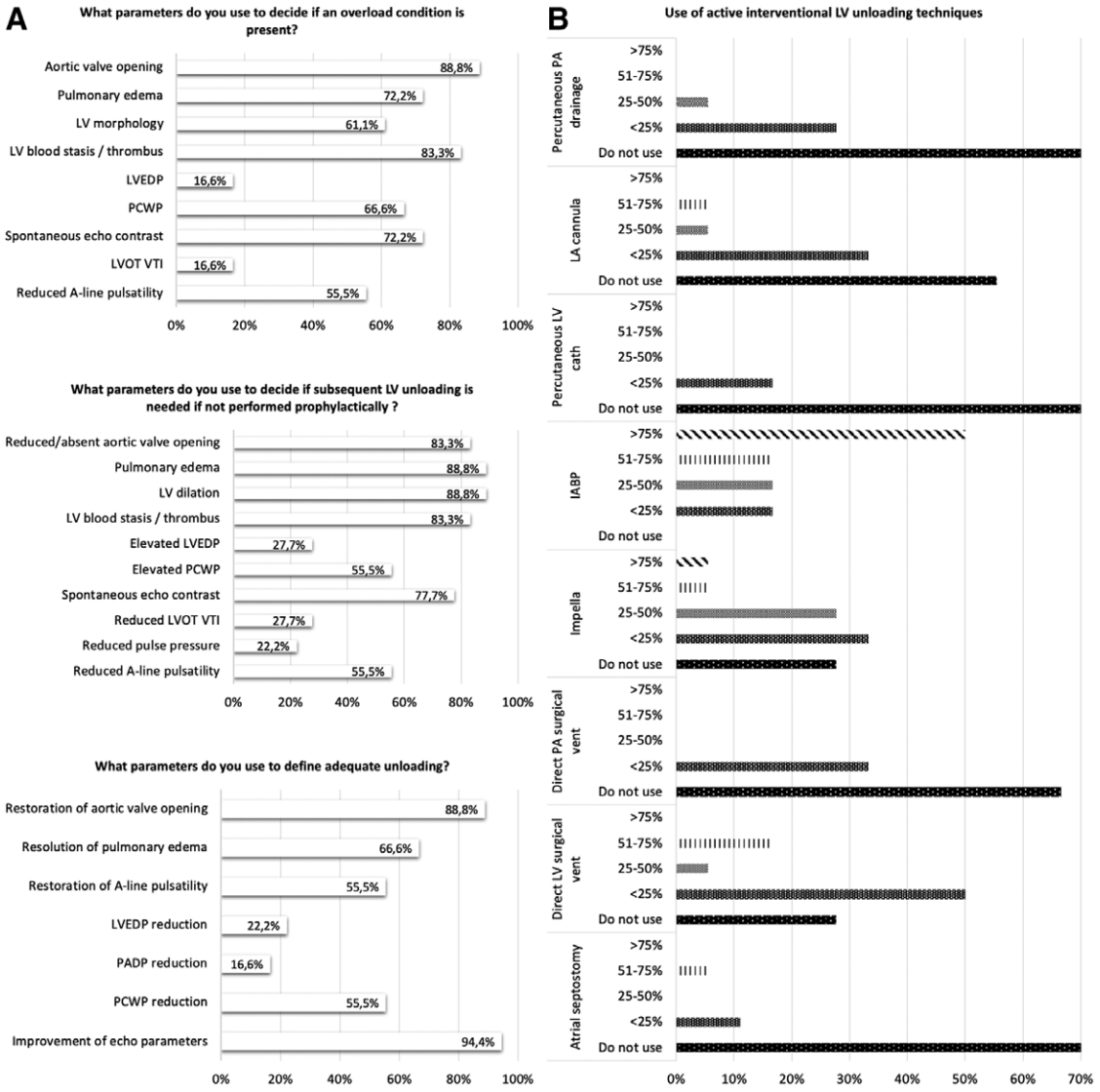


**Figure 1.** Methods and parameters used to detect LV overload and to define adequate unloading are highlighted in (**A**). LV venting active interventional techniques and their prevalence of use are shown in (**B**). A-line, arterial line; IABP, intra-aortic balloon pump; LA, left atrial; LV, left ventricle; LVEDP, left ventricular end-diastolic pressure; LVOT VTI, left ventricular outflow tract velocity time integral; PA, pulmonary artery; PADP, pulmonary artery diastolic pressure; PCWP, pulmonary capillary wedge pressure.

(88.8%), LV dilation (61.1%), and stasis with LV "smoke-like" effect (83.3%) as the most important overload ultrasound signs. Among them, AV opening impairment indicates a severe LV overload which does not even allow any effective pressure gradient across AV. This ultimately leads to a high risk for LV chamber thrombosis and pulmonary edema. Therefore, particularly in case of AV protracted closure, LV should be immediately and actively unloaded. In addition, restoring AV opening and improving echocardiographic parameters should be set as therapeutical targets every time an active unloading strategy is carried out. The LV outflow tract velocity time integral (LVOT VTI) was barely considered as a marker of LV overload (16.6%). Although LVOT VTI may estimate the native LV stroke volume, this quantitative parameter could be highly influenced by the increased afterload, particularly if VA ECLS is set at high flow per minute. Consequently, LVOT VTI should be reserved for the weaning phase.

Approximately 40% of centers declared the use of pulmonary artery catheter (PAC) in almost all VA ECLS-treated patients. Almost two out of three centers in our survey considered PAC as a useful tool in LV congestion detection and follow-up. The role of PAC is extremely controversial, particularly when combined with mechanical circulatory supports.[8] However, high postcapillary wedge pressure (beyond 15 mm Hg) may reflect a significant LV congestion requiring active unloading.[9]

In addition, the loss of arterial pulse may promptly indicates a significant mismatch between the ECLS backward flow and the native LV output. If the invasive arterial pulse drops, particularly in the early ECLS phase, further investigation aiming to detect any grade of LV congestion would be appropriate (*ie*, echocardiography).

The early detection of LV overload should be set as a primary goal during VA ECLS to avoid significant and life-threatening

complications. Even if lung congestion may dramatically worsen the outcomes,[10] this is theoretically a reversible condition, and its improvement should be set as a primary goal of any unloading strategy. On the contrary, LV thrombus might be a demanding complication which is frequently irreversible and lethal.[11]

Overall, the real clinical scenario has been showing a high variable rate of LV unloading, inconstantly ranging from 2% to 68%. As a matter of fact, indications and techniques for LV unloading are still based on local consensus and expert documents, leading to different management. The heterogeneity in LV overload diagnosis and LV venting indications and techniques was the major finding of the present survey. We strongly believe that an urgent action is required to create a universal algorithm for LV unloading to be used for patients on VA ECLS, including standardization of hemodynamic and ventilatory management, with the aim to truly compare the related clinical outcomes.



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