Received: 7 August 2023 | Revised: 7 November 2023 | Accepted: 20 November 2023

DOI: 10.1002/ccr3.8266

CASE REPORT

Clinical Case Reports Open Access WILEY

Transesophageal echocardiography combined with ProAQT/PulsioFlex hemodynamic monitoring in anesthetic management of a patient with septic shock associated with septic cardiomyopathy: A case report

Hui Gu | **Lei Yang**

Department of Anesthesiology, West China Hospital of Sichuan University, Chengdu, Sichuan, China

Correspondence
Lei Yang, Department of Anesthesiology, West China Hospital of Sichuan University, Chengdu, Sichuan 610041, China.
Email: yanglei.wcha@scu.edu.cn

Key Clinical Message

Patients with septic shock complicated by septic cardiomyopathy (SCM) can be extremely ill and at high risk for mortality. If early assessment of cardiac function is neglected during treatment, sepsis may be further exacerbated. We report a 77-year-old male patient with severe septic shock who underwent intraoperative transesophageal echocardiography (TEE) because of progressive circulatory instability, SCM was diagnosed. Further perioperative treatment to support the circulation was successfully adjusted based on TEE and pulse index continuous cardiac output (CO) by ProAQT/PulsioFlex hemodynamic monitoring. We should consider a diagnosis of SCM in the perioperative period and perform ultrasonography routinely. The use of TEE with ProAQT/PulsioFlex offers a new option for anesthetic management.

KEYWORDS

ProAQT/PulsioFlex, septic cardiomyopathy, septic shock, transesophageal echocardiography

1 | BACKGROUND

Sepsis, a life-threatening condition related to infection, occurs from dysregulated inflammatory response instigating organ failures.[1] Of the many vulnerable organs, the heart is one of the most important targets in septic dysfunction. First described over 40 years ago,[2] septic cardiomyopathy (SCM) can be defined as reversibly depressed intrinsic contractility induced by sepsis.[3,4] The reported incidence is inconsistent, ranging widely from 10% to 70% due to a lack of large-scale studies and uniform diagnostic criteria.[3,4] However, the mortality is increased 2–3 times up to 70%–90% in patients with SCM.[5] SCM in sepsis is a poorly understood phenomenon, and it poses a challenge for anesthetic management.[6,7] We report a patient with severe septic shock and progressive circulatory instability, whose symptoms improved under the guidance of transesophageal echocardiography (TEE) and pulse index continuous cardiac output (CO) using ProAQT/PulsioFlex hemodynamic monitoring during surgery. Early detection and effective treatment of myocardial suppression are important in reducing mortality in patients with sepsis,[8] and early ultrasound evaluation plays an important role in the diagnosis and treatment of SCM.[9]

2 | CASE PRESENTATION

A 77-year-old male, 75 kg, was admitted to our hospital with suspected intestinal perforation; he had presented with a 2-day history of fever, abdominal pain, and altered mental status. Besides, the patient had no past cardiac history, medication history, or relevant comorbidities and his New York Heart Association functional class was Grade II. He had undergone meningioma resection 15 days ago. Physical examination revealed drowsiness, temperature 37.1°C, blood pressure 66/38 mmHg, heart rate (HR) 130 beats/min, respiratory rate 24 beats/min, and peripheral oxygen saturation (SpO_2) 93% on room air. Chest radiography showed inflammation of the lower lobes of lungs. Abdominal CT showed a high probability of intestinal perforation with acute pancreatitis. Laboratory studies revealed as follows: hemoglobin, 11 g/dL; leukocytes, 17.4×10^9/L with 87% neutrophils; platelets, 575×10^9/L; prothrombin time, 25 s; international normalized ratio, 2.3; and activated partial thromboplastin time, 49.2 s. The patient's serum urea nitrogen level was 33.1 mmol/L, and his creatinine level was 240.0 mol/L; liver enzymes were also abnormal with alanine aminotransferase 353 IU/L and aspartate aminotransferase 1015 IU/L. Cardiac biomarkers were significantly increased with creatine kinase-myocardial band at 24.4 ng/L and B-type natriuretic peptide at 1014 ng/L. The patient was intubated in the emergency department to assist with breathing; radial artery catheterization and femoral vein catheterization were also established. He was diagnosed with septic shock with multiple organ dysfunction and scheduled for emergency laparotomy.

