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Systematic review

Dynamic Left Ventricular Outflow Tract Obstruction in Septic Shock: Prevalence, Hemodynamic Consequences, and Response to Therapy. A Systematic Review

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Abstract

Background: Dynamic left ventricular outflow tract obstruction (LVOTO) is an under-recognized cause of hypotension in septic shock. Its frequency and management remain unclear. This review synthesized its prevalence, hemodynamic consequences and response to therapy. Methods: Following PRISMA 2020, PubMed, Scopus and Web of Science were searched to 31 July 2026, with citation searching. Two authors independently screened records, extracted data and assessed risk of bias using the Newcastle-Ottawa Scale and Joanna Briggs Institute checklists. Synthesis was narrative. Results: Ten of 268 records were included: four observational cohorts (835 adults with septic shock) and six case reports or series. Obstruction affected 22% to 36% of patients in early septic shock, and a severe form with systolic anterior motion, severe mitral regurgitation and pulmonary oedema affected 1.9%. Affected ventricles were small and hypercontractile. Mortality was higher with obstruction in all comparative cohorts (28-day 55% versus 33%; ICU 76.9% versus 25.9%). A fluid bolus raised stroke index in 87% of obstructed patients and cut gradient velocity by 47%. Vasopressin

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26/11/2026

lowered norepinephrine dose and gradient, and beta-blockade reversed refractory hypotension in single cases. Risk of bias ranged from low to high. Conclusion: Dynamic LVOTO is frequent in early septic shock and is associated with high mortality. Early echocardiographic screening, preload restoration, catecholamine reduction and selective vasopressin or beta-blockade form a physiology-based approach. Prospective multicentre studies are needed to confirm these findings.

Keywords: Septic shock; Left ventricular outflow tract obstruction; Systolic anterior motion; Echocardiography; Fluid responsiveness; Vasopressin; Beta-blockers

Introduction

Sepsis is defined as life-threatening organ dysfunction caused by a dysregulated host response to infection, and septic shock is the subset that requires vasopressors to keep mean arterial pressure at or above 65 mmHg with serum lactate above 2 mmol/L despite adequate volume resuscitation (1). Global estimates for 2017 reached 48.9 million sepsis cases and 11.0 million sepsis-related deaths, close to one fifth of all deaths worldwide (2). Cardiovascular failure drives much of this mortality, and echocardiographic studies of adult septic shock show frequent global left ventricular hypokinesia during the first three days of care (3). At the opposite end of the spectrum, low systemic vascular resistance and high catecholamine levels in sepsis favour a hyperdynamic left ventricle, which, defined by an ejection fraction above 70%, was present in 324 of 2867 intensive care patients and carried higher adjusted 28-day mortality (4).

Left ventricular outflow tract obstruction (LVOTO) is defined as a peak instantaneous gradient of at least 30 mmHg, and gradients of 50 mmHg or more are considered hemodynamically important (5). In small, hyperkinetic ventricles, flow drag pulls the anterior mitral leaflet toward the septum and produces systolic anterior motion (SAM), a late-peaking Doppler signal and eccentric mitral regurgitation (6). Slama et al. described LVOTO as common in intensive care patients, particularly in septic shock, where reduced preload and afterload, faster heart rate and dobutamine-induced hyperkinesis alter left ventricular shape (7). Once established, obstruction lowers stroke volume and raises left atrial pressure, so inotropes and diuretics worsen hypotension and pulmonary oedema instead of correcting them (6).

Management therefore opposes standard shock care, and dobutamine withdrawal, fluid infusion and beta-blockade have been proposed as first measures in intensive care patients (7). The link between hyperdynamic physiology and death supports the identification of obstruction as a distinct and treatable phenotype within septic shock (4). Afterload support and a slower heart rate lengthen ejection and filling time and reduce the drag on the mitral leaflet (6). Evidence on this phenotype in septic shock remains limited to small single-centre cohorts and case reports with different definitions, thresholds and outcome time points, which prevents firm estimates of its frequency and prognosis (7). This systematic review therefore synthesized published data on the prevalence, hemodynamic consequences and response to therapy of dynamic LVOTO in adults with septic shock, because the available reviews on the subject are narrative.

