Cite as: Lin H, Ren HS. Advances in the application of echocardiography in septic cardiomyopathy [J]. Chin J Clin Res, 2024, 37(11):1665-1668.
DOI: 10.13429/j.cnki.cjcr.2024.11.005

Advances in the application of echocardiography in septic cardiomyopathy

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Abstract: Septic cardiomyopathy (SCM) is an acute cardiac dysfunction caused by sepsis. Literature reports its incidence fluctuating between 13.8% and 60% with a high mortality rate of 70% to 90%. Currently, there is no gold standard for diagnosis, nor specific indicators to assess prognosis. Echocardiography is widely used in SCM research due to its advantages of visualization, non-invasiveness, bedside operation, and reproducibility. Different types of ultrasounds have unique characteristics, for example, conventional echocardiography hardware is well established with easily obtained parameters, transesophageal echocardiography provides more accurate parameters, and speckle tracking echocardiography has high sensitivity. This article summarizes and reviews the application of echocardiographic techniques in SCM in recent years, aiming to provide clinical doctors with a reference for early diagnosis and prognostic assessment of SCM.

Keywords: Septic cardiomyopathy; Transthoracic echocardiography; Transesophageal echocardiography; Speckle-tracking echocardiography. Diagnosis; Prognosis

Fund program: Key Research and Development Program of Shandong Provincial Department of Science and Technology (2016GSF201052); Qilu Health and Health Leading Talent Support Project (2021.01.01-2025.12.31)

Septic cardiomyopathy (SCM) is defined as acute cardiac dysfunction induced by sepsis that is not related to ischemia[1-2]. In patients with sepsis, SCM is associated with a two- to three-fold increase in mortality, potentially reaching 70% to 90%[3]. SCM is characterized by systolic or diastolic dysfunction of the left ventricle, diastolic dysfunction of the right ventricle, or global/localized ventricular wall motion abnormalities, which is reversible and usually normalizes with early treatment of the disease[3-4] . Currently, there is no clear diagnostic standard to guide physicians in the clinical diagnosis and treatment of SCM patients, and the diagnosis of SCM is based on the patient's medical history, signs and symptoms, biological markers and echocardiographic manifestations[5]. Echocardiography has the advantages of visualization, non-invasive, bedside operation and repeatable examination, which can realize the real "semi-continuous" hemodynamic monitoring, and improves the prognosis of sepsis patients. This review examines recent advancements in transthoracic echocardiography(TTE), transesophageal echocardiography (TEE), and speckle-tracking echocardiography (STE) in the context of SCM, aiming to provide a reference for early diagnosis and prognosis.

1 TTE in SCM

1.1 *Indicators of left ventricular systolic function in SCM*

Indicators of left ventricular systolic function, such as left ventricular ejection fraction (LVEF), left ventricular systolic mitral annulus velocity (LV-Sm), and mitral annular plane systolic excursion (MAPSE), are crucial for diagnosing and predicting the prognosis of SCM.

1.1.1 LVEF

LVEF is a critical measure of left ventricular systolic function. The most widely accepted definition of SCM in many clinical and basic studies is an LVEF less than 45% to 50%. This condition is reversible after sepsis remission in patients without a prior cardiac history. Shin *et al.*[6] retrospectively analyzed data from 366 sepsis patients and discovered significantly higher mortality rates in those with LVEFs below 50% and above 70% (indicative of hyperdynamic left ventricular ejection fraction) compared to those with LVEFs between 50% to 70%. Furthermore, they noted that an LVEF below 30% and diffuse LV wall dyskinesia markedly increased mortality in patients with septic shock[7]. Severe sepsis can cause myocardial damage with substantially reduced contractility, leading to a lower LVEF. In contrast, septic patients with decreased systemic vascular resistance, excessive catecholamine release, and impaired left ventricular diastolic function may exhibit a hyperdynamic left ventricular ejection fraction. Thus, shifts in LVEF, whether decreases or increases, can serve as accurate prognostic indicators in sepsis and septic shock. However, contrary findings exist. A meta-analysis encompassing 7 single-center prospective studies involving 585 patients revealed that cardiac dysfunction related to sepsis, defined by an LVEF below 50%, had low diagnostic sensitivity and specificity (0.48 and 0.65, respectively) for predicting 30-day mortality[8]. Inflammatory responses in sepsis can lead to myocardial depression and reduced LVEF, which may improve as the infection is controlled and myocardial function recovers. Notably, most studies have classified patients based solely on their LVEF measured within 24 hours of admission, disregarding those whose LVEF improved later, potentially leading to inconsistent findings. In summary, it is essential to report LVEF in critically ill patients alongside vasopressor support and shock severity[9], and to monitor changes in LVEF dynamically.