Monitoring in the operation room showed: arterial blood pressure 104/67 mmHg, HR 114 beats/min, and SpO_2 95%. Norepinephrine was continued at a dose of 1.0 μg/kg/min. (Another 2 L of fluid had been given before the patient's arrival.) Anesthesia was induced with sufentanil 10 μg, cisatracurium 14 mg, midazolam 2 mg, and 1% sevoflurane. Circulatory instability persisted after the induction of anesthesia. Even broad-spectrum spectrum antibiotics, ulinastatin, hydrocortisone, and rapid fluid resuscitation were given; however, no significant improvement was observed in the patient's hemodynamics. Therefore, we connected the ProAQT/PulsioFlex system with the arterial catheter to estimate cardiac output (CO). Low CO and high peripheral vascular resistance were observed, and we used TEE to identify the cause. TEE revealed moderate to severe biventricular systolic dysfunction. The left ventricle was dilated, and the estimated left ventricular ejection fraction (LVEF) range was 20% to 30%; CO was 1.8 L /min. The fraction of change area (FAC) in the right ventricle was 24% (Usually, FAC>35% is considered to be normal right heart function). The cardiac valves appeared abnormal with severe aortic regurgitation as well as mild mitral valve and tricuspid valve regurgitation (Figure 1). No pericardial effusion was seen. The ProAQT/PulsioFlex system was corrected for cardiac index (CI) calculated by TEE, and the result showed low CO with high resistance: stroke volume variation (SVV) 8%, systemic vascular resistance index (SVRI) 2680 dyn · s · cm^{-5} · m^2. We adjusted the vasoactive drug; an infusion of adrenaline was started at 0.03 μg/kg/min, and the dosage of norepinephrine was gradually reduced. Within 30 min of initiation of the procedure, epinephrine was gradually increased to 0.07 μg/kg/min, and norepinephrine was adjusted downward to 0.2 μg/kg/min. At that time, TEE combined with the ProAQT/PulsioFlex system showed reduced aortic regurgitation: CO increased to 2.5 L/min, SVV increased to 10%, and SVRI decreased to 2200 dyn · s · cm^{-5} · m^2. After 1 h, the patient began to show hemodynamic improvement followed by an increase in CO to 3.0 L/min, SVV increased to 12%, and SVRI decreased to 2000 dyn · s · cm^{-5} · m^2.

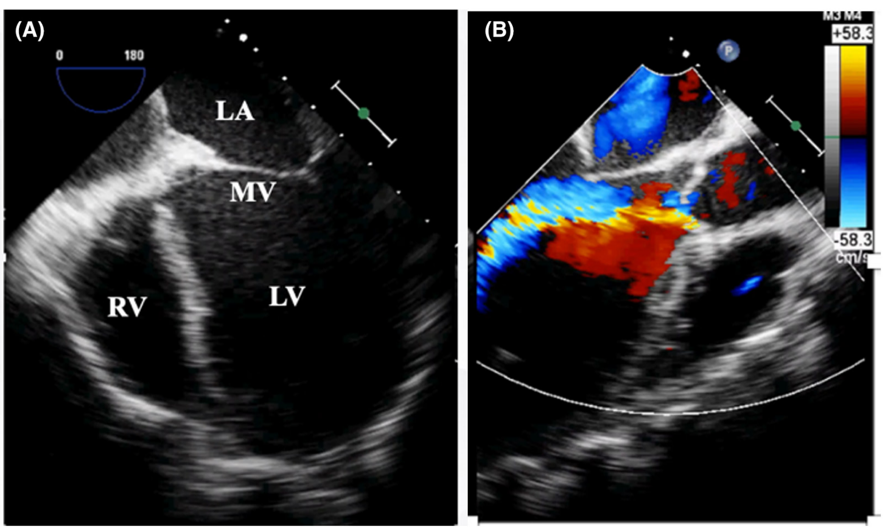

FIGURE 1 Transesophageal echocardiography. Findings include a dilated left ventricle, severely impaired cardiac function (A), and aortic regurgitation (B); left ventricular ejection fraction (LVEF) is 20%–30%.

The operation lasted 280 min. A total of 2000 mL of crystalloid was infused intraoperatively, with 100 mL of intraoperative bleeding, 200 mL of urine output, and 200 mL of ascites drainage. Jejunal perforation and a large amount of purulent discharge in the coeliac were found during surgery. After the operation, the patient was returned to ICU for further treatment and treated with meropenem for 7 days. Culture of abdominal fluid revealed *Enterococcus faecalis* and *Escherichia coli*. CO monitored was continued by TTE in the ICU. By the next morning, norepinephrine and adrenaline were discontinued. TTE revealed normal left ventricular size with normal systolic function, an estimated ejection fraction of 53%, no regional wall motion abnormalities, normal right ventricular size with normal systolic function, no pericardial effusion, and mild aortic regurgitation 3 days after surgery. Unfortunately, the patient was not extubated due to impaired consciousness and seizures related to meningioma probably. On postoperative Day 7, the patient's family decided to return to the local hospital for financial reasons, and subsequently died of a severe lung infection as a result of prolonged mechanical ventilation.