Methods

Protocol, eligibility criteria and outcomes

This review followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 statement, and the protocol was not registered. Eligible reports enrolled adults with sepsis or septic shock according to Sepsis-3 or the authors' definition, or shock related to a documented infection. The exposure was dynamic LVOTO or left intraventricular obstruction on

26/11/2026

transthoracic or transesophageal echocardiography, defined by a peak gradient, a velocity threshold or a late-peaking Doppler profile, with or without SAM. Outcomes were prevalence, hemodynamic consequences, mortality and response to therapy. Cohorts, cross-sectional studies, case series and case reports published in English before 1 August 2025 were eligible, while reviews, editorials, conference abstracts, paediatric reports, animal studies and post-cardiac surgery obstruction were excluded.

Information sources and search strategy

PubMed/MEDLINE, Scopus and Web of Science Core Collection were searched from inception to 31 July 2026. The PubMed strategy was: ("Shock, Septic"[Mesh] OR sepsis OR septic) AND ("Ventricular Outflow Obstruction"[Mesh] OR "outflow tract obstruction" OR "intraventricular obstruction" OR "intraventricular gradient" OR "systolic anterior motion" OR LVOTO). The terms were adapted to TITLE-ABS-KEY fields in Scopus and TS fields in Web of Science. Reference lists and citing articles of included reports were also screened.

Selection, data collection, risk of bias and synthesis

Two authors independently screened titles and abstracts, then full texts, and a third author resolved disagreements. The same two authors independently extracted design, setting, sample size, obstruction definition, prevalence, site, SAM, mitral regurgitation, gradient, ventricular size and function, therapy, hemodynamic response and mortality. They also independently applied the Newcastle-Ottawa Scale (NOS) to cohorts (7-9 points low, 5-6 moderate, ≤4 high risk) and the Joanna Briggs Institute (JBI) checklists to case reports and case series (≥70% low, 50-69% moderate, <50% high risk) (Table 1). Heterogeneous definitions, designs and outcome time points precluded meta-analysis, so results were synthesized narratively and tabulated.

Study selection

Database searching identified 259 records (PubMed n = 68, Scopus n = 112, Web of Science n = 79). After removal of 96 duplicates, 163 titles and abstracts were screened and 139 were excluded. Of 24 reports sought for retrieval, one full text was unavailable and 23 were assessed; 17 were excluded (no sepsis at the time of obstruction n = 9, obstruction not measured or not reported n = 5, no original data n = 3), leaving six studies. Citation searching identified nine further reports, of which four met the criteria, giving ten included studies.

Results

Characteristics of included studies

The ten reports, published between 2009 and 2022, came from France, Egypt, the Czech Republic, China, Canada, Italy, India, the United States and Spain (8-17). Four observational cohorts enrolled 835 adults with septic shock, of whom 88 had dynamic obstruction (8-11). One case series described seven patients with septic shock-triggered Takotsubo syndrome, and five case-level reports added five patients with obstruction (12-17). Definitions ranged from a peak outflow velocity of at least 0.9 m/s (8,11) to a severe phenotype requiring SAM, severe mitral regurgitation and pulmonary oedema (10).

Prevalence

In the largest cohort, intraventricular obstruction was present in 47 of 218 patients (22%) early after admission (8). Two Egyptian cohorts reported 32% among 40 patients and 36% among 50 ventilated patients (9,11). Over 29 months, the severe form occurred in 10 of 527 screened patients (1.9%) (10). Obstruction was mid-ventricular in 17 patients, at the outflow tract in 11 and at both levels in 19, and SAM accompanied 66% of cases (8). No obstruction was detected among seven patients with septic

26/11/2026

shock-triggered Takotsubo syndrome and a mean ejection fraction of 31.8% (12).

Hemodynamic consequences

Obstructed ventricles were small and hypercontractile, with a mean ejection fraction of 82%, an indexed end-diastolic area of 4.7 cm^2/m^2 and pseudohypertrophy in most patients with calculated mass (8). The severe phenotype combined septal hypertrophy, a median peak gradient of 78 mmHg and pulmonary oedema at a median norepinephrine dose of 0.58 µg/kg/min (10). Peak gradients in individual patients ranged from 90 to 165 mmHg (14,15,17). A new systolic murmur prompted echocardiography in two patients whose hypotension persisted despite vasopressors (16,17). A 20 mmHg respiratory swing in systolic pressure during mechanical ventilation reflected marked preload dependence (14). Obstruction carried higher mortality in every comparative cohort, with 28-day mortality of 55% versus 33% and a severity-adjusted odds ratio of 2.23 (95% CI 1.08-4.58) (8). ICU mortality reached 76.9% versus 25.9% in one cohort and overall mortality 72.2% versus 34.4% in another (9,11).