1.1.2 LV-Sm

The left ventricular systolic myocardial velocity (LV-Sm), as measured by tissue Doppler imaging (TDI), reflects long-axis contractility of the left ventricle. In one study, sepsis combined with an LV-Sm of less than 8 cm/s was identified as left ventricular systolic dysfunction (LVSD). Among 145 sepsis patients analyzed, LVSD was observed in 36 cases. Notably, the LV-Sm in patients who died within 28 days (n=47) was marginally higher than that in survivors (n=98), with values of 8.92±2.11 cm/s and 8.23±1.71 cm/s, respectively. This phenomenon contrasts with common cardiovascular diseases, where a lower LV-Sm is associated with increased mortality. The discrepancy in sepsis could be attributed to an elevated LV-Sm resulting from a persistent decrease in peripheral vascular resistance, complicating shock correction and potentially increasing mortality. However, a meta-analysis encompassing 13 studies with 1 197 septic patients and 442 deaths revealed no statistically significant difference in LV-Sm between deceased and surviving groups, suggesting that LV-Sm alone may not accurately reflect early myocardial damage in patients with infectious shock nor serve as a reliable marker for diagnosing SCD or predicting sepsis outcomes.

1.1.3 MAPSE

MAPSE assesses the overall change in LV contraction along the longitudinal axis and is quantified using M-mode in the apical four-chamber view. A prospective study involving 48 septic patients demonstrated a significantly higher MAPSE in the survival group compared to the mortality group, with measurements of 1.54 (1.39-1.69) cm versus 1.12 (0.90-1.35) cm, respectively (P=0.026)[12]. Furthermore, MAPSE has been identified as an independent risk factor for in-hospital mortality in children experiencing septic shock[13]. Recent scholarly advancements have led to the development of a novel parameter, Left Ventricular Longitudinal Wall Fractional Shortening (LV-LWFS), which is calculated as a percentage of MAPSE relative to the total length of the left ventricle[14]. Johansso *et al*.[15] conducted cardiac ultrasound examinations on 73 patients with infectious shock, revealing close correlations between LV-LWFS, MAPSE, and LV longitudinal strain, the latter measured by Speckle tracking imaging (STI)—a technique that demands high-resolution imaging and considerable operator expertise. In contrast, MAPSE and its derivatives can be readily measured using standard echocardiography techniques. The easy accessibility of MAPSE and its derived parameters, coupled with a significantly higher acquisition rate compared to other parameters such as LVEF, suggests their enhanced suitability for practical clinical application[16].

1.2 Indicators of LVSD in change in patients with SCM

Abnormal left ventricular diastolic function is commonly observed in patients with sepsis. One study categorized the combination of a peak early diastolic mitral inflow velocity to peak early diastolic mitral annular velocity (E/e') greater than 15, or a peak early diastolic mitral annular velocity (e') less than 8 cm/s, as LVSD. Among 145 sepsis patients examined, 60 developed LVSD. Furthermore, e' values were significantly lower in the 28-day mortality group compared to the survival group (7.81±1.12 cm/s *vs* 8.61±1.02 cm/s, P=0.013) [10]. Additionally, a retrospective study involving 495 sepsis patients identified left ventricular diastolic dysfunction as a risk factor for sepsis-associated acute kidney injury, suggesting that measurements of e' and E/e' can predict the occurrence of acute kidney injury in patients with severe sepsis and septic shock [17]. Moreover, a meta-analysis by Sanfilippo *et al.* [18] encompassing 16 studies and 1,507 patients revealed that both lower e' and higher E/e' ratios were strongly linked to increased mortality (e' standardized mean difference = 0.33, P=0.02; E/e' standardized mean difference = -0.33, P=0.006). These findings underscore the diagnostic and prognostic significance of e' and E/e' in assessing diastolic dysfunction and its implications in septic patients.

