rates leading to higher adjusted inpatient hospital costs at 30-, 60-, and 90-day follow-up. Quantifying the differences in hospital resource utilization should not necessarily lead to radical changes in patient care principles, but it is important to understand the full scope of what it takes to care for these patients.

Use of an administrative database has several inherent limitations, particularly in a study such as this where comorbidities and other patient characteristics are of paramount importance. The identification of these clinical diagnoses using International Classification of Diseases-Clinical Modifications codes can be problematic and not accurately capture the exact cohort that is desired. As the authors state, only mortality within the index hospitalization is captured in the Premier database and only readmissions to the same index hospital are captured—this

could cause very inaccurate readmission data. Even after consideration of the limitations of the Premier database, this study has merit in evaluating the risk factors for postcardiotomy low cardiac output syndrome and in quantifying its hospital resource utilization profile.

References

1. Maganti M, Badiwala M, Sheikh A, Scully H, Feindel C, David TE, et al. Predictors of low cardiac output syndrome after isolated mitral valve surgery. *J Thorac Cardiovasc Surg*. 2010;140:790-6.
2. Algami KD, Maganti M, Yau TM. Predictors of low cardiac output syndrome after isolated coronary artery bypass surgery: trends over 20 years. *Ann Thorac Surg*. 2011;92:1678-84.
3. Sultan I, Habertheuer A, Wallen T, Siki M, Szeto W, Bavaria JE, et al. The role of extracorporeal membrane oxygenator therapy in the setting of type A aortic dissection. *J Card Surg*. 2017;32:822-5.
4. Duncan AE, Kartashov A, Robinson S, Randall D, Zhang K, Luber J, et al. Risk factors, resource utilization and cost of postoperative low cardiac output syndrome. *J Thorac Cardiovasc Surg*. 2022;163:1890-8.e10.

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Commentary: The high cost of low output

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The lack of a universal definition of low cardiac output syndrome (LCOS) poses a significant barrier for clinicians and researchers investigating this common and highly morbid complication of cardiac surgery. Duncan and colleagues¹ present a study of the incidence, predictors, cost, and clinical implications of LCOS in adult cardiac surgery patients.

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CENTRAL MESSAGE

Low cardiac output syndrome after cardiac surgery is common and has poor clinical outcomes despite pharmacologic and mechanical circulatory support. We must identify high-risk patients and optimize their perioperative care.

Previous literature is largely limited to single-center and retrospective reports. Furthermore, these studies often span up to 20 years, encompassing a wide range of evolving surgical and critical care practices.

The present study is large, multicenter, and contemporary. The authors define LCOS as hemodynamic instability

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requiring 2 or more inotropes on the first postoperative day, or mechanical circulatory support (MCS) during or within 5 days of surgery. Their definition does not depend on clinicians' bedside assessment of volume status and tissue perfusion, which can vary widely. It acknowledges that short-term inotropic support can be part of routine early recovery from cardiac surgery and excludes patients whose myocardial function recovers by the first postoperative day. However, the absence of clinical or biochemical criteria for the initiation of inotropic or mechanical support calls into question the definition's validity and reproducibility.

After excluding patients requiring preoperative MCS, Duncan and colleagues.¹ report an overall LCOS incidence of 10.1% amongst 59,810 studied patients. When separated by procedure type, the rates of LCOS in patients undergoing isolated coronary artery bypass grafting, isolated aortic valve replacement, and isolated mitral valve replacement are similar to previous literature at 6% to 10%.²⁻⁴ Combined coronary artery bypass grafting and mitral valve replacement had the highest incidence of LCOS at 27%.

The authors examined the relationship between LCOS and clinical outcomes, including in-hospital mortality, postoperative complications (eg, myocardial infarction, acute kidney injury, need for hemodialysis, and acute respiratory failure), and discharge status. The significant association between LCOS and most of these outcomes emphasizes that LCOS is associated with multiple end-organ failure despite intensive pharmacological therapy and MCS.

These data provide impetus for perioperative teams to seek to optimize patients at risk of LCOS in each stage of care. Preoperatively, malnutrition and frailty can be optimized. Malnutrition, defined as an unintentional nutritional intake imbalance (not necessarily decreased intake), is present in as many as 1 in 5 patients presenting for cardiac surgery and has been strongly associated with postoperative LCOS, prolonged intensive care unit and hospital length of stay, and postoperative complications.^{5,6} The use of enhanced recovery protocols, such as nutritional and

exercise prehabilitation, has been associated with a reduction in complications and hospital length of stay of up to 50% in vulnerable patients, although it has yet to be shown that this may mitigate LCOS in cardiac surgery patients.⁷ Intraoperatively, improving myocardial protection strategies may reduce ischemia/reperfusion injury and subsequent depressed myocardial function, which is central to LCOS.⁸ And postoperatively, there is evidence that early identification of LCOS through hemodynamic monitoring, combined with goal-directed fluid and inotropic therapy, can decrease intensive care unit and hospital length of stay.^{9,10} This patient-centered approach may decrease the financial costs of LCOS while enhancing recovery and quality of life in vulnerable patients.

References

1. Duncan AE, Kartashov A, Robinson SB, Randall D, Zhang K, Luber J, et al. Risk factors, resource use, and cost of postoperative low cardiac output syndrome. *J Thorac Cardiovasc Surg*. 2022;163:1890-8.e10.
2. Algarni KD, Maganti M, Yau TM. Predictors of low cardiac output syndrome after isolated coronary artery bypass surgery: trends over 20 years. *Ann Thorac Surg*. 2011;92:1678-84.
3. Maganti MD, Rao V, Borger MA, Ivanov J, David TE. Predictors of low cardiac output syndrome after isolated aortic valve surgery. *Circulation*. 2005;112(9 Suppl):I448-52.
4. Maganti M, Badiwala M, Sheikh A, Scully H, Feindel C, David TE, et al. Predictors of low cardiac output syndrome after isolated mitral valve surgery. *J Thorac Cardiovasc Surg*. 2010;140:790-6.
5. Lomivorotov VV, Efremov SM, Boboshko VA, Nikolaev DA, Vedernikov PE, Lomivorotov VN, et al. Evaluation of nutritional screening tools for patients scheduled for cardiac surgery. *Nutrition*. 2013;29:436-42.
6. Pathirana AK, Lokunarangoda N, Ranathunga I, Santharaj WS, Ekanayake R, Jayawardena R. Prevalence of hospital malnutrition among cardiac patients: results from six nutrition screening tools. *Springerplus*. 2014;3:412.
7. Thiele RH, Rea KM, Turrentine FE, Friel CM, Hassinger TE, McMurphy TL, et al. Standardization of care: impact of an enhanced recovery protocol on length of stay, complications, and direct costs after colorectal surgery. *J Am Coll Surg*. 2015;220:430-43.
8. Lomivorotov VV, Efremov SM, Kirov MY, Fominskiy EV, Karaskov AM. Low-cardiac-output syndrome after cardiac surgery. *J Cardiothorac Vasc Anesth*. 2017;31:291-308.
9. Giglio M, Dalfino L, Puntillo F, Rubino G, Marucci M, Brienza N. Haemodynamic goal-directed therapy in cardiac and vascular surgery. A systematic review and meta-analysis. *Interact Cardiovasc Thorac Surg*. 2012;15:878-87.
10. Aya HD, Cecconi M, Hamilton M, Rhodes A. Goal-directed therapy in cardiac surgery: a systematic review and meta-analysis. *Br J Anaesth*. 2013;110:510-7.