Response to therapy

A 500 mL fluid bolus increased stroke index by at least 12% in 87% of obstructed patients, reduced peak intraventricular velocity by 47% and abolished the gradient in 36% (8). Fluid responsiveness was more frequent with obstruction than without it (88.9% versus 62.5%) (11). Stopping dopamine and furosemide, colloid loading and later atenolol lowered a 100 mmHg gradient to 37 mmHg, and fluids with vasopressor reduction resolved SAM-related hypotension in a structurally normal heart (14,16). Vasopressin at a median of 4 IU/h reduced norepinephrine to 0.18 µg/kg/min, lowered the gradient to 35 mmHg, decreased mitral regurgitation and raised PaO2/FiO2 to 174 mmHg (10). Esmolol raised mean arterial pressure from 65 to 85 mmHg within minutes and allowed norepinephrine reduction from 1.8 to 0.4 µg/kg/min (17). Fluid with intravenous metoprolol lowered heart rate, filling pressures and vasoactive needs, and emergency alcohol septal ablation relieved a 90 mmHg gradient in hypertrophic cardiomyopathy (13,15). Risk of bias was low in six reports, moderate in two and high in two cohorts (Table 1) (8-17).

26/11/2026

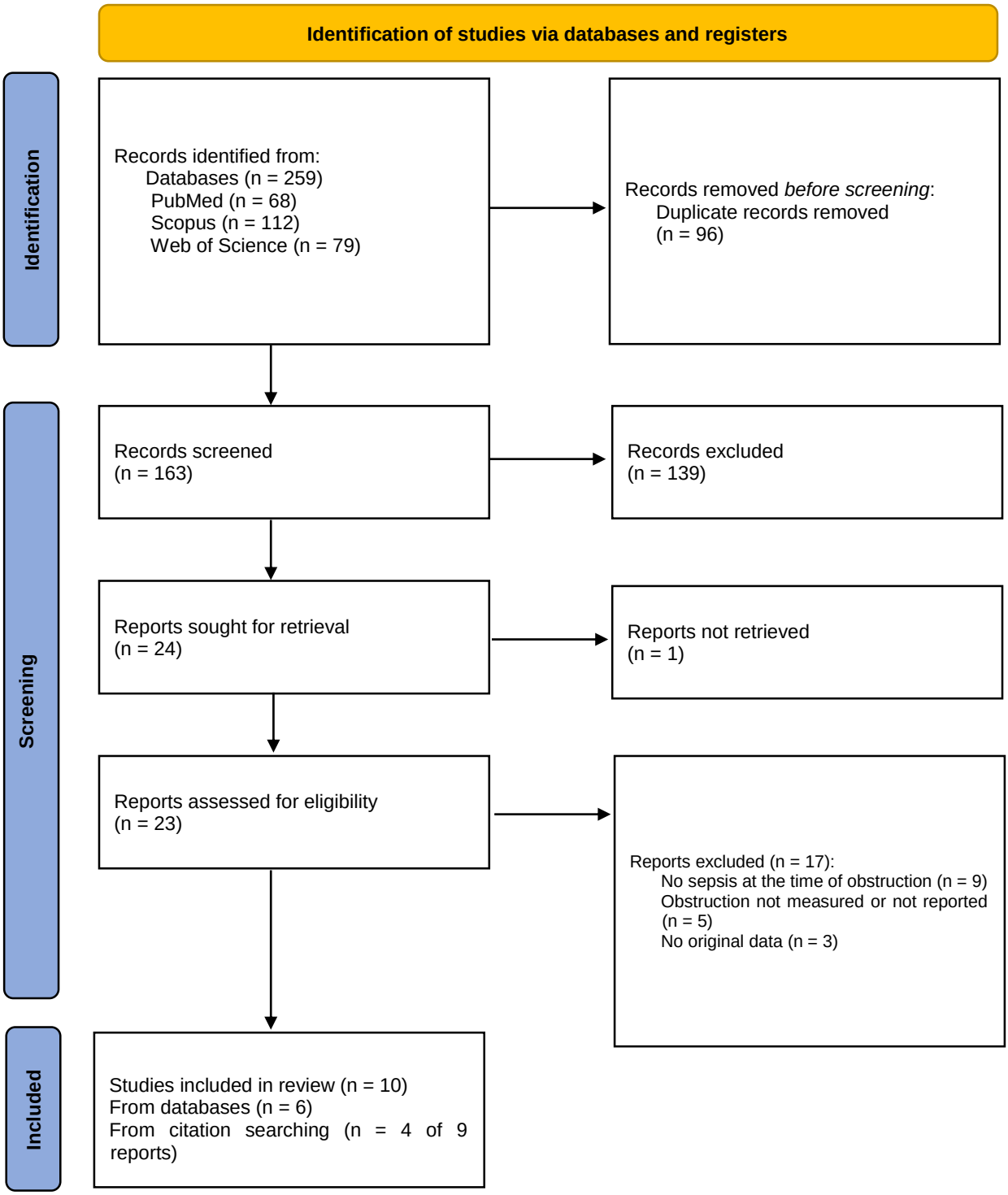


Figure 1: PRISMA flow chart

26/11/2026

Table 1. Risk of bias of the included studies

Study	Design	Tool	Score	Risk
Chauvet et al., 2015	Cohort	NOS	7/9 (S3, C1, O3)	Low
Elhadidy et al., 2019	Cohort	NOS	5/9 (S3, C0, O2)	Moderate
Balik et al., 2020	Cohort	NOS	4/9 (S2, C0, O2)	High
El Maraghi et al., 2022	Cohort	NOS	4/9 (S3, C0, O1)	High
Jing et al., 2022	Case series	JBI	9/10 (90%)	Low