1.3 Indicators of right ventricular systolic function in patients with LVSD

The prevalence of right ventricular systolic dysfunction in patients with sepsis ranges between 34% and 48%. Of these, 71% exhibit concurrent left ventricular systolic dysfunction, while 29% present with isolated right ventricular systolic insufficiency [19]. Right heart dysfunction independently predicts mortality at both 28 days and 45 days in septic patients [19-20]. Tricuspid annular plane systolic excursion (TAPSE), which assesses the longitudinal systolic function of the right ventricle using M-mode, indicates right ventricular systolic insufficiency when less than 16 mm. Dong *et al*. [21] analyzed 183 patients with septic shock, finding an association between reduced TAPSE values, ICU mortality, and 90-day mortality. However, Lahham *et al.* [22] who measured TAPSE in 24 septic patients admitted to the emergency department, did not find it predictive of ICU admission, ICU / hospital length of stay, or mortality, contrasting with Dong *et al.*'s findings [21]. Zhang *et al.* [23] studied 215 sepsis patients, defining right heart dysfunction as TAPSE less than 16 mm or right ventricular fractional area change (FAC) less than 35%. They discovered that right ventricular dysfunction alone did not correlate with 30-day mortality. However, patients with right ventricular dysfunction, combined with a right-to-left ventricular end-diastolic area ratio greater than 0.6 and a central venous pressure over 8 mmHg, exhibited significantly higher mortality rates. Mechanisms of right ventricular failure include both anterior and posterior overload and compromised systolic and diastolic function, which often coexist. Given the complex impacts of sepsis on cardiac loads, the utility of TAPSE alone in assessing right ventricular dysfunction and its prognosis in sepsis may be limited.

1.4 Relationship between Tei index and prognosis of SCM patients

The myocardial function index, also known as the Tei index or myocardial performance index (MPI), evaluates both the systolic and diastolic functions of the heart. A prospective study involving 86 SCM patients showed that the average LV Tei index was significantly lower in the 28-day survival group (0.51) compared to the death group (0.75). It also correlated with LVEF, brain natriuretic peptide (BNP), and cardiac troponin I (cTnI), with the LV Tei index offering the highest predictive value for 28-day morbidity and mortality in these patients [24]. Nizamuddin *et al*. [25] observed 47 patients with sepsis or septic shock, dividing them into two groups based on MPI changes: improved (MPI decreased from 0.66 to 0.5) and deteriorated (MPI increased from 0.48 to 0.63). They found that the 90-day mortality rate was significantly lower in the MPI-improved group (16.7% *vs.* 47.1%). Furthermore, Li *et al.* [26] reported that the area under the ROC curve for the right ventricular Tei index reached 0.962 in predicting mortality in sepsis patients, identifying an elevated right ventricular Tei index as an independent risk factor for death. SCM typically features both systolic and diastolic insufficiencies, making the Tei index a reliable and noninvasive measure for assessing cardiac function and prognosis in these patients.

2 TEE in SCM

TEE is a diagnostic imaging technique that uses a small ultrasound probe mounted on the tip of an endoscope to examine the heart's anatomy and blood flow through the esophagus. This method often provides superior images compared to transthoracic echocardiography, especially in cases involving invasive mechanical ventilation, obesity, or surgical dressings, allowing for clear and stable visualizations. TEE is particularly useful in detecting abnormalities such as left atrial appendage thrombus in patients with sepsis who develop new-onset atrial fibrillation. However, the accuracy of TEE heavily depends on the operator's expertise. As a semi-invasive procedure, it carries risks of serious complications, including bleeding from nasopharyngeal and esophageal mucosal injuries and malignant arrhythmias, which makes it a less preferred option in some clinical settings.

3 STE in SCM

STE is an advanced technique developed recently that employs STI to monitor and map the spatial movements of echogenic speckles within the myocardium. This is achieved through high-frame-rate two-dimensional grayscale ultrasound imaging, utilizing an optimal pattern-matching method to track the location of these speckles in each image frame [27]. This process delineates the trajectory of myocardial motion at consistent positions across different frames [28]. Crucially, STE's accuracy is not dependent on the angle between the acoustic beam and the direction of ventricular wall motion, enabling the detection of myocardial movement in multiple directions.