3 | DISCUSSION AND CONCLUSIONS

Based on the low CO with high resistance results determined by the ProAQT/PulsioFlex system, we suspected the patient had developed unexplained cardiac dysfunction. There are many possible reasons, including SCM, takotsubo cardiomyopathy, cardiac valve problems, pericardial effusion, or ischemic disease. The patient had no previous history of cardiac disease. Besides, the main characteristic feature of takotsubo cardiomyopathy is the regional left ventricular wall motion abnormality and result in a conspicuous ballooning of the left ventricle during systole. It occurs commonly after a recent stressful event, in particular emotional stress, and is relatively common in middle-aged and older women.[10,11] In contrast, SCM is characterized by global ventricular dysfunction and dilation and lacks regional wall motion abnormalities.[3] Currently, it commonly characterized TEE was the best choice to identify the diagnosis and revealed the diagnosis of SCM. The subsequent combination of TEE with ProAQT/PulsioFlex monitoring allowed us to perform continuous monitoring of CO, preload, and afterload.[12] Further perioperative treatment was then successfully adjusted.

SCM is an increasingly recognized problem encountered in critical care medicine. It is commonly characterized by the presence of left ventricular systolic dysfunction or diastolic dysfunction, right ventricular systolic dysfunction, or biventricular systolic dysfunction in the absence of other etiologies.[13] SCM is not negligible given it is the most frequent cause of admission to an intensive care unit and the leading cause of death in hospitalized patients as a low cardiac output state could worsen septic shock and increase mortality.[14] In a systematic review, the authors examined the prevalence and its impact on mortality of SCM. It was demonstrated that SCM was associated with significantly higher short-term mortality. (The pooled odds ratio = 2.30, 95% CI = 1.43–3.69; $I^2 = 0\%$, $p = 0.001$.)[8] Furthermore, a retrospective study of 6361 patients has shown that significant benefit in terms of 28-day mortality was observed among patients in the transthoracic echocardiography (TTE) group compared with the control (no TTE) group (odds ratio = 0.78, 95% CI = 0.68–0.90, $p < 0.001$). Patients in TTE group were weaned off vasopressors more quickly than those in no TTE group.[15] so I think early identification of cardiac function is beneficial in reducing short-term mortality.

We suggest anesthetists should consider a diagnosis of SCM in all septic patients with sepsis-associated organ dysfunction, particularly in cases of septic shock requiring vasopressor therapy, as demonstrated in our case.[16] On one hand, early recognition and intervention are important in improving prognosis. On the other hand, the alterations of vascular and cardiac function may rapidly and widely change over time, CO should be measured repeatedly to select appropriate therapeutic intervention and evaluate the patient's response to therapy. To achieve the goal, several tools can be used intraoperatively, such as Echocardiography,[17] pulmonary arterial catheterization (PAC),[18] and CO based on pulse contour [e.g., transpulmonary thermodilution such as pulse indicator continuous cardiac output (PiCCO), ProAQT/PulsioFlex].[12]

Echocardiography is the gold standard for the diagnosis of SCM.[9] It can aid in the diagnosis of SCM by detecting parameters such as LVEF, FAC, myocardial performance index (MPI), and global longitudinal strain (GLS).[2] Furthermore, TEE is a semi-invasive imaging technique and it can provide a rapid, real-time, bedside assessment of cardiac function and morphology, which provides information about the anatomy of all cardiac structures and their functional status. A comprehensive examination evaluates the ventricles' morphology, dimensions, wall motion, any anatomical abnormalities, and the presence of intracardiac masses or thrombi.[19,20] However, afterload parameters cannot be obtained directly. Moreover, TEE does not allow for continuous monitoring and should be repeated at multiple time points as cardiac ultrasound parameters are influenced by loading conditions.

Among the other techniques used in SCM, PAC is still considered the standard reference method for measuring CO. It enables measurement of pulmonary artery

TABLE 1 Main characteristics of techniques for measurement of CO.