Rochon et al., 2009	Case series	JBI	5/10 (50%)	Moderate
Caselli et al., 2010	Case report	JBI	7/8 (88%)	Low
Barwad et al., 2012	Case report	JBI	6/8 (75%)	Low
Abbas et al., 2019	Case report	JBI	7/8 (88%)	Low
Catalá-Ruiz et al., 2021	Case report	JBI	8/8 (100%)	Low
S, selection; C, comparability; O, outcome.				

Table 2. Characteristics of the included studies

Study	Country	Design	Population	Definition	Frequency
Chauvet et al., 2015 (8)	France	Cohort	218 septic shock	LVOT velocity ≥0.9 m/s, TTE ≤6 h	47 (22%)
Elhadidy et al., 2019 (9)	Egypt	Cohort	40 septic shock	Doppler signs of IVO	13 (32%)
Balik et al., 2020 (10)	Czech Republic	Cohort	527 ventilated septic shock	LVOTO with SAM, severe MR, pulmonary oedema	10 (1.9%)
El Maraghi et al., 2022 (11)	Egypt	Cohort	50 ventilated septic shock	LVOT velocity ≥0.9 m/s	18 (36%)
Jing et al., 2022 (12)	China	Case series	7 septic TTS (of 84 septic shock)	Echocardiography	0
Rochon et al., 2009 (13)	Canada	Case series	Young man, septic shock	TEE	1
Caselli et al., 2010 (14)	Italy	Case report	72-year-old man, pneumonia-related shock	TEE, SAM, 100 mmHg	1

26/11/2026

Study	Country	Design	Population	Definition	Frequency
Barwad et al., 2012 (15)	India	Case report	55-year-old man, HCM, cholangitis sepsis	Gradient 90 mmHg	1
Abbas et al., 2019 (16)	United States	Case report	Adult man, presumed septic shock	SAM, severe MR	1
Catalá-Ruiz et al., 2021 (17)	Spain	Case report	40-year-old man, pneumonia-related septic shock	TEE, SAM, 165 mmHg	1
Abbreviations as in the list of abbreviations.					