3.1 Value of STE for early diagnosis of SCM

STE primarily studies longitudinal strain (LS) in SCM, focusing on global longitudinal strain (GLS) and segmental longitudinal strain. Currently, there are no established normal reference values for strain. A meta-analysis of 24 studies encompassing 2 597 subjects indicated that GLS typically ranges from -15.9% to -22.1% in healthy individuals [29]. However, the abnormal GLS cut-off values used in various studies on sepsis and infectious shock are not consistent. Vallabhajosyula *et al.* [30] reviewed five prospective studies on GLS measurement by STE in sepsis and reported abnormal GLS cut-off values ranging from -10% to -17%. Hai *et al.* [31] analyzed 90 cases of septic shock and 37 cases of sepsis without shock, confirming that GLS values in healthy individuals typically fall within the same range as previously mentioned. They noted differences in GLS between the two groups and significant deterioration in LV GLS at 24 hours in patients with septic shock, whereas LVEF did not show significant changes [32]. Haileselassie *et al.* [33] assessed STE's value in pediatric sepsis by conducting echocardiography on 23 children (mean age: 7.21 years), finding an average GLS of -13%, significantly lower than the -19% reported for healthy children by the Johns Hopkins Children's Center. Despite normal LV short-axis shortening (FS), these children exhibited abnormal strain and reduced LS. Zaky *et al.* [34] demonstrated that reductions in tissue motion annular displacement (TMAD) were associated with ventricular systolic and diastolic dysfunction, suggesting that TMAD may be more reliable than LV longitudinal strain. These findings underscore that STE can detect early cardiac function changes in sepsis and infectious shock, offering valuable insights for the early diagnosis of SCM.

3.2 Value of STE for prognostic assessment in SCM

Bazalgette *et al.* [35] discovered that GLS can detect myocardial depression in the early stages of infectious shock (within 24 hours), noting a mean GLS of approximately -11%, which gradually improves to around -16%. They also observed that LVEF and LV-Sm remain stable over time, highlighting GLS's high sensitivity and potential for real-time monitoring of myocardial function. Additionally, studies have indicated a positive correlation between GLS and biomarkers such as TnI and NT-proBNP, which are indicative of myocardial injury and cardiac dysfunction [36]. Innocenti *et al*. [37] examined 354 sepsis patients and conducted ultrasonography within 24 hours, defining LV systolic dysfunction as LV GLS greater than -14% [34]. This condition was linked to an increased allcause mortality at 28 days, particularly when accompanied by a decrease in segmental strain of the LV anterior wall basal. Beesley *et al*. [38] explored the long-term impact of abnormal LV systolic strain during sepsis, defining a GLS greater than -17% as abnormal. Their findings revealed a U-shaped relationship between LV GLS and the incidence of adverse cardiovascular events in sepsis patients up to 24 months post-hospital discharge. These findings collectively underscore the value of GLS in assessing the prognosis of sepsis.

3.3 Shortcomings of STE

Despite the significant clinical value of STE in the early diagnosis, treatment monitoring, and prognosis assessment of SCM, several limitations persist. Key among these is the absence of a universally recognized threshold for defining GLS in SCM. Furthermore, STE demands high-quality imaging that heavily depends on the skill level of the professionals involved. Additionally, there are notable discrepancies across different image acquisition platforms and variability in speckle tracking algorithms among vendors, complicating the standardization and interpretation of results.

4 Perspectives of Echocardiography in SCM

Echocardiography, known for its noninvasiveness and reproducibility, holds significant value in the diagnosis and prognostic assessment of SCM. STE, in particular, despite its current limitations, shows promise as a crucial tool for detecting early myocardial injury and understanding its mechanisms in SCM patients. The potential of STE could be fully realized with advancements in threshold standardization and algorithm optimization, positioning it as an important method in the clinical setting.

Conflict of interest None

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Submission received:2023-10-05/**Revised:** 2023-12-19

· 研究进展 ·

超声心动图在脓毒症心肌病中的应用进展

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摘要：脓毒症心肌病(SCM)是由脓毒症引起的急性心功能障碍,文献报道其发病率为 13.8%~60.0%,病死率高,可达 70%~90%,目前尚无诊断的金标准,也无特异性指标以判断预后。超声心动图因其具有可视化、无创、可床旁操作、可重复再现等优势,被广泛应用于 SCM 的研究中。不同类别的超声,具有不同的特点,比如常规传统超声心动图硬件设备已很成熟,参数容易获取;经食道超声参数更加精确;斑点追踪超声心动图参数敏感度高等。本文对近年来超声心动图技术在 SCM 中的应用进行总结和综述,以期为临床医生对 SCM 的早期诊断及预后判断提供参考依据。