Techniques	Measurements	Advantages	Limitations
TEE	CO, SV, SVV, PAP, preload, afterload	Semi-invasive Rapid to implement Distinguish between left and right heart dysfunction Identifies severe valvopathy, thrombi, cardiac tamponade Identifies ventricles' morphology, dimensions, wall motion	Intermittent assessment Operator-dependence Depends on adequate image quality Limited for esophagus diseases
PAC	PAP, PCWP, RAP SvO2, CO	Standard reference method Reliability and accurately Continuous measurement of right function SvO2	Invasive Complications associated with catheter insertion: hemorrhage, pseudoaneurysm formation Fails to obtain left ventricular afterload
PiCCO ProAQT	CO, PPV, CVP, SVV SVRI, ELWI CO, PPV, SVV SVRI	Continuous measurement Minimally invasive Provides SVV and PPV Simple to use Not operator-dependent Provides ELWI by PiCCO	Requires regular external calibrations Inaccurate measurement when intracardiac shunt and Valve disease existed Fails to differentiate between left and right ventricular failure Fails to identify specific mechanisms of low cardiac output (e.g., left ventricular obstruction, severe valvopathy, tamponade)

pressure, pulmonary artery occlusion pressure, right atrial pressure, and CO mixed venous oxygen saturation (SvO_2).[18] Nevertheless, PAC cannot determine left ventricular afterload, and its use has gradually decreased. because recent advances have reached in less invasive hemodynamic monitoring techniques and the results of several randomized trials failed to show improvements in outcome with the use of PAC.[21] Methods based on pulse wave analysis (PWA) include the ProAQT/PulsioFlex system and transpulmonary thermodilution (e.g., PiCCO).[22] The technique is minimally invasive and can be used in a timely manner to safely, accurately, and continuously monitor a patient's hemodynamic parameters and reflect the vascular tone, preload, and cardiac function.[23,24] However, the limitations are also obvious. The ProAQT/PulsioFlex system is sensitive to alterations in vascular tone, and its reliability in patients has been questioned. PiCCO cannot discriminate between right and left heart dysfunction.[25] If the patient has a comorbid disease such as aortic regurgitation or intracardiac shunt, the accuracy of PiCCO and ProAQT/PulsioFlex is affected.[26,27]

We have compared and summarized perioperative monitoring methods in Table 1. We favor using TEE as a first-line modality to initially evaluate the hemodynamic profile associated with SCM intraoperatively and can combine TEE with continuous CO monitoring in conjunction with PiCCO or ProAQT/PulsioFlex if necessary.

In conclusion, septic shock, especially in combination with SCM, is very dangerous and has a high mortality rate. We should consider a diagnosis of SCM in all septic patients and perform ultrasonography routinely. The use of TEE with ProAQT/PulsioFlex offers a new option for anesthetic management and might result in decreased morbidity and mortality of these patients in the future.

AUTHOR CONTRIBUTIONS

Hui Gu: Data curation; writing – original draft. **Lei Yang:** Methodology; supervision; writing – review and editing.

ACKNOWLEDGMENTS

Not applicable.

FUNDING INFORMATION

Not applicable.

CONFLICT OF INTEREST STATEMENT

The authors declare that they have no competing interests.

DATA AVAILABILITY STATEMENT

All data generated and analyzed are included in this article.

ETHICS STATEMENT AND CONSENT TO PARTICIPATE

Not applicable.

CONSENT

Written informed consent for publication of patient details of this case report was obtained from the patients next of kin.