Table 3. Hemodynamic findings and response to therapy

Study	Findings	Intervention	Response	Outcome
Chauvet et al., 2015 (8)	LVEF 82%; SAM 66%	500 mL fluid	SI rise ≥12% in 87%; velocity fell 47%	28-day mortality 55% vs 33%
Elhadidy et al., 2019 (9)	Dynamic IVO	Observational	Not applicable	ICU mortality 76.9% vs 25.9%
Balik et al., 2020 (10)	Gradient 78 mmHg; severe MR; NE 0.58 µg/kg/min	Vasopressin	NE 0.18 µg/kg/min; gradient 35 mmHg	Hemodynamic improvement
El Maraghi et al., 2022 (11)	Similar NE dose in both groups	Fluid challenge	Responders 88.9% vs 62.5%	Mortality 72.2% vs 34.4%
Jing et al., 2022 (12)	Mean LVEF 31.8%; no obstruction	Usual care	Not applicable	2/7 deaths
Rochon et al., 2009 (13)	HR 120/min; high filling pressures	Fluid; IV metoprolol	Lower HR and vasoactive need	Improved
Caselli et al., 2010 (14)	BP 65/30 mmHg on dopamine	Dopamine stopped; colloid; atenolol	Gradient 37 mmHg	Recovered
Barwad et al., 2012 (15)	MAP 44 mmHg on inotropes	Alcohol septal ablation	Lower gradient; higher BP	Improved
Abbas et al., 2019 (16)	Hyperdynamic LV; new murmur	Fluids; vasopressor reduction	Hypotension resolved	Trace MR at discharge
Catalá-Ruiz et al., 2021 (17)	NE 1.8 µg/kg/min	Esmolol	MAP 65 to 85 mmHg; NE 0.4 µg/kg/min	Died, stroke-related
Abbreviations as in the list of abbreviations.				

26/11/2026

Discussion

Dynamic intraventricular or outflow obstruction affected roughly one in four to one in three adults examined early in septic shock (8,9,11). The most severe form, combining SAM, severe mitral regurgitation and pulmonary oedema, was rare at 1.9% (10). These figures are consistent with a meta-analysis that reported hyperdynamic left ventricular function in 18.2% of septic patients and a mortality odds ratio of 2.37 (18). Higher outflow velocities also tracked shock severity, with a mean of 87.3 cm/s in septic shock against 71.5 cm/s in sepsis and 75.8% 28-day mortality in the high-velocity group (19).

The obstructed ventricles were small, hyperkinetic and pseudohypertrophic, a geometry that brings the mitral apparatus close to the septum and accelerates outflow (8). Gradient reduction after a fluid bolus and the higher rate of fluid responsiveness point to absolute or relative hypovolemia as the dominant trigger (8,11). Only about half of unstable patients respond to fluid, so obstruction on echocardiography adds a visible marker of preload dependence to dynamic tests (20). Catecholamines act as a second trigger, as shown in a predisposed patient with myocardial hypertrophy whose gradient fell from 53 to 26 mmHg after norepinephrine was reduced and phenylephrine and vasopressin were added (21). Obstruction complicates about one fifth of Takotsubo syndrome, mainly in older patients with septal bulging (22). No obstruction appeared in the septic Takotsubo series with a mean ejection fraction of 31.8%, which supports hypercontractility as a prerequisite (12).

Treatment responses in the included reports followed the physiology of obstruction rather than standard shock algorithms (8,10,17). Current guidelines recommend norepinephrine as the first vasopressor and suggest adding vasopressin when norepinephrine reaches 0.25 to 0.5 µg/kg/min (23). Vasopressin spared norepinephrine without a mortality difference in a large trial, and its addition to catecholamines lowered atrial fibrillation risk (relative risk 0.77) in a meta-analysis (24,25). These properties suit obstructed patients, in whom vasopressin reduced both the catecholamine dose and the gradient (10). Esmolol titrated to a heart rate of 80 to 94 beats/min reduced norepinephrine requirements and 28-day mortality in a single-centre trial of tachycardic septic shock (26). Landiolol did not reduce organ failure in a later multicentre trial, and a second trial controlled heart rate without higher vasopressor needs, although neither selected patients by obstruction (27,28). Here, beta-blockade followed echocardiographic confirmation and restored blood pressure within minutes to hours (13,17).

The evidence base is small, with four cohorts and six case-level reports (8-17). Varied definitions limit comparison of prevalence across cohorts (8,10,11). The largest cohort adjusted mortality for illness severity, while the smaller comparisons were reported as crude proportions (8,9,11). One cohort reported different mortality figures in its abstract and results, which lowered confidence in its estimates (11). Case reports favour dramatic responses and carry a risk of publication bias (13-17). Early echocardiography in septic shock warrants a targeted search for outflow acceleration, SAM and mitral regurgitation before inotrope escalation (8,19). Prospective multicentre cohorts with a uniform gradient threshold and trials of vasopressin or beta-blockade stratified by obstruction are the next step (10,26).