关键词：脓毒症心肌病；经胸超声心动图；食道超声心动图；斑点追踪超声心动图；诊断；预后

中图分类号：R631　**文献标识码**：A　**文章编号**：1674-8182(2024)11-1665-05

Advances in the application of echocardiography in septic cardiomyopathy

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Abstract: Septic cardiomyopathy (SCM) is an acute heart dysfunction caused by sepsis. Literature reports its incidence fluctuating between 13.8% and 60.0%, with a high mortality rate of 70% to 90%. Currently, there is no gold standard for diagnosis, nor specific indicators to assess prognosis. Echocardiography is widely used in SCM research due to its advantages of visualization, non-invasiveness, bedside operation, and reproducibility. Different types of ultrasounds have unique characteristics, for example, conventional echocardiography hardware is well-established with easily obtainable parameters, transesophageal echocardiography provides more accurate parameters, and speckle tracking echocardiography has high sensitivity. This article summarizes and reviews the application of echocardiographic techniques in SCM in recent years, aiming to provide clinical doctors with reference for early diagnosis and prognostic assessment of SCM.

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脓毒症心肌病(septic cardiomyopathy, SCM)是由脓毒症引起的、与缺血无关的急性心功能障碍[1-2]。脓毒症患者一旦合并心肌病,病死率将升高 2~3 倍,可达 70%~90%[3]。SCM 主要表现为左心室收缩或舒张功能障碍、右心室舒张功能障碍或整体/局部室壁运动异常,具有可逆性,通常在疾病早期治疗可恢复正常[3-4]。目前尚无明确的诊断标准指导医师对 SCM 患者进行临床诊断和治疗,主要根据患者病史、症状体征,结合生物学标志物、超声心动图表现等综合诊断 SCM[5]。超声心动图具有可视化、无创、可床边操作、可重复检查等优势,实现了真正的"半连续"血流动力学监测,改善了脓毒症患者的预后。本文对近年来经胸超声心动图(transthoracic echocardiography, TTE)、经食道超声心动图(transesophageal echocardiography, TEE)及斑点追踪超声心动图(speckle-tracking echocardiography, STE)在 SCM 中的应用进展进行综述,以期为 SCM 的早期诊断及预后判断提供参考依据。

DOI：10.13429/j.cnki.cjcr.2024.11.004

基金项目：山东省科技厅重点研发计划（2016GSF201052）；齐鲁卫生与健康领军人才资助项目（2021.01.01—2025.12.31）

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出版日期：2024-11-20

QR code for English version

1　TTE 在 SCM 中的应用

1.1　*左心室收缩功能的指标在 SCM 中的变化*　左心室收缩功能指标包括左心室射血分数(left ventricular ejection fraction, LVEF)、左心室收缩期二尖瓣环运动速度(left ventricular myocardial systolic mitral annulus velocity, LV-Sm)及二尖瓣环平面收缩期位移(mitral annular plane systolic excursion, MAPSE)等,均与 SCM 的诊断和/或预后相关。

1.1.1　LVEF　LVEF 是反应左心室收缩功能的重要指标。目前,在多数临床或基础研究中,SCM 最被接受的定义为 LVEF 小于 45%,如既往无心脏病史,脓毒症病情缓解后心脏功能可逆转。Shin 等[6] 回顾性收集 366 例脓毒症患者分析发现,LVEF<50%和>70%(高动力 LVEF)的患者死亡率显著高于 LVEF 为 50%~70%的患者。还有研究发现,LVEF<30%和弥漫性左室壁运动障碍显著影响脓毒性休克患者的死亡率[7]。严重脓毒症时心肌受损,收缩功能明显减弱,会引起 LVEF 下降;脓毒症患者出现体循环阻力下降、过多的儿茶酚胺释放、左室舒张功能受损等情况时,会表现为高动力 LVEF。也就是说,当 LVEF 下降或升高到一定程度时,可以准确地预测脓毒症、脓毒性休克患者的预后。但也有研究得到了相反的结果。一项纳入 7 项单中心前瞻性研究的荟萃分析,共纳入 585 例患者,结果显示,脓毒症相关心功能障碍定义为 LVEF<50%,作为预测患者 30 d 死亡率的指标,其诊断敏感度和特异性均很低(分别为 0.48 和 0.65)[8]。脓毒症时炎性因子的释放可引起心肌抑制,出现 LVEF 下降,随着感染的控制,心肌抑制有所改善,LVEF 将会升高。而多数研究仅是根据入院 24 h 内的 LVEF 进行分组,忽略了后期 LVEF 有改善的患者,这可能造成结果不一致。综上所述,危重患者的 LVEF 应与血管升压药物支持量以及休克程度一起报告[9],同时应动态监测 LVEF 的变化。