ORCID

Hui Gu https://orcid.org/0000-0003-3291-9778

REFERENCES

1. Singer M, Deutschman CS, Seymour CW, et al. The third international consensus definitions for sepsis and septic shock (Sepsis-3). *JAMA*. 2016;315(8):801-810.
2. Parker MM, Shelhamer JH, Bacharach SL, et al. Profound but reversible myocardial depression in patients with septic shock. *Ann Intern Med*. 1984;100(4):483-490.
3. Beesley SJ, Weber G, Sarge T, et al. Septic cardiomyopathy. *Crit Care Med*. 2018;46(4):625-634.
4. Lin H, Wang W, Lee M, Meng Q, Ren H. Current status of septic cardiomyopathy: basic science and clinical Progress. *Front Pharmacol*. 2020;11:210.
5. Ehrman RR, Sullivan AN, Favot MJ, et al. Pathophysiology, echocardiographic evaluation, biomarker findings, and prognostic implications of septic cardiomyopathy: a review of the literature. *Crit Care*. 2018;22(1):112.
6. Perdue SM, Poore BJ, Babu AN, Stribling WK. Successful use of extracorporeal membrane oxygenation support in severe septic shock with associated acute cardiomyopathy. *J Card Surg*. 2018;33(1):50-52.
7. Subla MR, Khan SA, Behl D, Peters SG. Sepsis and myocardial depression in a young woman. *Mayo Clin Proc*. 2005;80(6):810-814.
8. Hasegawa D, Ishisaka Y, Maeda T, et al. Prevalence and prognosis of sepsis-induced cardiomyopathy: a systematic review and meta-analysis. *J Intensive Care Med*. 2023;38(9):797-808.
9. Cecconi M, De Backer D, Antonelli M, et al. Consensus on circulatory shock and hemodynamic monitoring. Task force of the European Society of Intensive Care Medicine. *Intensive Care Med*. 2014;40(12):1795-1815.
10. Kono T, Sabbah HN. Takotsubo cardiomyopathy. *Heart Fail Rev*. 2014;19(5):585-593.
11. Dawson DK. Acute stress-induced (takotsubo) cardiomyopathy. *Heart*. 2018;104(2):96-102.
12. Weil G, Motamed C, Eghiaian A, Monnet X, Suria S. Comparison of Proaqt/Pulsioflex® and oesophageal Doppler for intraoperative haemodynamic monitoring during intermediate-risk abdominal surgery. *Anaesth Crit Care Pain Med*. 2019;38(2):153-159.
13. Sanfilippo F, Orde S, Oliveri F, Scolletta S, Astuto M. The challenging diagnosis of septic cardiomyopathy. *Chest*. 2019;156(3):635-636.
14. Perner A, Gordon AC, De Backer D, et al. Sepsis: frontiers in diagnosis, resuscitation and antibiotic therapy. *Intensive Care Med*. 2016;42(12):1958-1969.
15. Feng M, McSparron JI, Kien DT, et al. Transthoracic echocardiography and mortality in sepsis: analysis of the MIMIC-III database. *Intensive Care Med*. 2018;44(6):884-892.
16. Hollenberg SM, Singer M. Pathophysiology of sepsis-induced cardiomyopathy. *Nat Rev Cardiol*. 2021;18(6):424-434.
17. Vieillard-Baron A, Millington SJ, Sanfilippo F, et al. A decade of progress in critical care echocardiography: a narrative review. *Intensive Care Med*. 2019;45(6):770-788.
18. Arias-Ortiz J, Vincent J-L. The pulmonary artery catheter. *Curr Opin Crit Care*. 2023;29(3):231-235.
19. Hahn RT, Abraham T, Adams MS, et al. Guidelines for performing a comprehensive transesophageal echocardiographic examination: recommendations from the American Society of Echocardiography and the Society of Cardiovascular Anesthesiologists. *J Am Soc Echocardiogr*. 2013;26(9):921-964.
20. Guarracino F, Baldassarri R. Transesophageal echocardiography in the OR and ICU. *Minerva Anestesiol*. 2009;75(9):518-529.
21. Connors AF, Speroff T, Dawson NV, et al. The effectiveness of right heart catheterization in the initial care of critically ill patients SUPPORT **Investigators**. *JAMA*. 1996;276(11):889-897.
22. Kouz K, Scheeren TWL, de Backer D, Saugel B. Pulse wave analysis to estimate cardiac output. *Anesthesiology*. 2021;134(1):119-126.
23. Liu X, Ji W, Wang J, Pan T. Application strategy of PiCCO in septic shock patients. *Exp Ther Med*. 2016;11(4):1335-1339.
24. Saugel B, Kouz K, Scheeren TWL, et al. Cardiac output estimation using pulse wave analysis-physiology, algorithms, and technologies: a narrative review. *Br J Anaesth*. 2021;126(1):67-76.
25. Mahjoub Y, Pila C, Friggeri A, et al. Assessing fluid responsiveness in critically ill patients: false-positive pulse pressure variation is detected by Doppler echocardiographic evaluation of the right ventricle. *Crit Care Med*. 2009;37(9):2570-2575.
26. Thomsen KK, Kouz K, Saugel B. Pulse wave analysis: basic concepts and clinical application in intensive care medicine. *Curr Opin Crit Care*. 2023;29:215-222.
27. Balik M, Pachl J, Hendl J. Effect of the degree of tricuspid regurgitation on cardiac output measurements by thermodilution. *Intensive Care Med*. 2002;28(8):1117-1121.

How to cite this article: Gu H, Yang L. Transesophageal echocardiography combined with ProAQT/PulsioFlex hemodynamic monitoring in anesthetic management of a patient with septic shock associated with septic cardiomyopathy: A case report. *Clin Case Rep*. 2023;11:e8266. doi:10.1002/ccr3.8266