Conclusion

Dynamic left ventricular outflow or intraventricular obstruction affected about one quarter to one third of adults examined early in septic shock and was associated with higher mortality. Affected patients had small, hypercontractile ventricles, frequent systolic anterior motion and marked preload

26/11/2026

dependence. Fluid loading, reduction of inotropic and chronotropic catecholamines, vasopressin and echocardiography-guided beta-blockade improved hemodynamics in the available reports. These findings rest on four small cohorts and six case-level reports with heterogeneous definitions. Early echocardiographic screening for obstruction in septic shock is justified, and prospective multicentre studies with standard thresholds are needed to confirm prevalence, prognosis and optimal therapy.

List of abbreviations

BP: blood pressure; CI: confidence interval; FiO2: fraction of inspired oxygen; HCM: hypertrophic cardiomyopathy; HR: heart rate; ICU: intensive care unit; IV: intravenous; IVO: intraventricular obstruction; JBI: Joanna Briggs Institute; LV: left ventricle; LVEF: left ventricular ejection fraction; LVOT: left ventricular outflow tract; LVOTO: left ventricular outflow tract obstruction; MAP: mean arterial pressure; MR: mitral regurgitation; NE: norepinephrine; NOS: Newcastle-Ottawa Scale; PaO2: arterial oxygen partial pressure; PRISMA: Preferred Reporting Items for Systematic Reviews and Meta-Analyses; SAM: systolic anterior motion; SI: stroke index; TEE: transesophageal echocardiography; TTE: transthoracic echocardiography; TTS: Takotsubo syndrome.

References

1. Singer M, Deutschman CS, Seymour CW, Shankar-Hari M, Annane D, Bauer M, et al. The Third International Consensus Definitions for Sepsis and Septic Shock (Sepsis-3). JAMA. 2016;315(8):801-10.
2. Rudd KE, Johnson SC, Agesa KM, Shackelford KA, Tsoi D, Kievlan DR, et al. Global, regional, and national sepsis incidence and mortality, 1990-2017: analysis for the Global Burden of Disease Study. Lancet. 2020;395(10219):200-11.
3. Vieillard-Baron A, Caille V, Charron C, Belliard G, Page B, Jardin F. Actual incidence of global left ventricular hypokinesia in adult septic shock. Crit Care Med. 2008;36(6):1701-6.
4. Paonessa JR, Brennan T, Pimentel M, Steinhaus D, Feng M, Celi LA. Hyperdynamic left ventricular ejection fraction in the intensive care unit. Crit Care. 2015;19:288.
5. Ommen SR, Mital S, Burke MA, Day SM, Deswal A, Elliott P, et al. 2020 AHA/ACC guideline for the diagnosis and treatment of patients with hypertrophic cardiomyopathy: a report of the American College of Cardiology/American Heart Association Joint Committee on Clinical Practice Guidelines. Circulation. 2020;142(25):e558-631.
6. Evans JS, Huang SJ, McLean AS, Nalos M. Left ventricular outflow tract obstruction - be prepared! Anaesth Intensive Care. 2017;45(1):12-20.
7. Slama M, Tribouilloy C, Maizel J. Left ventricular outflow tract obstruction in ICU patients. Curr Opin Crit Care. 2016;22(3):260-6.
8. Chauvet JL, El-Dash S, Delastre O, Bouffandeau B, Jusserand D, Michot JB, et al. Early dynamic left intraventricular obstruction is associated with hypovolemia and high mortality in septic shock patients. Crit Care. 2015;19:262.
9. Elhadidy S, Rafea M, Fawzy S, Elazab A. Dynamic left intraventricular obstruction in patients with septic shock: pathogenetic role and prognostic implications. Res Opin Anesth Intensive Care. 2019;6(4):424-8.
10. Balik M, Novotny A, Suk D, Matousek V, Maly M, Brozek T, et al. Vasopressin in patients with septic shock and dynamic left ventricular outflow tract obstruction. Cardiovasc Drugs Ther. 2020;34(5):685-8.
11. El Maraghi S, ElHossainy R, Samy M. Assessment of dynamic left ventricular