1.1.2　LV-Sm　LV-Sm 反映左心室长轴收缩能力,它是通过组织多普勒成像(tissue Doppler imaging, TDI)技术测得。有研究将脓毒症合并 LV-Sm<8 cm/s 定义为 SCM(左室收缩功能障碍性),收集的 145 例脓毒症患者中 36 例患者出现了 SCM,且 28 d 死亡组(47 例)患者的 LV-Sm 略高于存活组(98 例),分别为(8.92±2.11)cm/s 和(8.23±1.71)cm/s[10]。而普通心血管疾病 LV-Sm 降低,死亡率升高,这可能是由于脓毒症或脓毒性休克患者持续性外周血管阻力降低引起 LV-Sm 升高,而外周血管阻力持续降低使得休克难以纠正,继而增加患者死亡率。一项荟萃分析共纳入 13 项研究,共 1 197 例脓毒症患者,死亡 442 例,结果发现死亡组与生存组的 LV-Sm 差异无统计学意义;且 LV-Sm 并不能反映感染性休克患者早期的心肌损害[11]。这说明不能用单一的 LV-Sm 去诊断 SCM 及评估脓毒症预后。

1.1.3　MAPSE　MAPSE 可以评估左室收缩在长轴方向上的整体变化。于心尖四腔心切面,在 M 超下测得。一项前瞻性研究共纳入 48 例脓毒症患者,结果显示生存组患者的 MAPSE 显著高于死亡组[1.54(1.39~1.69) cm *vs* 1.12(0.90~1.35) cm, $P=0.026$][12]。MAPSE 是脓毒性休克患儿住院死亡率的独立危险因子[13]。近期有学者在 MAPSE 的基础上提出了一个新的参数,左心室纵向壁缩短分数(left ventricular longitudinal wall fractional shortening, LV-LWFS),为 MAPSE 与左心室长度的百分比[14]。Johansso 等[15] 对 73 例感染性休克患者进行了心脏超声监测,结果发现,LV-LWFS、MAPSE 与由斑点追踪成像(speckle tracking imaging, STI)技术测量的左心室纵向应变密切相关。STI 为一项新的技术,对图像要求高,很大程度依赖专业人员的专业知识;而 MAPSE 及由其衍生出来的参数可以经传统超声心动图轻松获得,并且也有研究发现临床上 MAPSE 的获取率显著高于 LVEF 等其他参数[16],或许 MAPSE 及其衍生参数在实际临床应用中更为适用。

1.2　*左心室舒张功能的指标在 SCM 患者中变化*　左心室舒张功能异常在脓毒症患者中非常常见。有研究将脓毒症合并舒张早期二尖瓣血流峰值速度/舒张早期二尖瓣环峰值速度(E/e′)>15 或舒张早期二尖瓣环峰值速度(e′)<8 cm/s 定义为 SCM(左室舒张功能障碍性),收集的 145 例脓毒症患者中 60 例出现了 SCM(左室舒张功能障碍性),28 d 死亡组患者 e′ 显著低于存活组[(7.81±1.12)cm/s *vs* (8.61±1.02)cm/s, $P=0.013$][10]。除此之外,在对 495 例脓毒症患者的回顾性研究中,左心室舒张功能障碍是脓毒症相关急性肾损伤的危险因素,E/e′和 e′可用于预测严重脓毒症和脓毒性休克患者脓毒症相关急性肾损伤的发生[17]。Sanfilippo 等[18] 对 16 项研究共 1 507 例脓毒症及脓毒性休克患者进行荟萃分析,结果发现较低的 e′和较高的 E/e′比值均与死亡率密切相关(e′标准化均数差为 0.33, $P=0.02$; E/e′标准化均数差为−0.33, $P=0.006$)。因此 e′和 E/e′在脓毒症患者心脏舒张功能障碍诊断及其预后评估方面有着重要价值。

1.3　*右心室收缩功能的指标在 SCM 患者中的变化*　脓毒症患者右心室收缩功能障碍发生率为 34%~48%,其中 71%合并左心室收缩功能障碍,29%为单纯的右心室收缩功能不全[19]。右心功能障碍是脓毒症患者 28 d 死亡及 45 d 死亡的独立危险因素[19-20]。三尖瓣环收缩期位移(tricuspid annular plane systolic excursion, TAPSE)反映右心室纵向收缩功能,由 M 模式测量所得,TAPSE<16 mm 提示右心室收缩功能不全。Dong 等[21] 收集 183 例脓毒性休克患者,发现 TAPSE 与脓毒性休克患者的 ICU 死亡率及 90 d 死亡率相关。但 Lahham 等[22] 于急诊室收入 24 例脓毒症患者,测量 TAPSE,结果发现其水平与患者是否入住 ICU、住 ICU 时间、住院总时间、是否死亡均无关,得出与 Dong 等[21] 相反的结论。Zhang 等[23] 收集 215 例脓毒症患者,将右心功能障碍定义为 TAPSE<16 mm 或右室面积变化分数(fractional area change, FAC)<35%,结果发现仅仅存在右心功能障碍与患者 30 d 死亡率无关,而在右心功能障碍基础上合并右室舒张末期面积与左室舒张末期面积之比大于 0.6 且中心静脉压大于 8 mmHg 的患者,死亡率明显升高。右心室功能衰竭的机制包括前后负荷过重、收缩及舒张能力减弱,这些机制经常并存。TAPSE 只是反映右心室长轴的收缩功能,而脓毒症时常出现心脏前后负荷的改变,

共同影响右心功能,所以单纯用 TAPSE 去评估脓毒症右心功能障碍及其预后的价值也许是有限的。

1.4　Tei 指数与 SCM 患者预后的关系　心肌功能指数,也称之为 Tei 指数、心肌综合指数(myocardial performance index, MPI),可以同时反映心脏的收缩及舒张功能。一项前瞻性研究共纳入 86 例 SCM 患者,发现 28 d 生存组患者的左心室 Tei 指数平均值为 0.51,明显低于死亡组患者的平均值 0.75;并且与 LVEF、B 型脑钠肽(type B natriuretic peptide, BNP)、心肌肌钙蛋白 I(cardic troponin I, cTnI)相比,左心室 Tei 指数对 SCM 患者 28 d 病死率的预测价值最高[24]。Nizamuddin 等[25]收集了 47 例脓毒症或脓毒性休克患者,根据入院时及 24 h 后监测的 MPI,分为 MPI 改善组(MPI 由 0.66 降至 0.50,$n=30$)和 MPI 恶化组(MPI 由 0.48 升至0.63, $n=17$),发现 MPI 改善组患者 90 d 死亡率显著低于 MPI 恶化组(16.7% *vs* 47.1%)。李跃东等[26]发现右心室 Tei 指数对脓毒症患者死亡预测的 ROC 曲线下面积可高达0.962,右心室 Tei 指数升高是脓毒症患者死亡的独立危险因素。SCM 往往表现为心脏收缩和或舒张功能不全,而 Tei 指数可同时反映心脏的收缩功能和舒张功能,所以在评估 SCM 患者心脏功能及其预后方面是较为可靠的无创指标。

2　TEE 在 SCM 中的应用

TEE 是指利用安装在内镜尖端的小型超声探头,经食管内探查心脏和大血管解剖结构和血流信息的影像诊断技术。与 TTE 相比,它可以在有创机械通气、肥胖、有外科敷料等情况下,获得清晰、稳定的图像[27]。TEE 可以发现脓毒症伴新发房颤患者的很多异常表现,如左心耳血栓等[28]。TEE 的准确性与操作者的技术水平密切相关,属于半侵入性检查,检查中有鼻咽部及食道黏膜损伤出血、恶性心律失常等严重并发症发生的可能性,所以并非临床的首选检测手段。