26/11/2026

outflow track obstruction as fluid responsiveness marker in mechanically ventilated septic patients. Egypt J Med Res. 2022;3(3):63-74.
12. Jing C, Wang Y, Kang C, Dong D, Zong Y. Clinical features of patients with septic shock-triggered Takotsubo syndrome: a single-center 7 case series. BMC Cardiovasc Disord. 2022;22(1):340.
13. Rochon AG, L'Allier PL, Denault AY. Always consider left ventricular outflow tract obstruction in hemodynamically unstable patients. Can J Anaesth. 2009;56:962-8.
14. Caselli S, Martino A, Genuini I, Santini D, Carbone I, Agati L, et al. Pathophysiology of dynamic left ventricular outflow tract obstruction in a critically ill patient. Echocardiography. 2010;27(10):E122-4.
15. Barwad PW, Ramakrishnan S, Seth S, Bhargava B. Rescue alcohol septal ablation in sepsis with multiorgan failure. Indian Heart J. 2012;64(6):588-90.
16. Abbas H, Senthil Kumaran S, Zain MA, Ahmad A, Ali Z. Transient systolic anterior motion of the anterior mitral valve leaflet in a critical care patient with a structurally normal heart. Cureus. 2019;11(1):e3963.
17. Catalá-Ruiz P, Andaluz-Ojeda D, Veras C, Aparisi Á, Hinojosa W, Iglesias C, et al. Beta blockers as salvage treatment in refractory septic shock complicated with dynamic left ventricular outflow tract obstruction: a rare case presentation. J Investig Med High Impact Case Rep. 2021;9:23247096211056491.
18. Sato R, Sanfilippo F, Hasegawa D, Prasitlumkum N, Duggal A, Dugar S. Prevalence and prognosis of hyperdynamic left ventricular systolic function in septic patients: a systematic review and meta-analysis. Ann Intensive Care. 2024;14(1). doi:10.1186/s13613-024-01255-9.
19. Serin ME, Ozluer YE, Kıy M, Avcil M. The role of left ventricular outflow tract peak velocity measurement in patients with sepsis and septic shock. Cureus. 2022;14(7):e26840.
20. Monnet X, Marik PE, Teboul JL. Prediction of fluid responsiveness: an update. Ann Intensive Care. 2016;6(1):111.
21. Mampuya WM, Dumont J, Lamontagne F. Norepinephrine-associated left ventricular outflow tract obstruction and systolic anterior movement. BMJ Case Rep. 2019;12(12):e225879.
22. De Backer O, Debonnaire P, Gevaert S, Missault L, Gheeraert P, Muyldermans L. Prevalence, associated factors and management implications of left ventricular outflow tract obstruction in takotsubo cardiomyopathy: a two-year, two-center experience. BMC Cardiovasc Disord. 2014;14:147.
23. Evans L, Rhodes A, Alhazzani W, Antonelli M, Coopersmith CM, French C, et al. Surviving sepsis campaign: international guidelines for management of sepsis and septic shock 2021. Intensive Care Med. 2021;47(11):1181-247.
24. Russell JA, Walley KR, Singer J, Gordon AC, Hébert PC, Cooper DJ, et al. Vasopressin versus norepinephrine infusion in patients with septic shock. N Engl J Med. 2008;358(9):877-87.
25. McIntyre WF, Um KJ, Alhazzani W, Lengyel AP, Hajjar L, Gordon AC, et al. Association of vasopressin plus catecholamine vasopressors vs catecholamines alone with atrial fibrillation in patients with distributive shock: a systematic review and meta-analysis. JAMA. 2018;319(18):1889-900.
26. Morelli A, Ertmer C, Westphal M, Rehberg S, Kampmeier T, Ligges S, et al. Effect of heart rate control with esmolol on hemodynamic and clinical outcomes in patients with septic shock: a randomized clinical trial. JAMA. 2013;310(16):1683-91.
27. Whitehouse T, Hossain A, Perkins GD, Gordon AC, Bion J, Young D, et al. Landiolol

26/11/2026

and organ failure in patients with septic shock: the STRESS-L randomized clinical trial. JAMA. 2023;330(17):1641-52.

28. Rehberg S, Frank S, Černý V, Cihlář R, Borgstedt R, Biancofiore G, et al. Landiolol for heart rate control in patients with septic shock and persistent tachycardia. A multicenter randomized clinical trial (Landi-SEP). Intensive Care Med. 2024;50(10):1622-34.

26/11/2026