3　STE 在 SCM 中的应用

STE 是近年来发展起来的一种新技术,它是利用 STI 在高帧频二维灰阶超声成像的基础上,采用最佳模式匹配技术追踪识别心肌内回声斑点的空间运动,并跟踪其在每一帧图像中的位置,标测不同帧之间同一位置的心肌运动轨迹。该技术不受声束方向与室壁运动方向夹角的影响,可以检测心肌各个方向上的运动。

3.1　STE 对 SCM 早期诊断的价值　STE 在 SCM 中的应用,研究中涉及最多的参数是纵向应变(longitudinal strain, LS),包括整体纵向应变(global longitudinal strain, GLS)和节段性纵向应变。应变的正常参考值尚未确定,对 24 项研究共 2 597 个对象进行荟萃分析,结果发现健康个体中的 GLS 通常介于−22.1%和−15.9%之间[29]。脓毒症及感染性休克各项研究中,所赋予的异常 GLS 截断值不统一。Vallabhajosyula 等[30]收集了 5 项关于通过 STE 测量 GLS 以评估脓毒症心功能障碍的前瞻性研究,发现研究中定义的异常 GLS 截断值介于−17%～−10%。Hai 等[31]收集了 90 例脓毒性休克和 37 例脓毒症但无休克患者的超声参数,比较发现两组间 GLS 存在差异,而 LVEF 无差别,且脓毒性休克患者左心室 GLS 在 24 h 时即出现了明显恶化,而 LVEF 无显著变化[32]。Haileselassie 等[33]研究了 STE 在儿童脓毒症中的应用价值,对 23 例脓毒症患儿(平均年龄 7.21 岁)入院即完成超声心动图,于心尖四腔切面计算 GLS,结果发现,GLS 平均值为−13%,与翰·霍普金斯儿童中心公布的健康儿童的 GLS(−19%)不同。同时该研究还发现,即使脓毒症患儿监测的左心室短轴缩短率(fractional shortening, FS)正常,但应变已经发生异常,LS 出现降低。Zaky 等[34]的研究表明,组织运动瓣环位移(tissue motion annular displacement, TMAD)的降低与心室收缩和舒张功能障碍有关,且 TMAD 比左室 LS 更具有可靠性。这些表明 STE 可以比传统超声心动图更早地检测出脓毒症及感染性休克引起的心功能早期改变,它对 SCM 早期诊断有一定的参考价值。

3.2　STE 对 SCM 预后评估的价值　Bazalgette 等[35]研究发现,GLS 可以发现感染性休克早期(24 h 内)的心肌抑制,GLS 平均值约为−11%,随着时间推移,GLS 会有改善,平均值为−16%,而 LVEF、LV-Sm 不随时间变化,GLS 的灵敏度高,或许能实时监测心肌功能。有研究表明,GLS 与 TnI、NT-proBNP 这些反映心肌损伤、心功能障碍的指标正相关[36]。Innocenti 等[37]收集 354 例脓毒症患者,24 h 内完善超声检查,将左心室 GLS>−14%定义为左心室收缩功能障碍,与患者 28 d 全因死亡率增加有关,且左室前壁基底段应变的降低与脓毒症患者的死亡率增加有关[34]。Beesley 等[38]研究脓毒症期异常左心室收缩应变的长远影响,结果发现,左心室 GLS 与脓毒症患者出院后 24 个月内不良心血管事件发生率呈 U 型关系。综上可见 GLS 对评估脓毒症的预后具有一定的价值。

3.3　STE 的不足　尽管 STE 在 SCM 的早期诊断、治疗监测、预后等方面具有重要的临床价值,但也存在很多不足之处。比如,目前还没有公认的定义 SCM 中 GLS 的阈值;对图像要求高,很大程度依赖专业人员的专业知识;图像采集平台差异和斑点追踪算法的供应商间差异等。

4　超声心动图在 SCM 中的展望

超声心动图具有无创、可重复等优势,在 SCM 的诊断及预后评估方面有着一定的应用价值,尤其是 STE,虽然目前有一些不足之处,但在克服阈值标准化、算法优化等困难后,有望成为探查 SCM 患者早期心肌损伤及其发生机制的重要手段。

利益冲突　无

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收稿日期:2023-10-29　**修回日期**:2023-11-14　**编辑**:李方

(上接第 1668 页)

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收稿日期:2023-10-05　**修回日期**:2023-12-19　**编辑**:叶小舟