美国超声心动图学会专家共识

急诊超声心动图：美国超声心动图学会及美国急诊医师学会共识

Focused Cardiac Ultrasound in the Emergent Setting:
A Consensus Statement of the American Society of Echocardiography and American College of Emergency Physicians

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在过去 50 年中，超声已经发展成为对患者进行心脏评估不可或缺的一线检查手段。由于探头技术的进步和微型化，以及住院医培训项目和一些专科培训课程的改变，使得急诊超声心动图得以融入一些专科尤其是急诊科的临床实践中。在急诊科，急诊超声心动图已成为急诊科医生在床旁对病人进行快速的评估以便于快速开始治疗和判断病情急缓的基本工具。(J Am Soc Echocardiogr 2010;23:1225-30.)

关键词: 超声心动图 急诊科 急诊超声心动图 复苏

本共识由美国超声心动图学会（the American Society of Echocardiography, ASE）与美国急诊医师学会（the American College of Emergency Physicians, ACEP）共同拟定，主要目的为阐述急诊超声心动图（focused cardiac ultrasound，FOCUS）在病人诊治中的重要作用，以及急诊超声心动图对常规完整超声心动图的补充作用。我们将列出急诊超声心动图各项可能的临床应用，这也是超声心动图室和急诊科之间合作关系演变的一部分。在急诊科进行的超声心动图检查通常是由急诊科医师在进行其他系统的简要超声检查时同时进行（例如对低血压患者进行腹主动脉瘤、异位妊娠破裂或外伤造成的腹内出血的筛查），但本共识仅限于急诊超声心动图对于心脏方面的应用。在急诊科进行的常规超声心动图或经食道超声心动图也十分重要，但在本文中不作讨论。

急诊超声心动图与常规超声心动图

急诊超声心动图的主要作用是及时评估有心脏相关症状的患者 [1-5]。评估主要包括检出心包积液、评估心腔大小、心脏整体功能及患者容量状态（表 1）。血管内容量可以通过左心室大小、心室功能、下腔静脉宽度及呼吸变化率来估计。此外，急诊超声心动图还可以用于引导急诊侵入性操作，例如心包穿刺、评估经静脉起搏器植入的位置等 [3,5]。

其他的一些病理性诊断（心脏肿瘤、左心室血栓、瓣膜功能不全、节段性室壁运动障碍、心内膜炎、主动脉夹层）可能通过急诊超声心动图首诊疑似，但建议还需要通过常规超声心动图或心脏专科会诊来进一步评价。如需对心腔压力、瓣膜病理及舒张功能进行进一步的评价，则需要进一步培训常规超声心动图的技能。

当急诊超声心动图的发现与临床表现不符合时，需要进行常规超声心动图或其他影像方法的检查。急诊超声心动图的临床应用以及所获得的信息与常规超声心动图截然不同，下面几个章节主要阐述二者在患者诊疗中的不同作用。美国急诊医师学会（ACEP）急诊超声成像概要 [3] 中也论述了急诊超声，包括急诊超声心动图及其他主要急诊超声项目的应用。

表 1 急诊超声心动图在有症状患者中的应用

评估心包积液是否存在
评估心脏整体收缩功能
识别右心室和左心室的显著扩大
评估血管内容量
心包穿刺的超声导引
确认经静脉起搏导线的放置位置

急诊超声心动图检查所见

心包积液

研究表明急诊超声心动图对于检出医源性或外伤性的心包积液均具有较高的敏感性和特异性[6-10]。多平面、多窗口的观察能够更准确地诊断心包积液。重要的是认识到心包填塞是一项临床诊断，是在血压低、心率快、奇脉或颈静脉怒张等临床征象的同时，合并心包腔的积液、积血或血栓等超声表现。

虽然急诊超声心动图可以观察到右室壁舒张延迟、右房或右室舒张期塌陷等心包压力升高的表现，但常常需要用常规超声心动图二维及多普勒成像进一步确定是否有血流动力学改变及其程度，并序列监测其进展[10-12]。此外，小量的、局限性的心包积液通过急诊超声心动图常常难以发现，如果临床高度怀疑心包积液而急诊超声心动图并未显示心包积液，则建议进行常规超声心动图或其他影像检查。

对外伤患者而言，足以引起血流动力学明显变化的心包积液可能只是小量的或局限性的，出血可能仅仅表现为血栓的形成，然而血流动力学的不稳定可能已十分显著。对于这样血流动力学极不稳定的患者，常常来不及进行常规超声心动图就必须开始给予相应的治疗。

如果需要进行急诊心包穿刺，超声可以通过从剑突下、肋缘下或其他经胸切面显示积液聚集的部位从而帮助确定穿刺进针的路径[13-15]。有研究证实，对于病情危重的患者，如果能够迅速地在床旁确定心包积液是否可以穿刺引流，由超声引导的心包穿刺较无超声引导的心包穿刺成功率更高、并发症发生率更低[12,13]。穿刺过程中注射空气微泡（agitated saline）有助于判断针头的位置[14]。

心脏整体收缩功能

急诊超声心动图可以用于评价左心室整体收缩功能。主要通过在胸骨旁、剑突下、心尖等多个窗口观察心内膜的位移、室壁的增厚来评价。需要注意的是，急诊超声心动图只能用于评估整体的心功能，区分“正常”或轻微受损的心功能与“减低”或明显减低的心功能。非超声心动图专业人员进行的这种描述性诊断与专业超声心动图人员的解释有较好的相关性[16]。这种急诊简要检查有助于临床决策——判断急性呼吸困难或急性胸痛的患者是否伴有收缩功能减低，因而能通过药物或其他治疗而使患者受益[17]。室壁运动障碍或其他原因引起的呼吸困难（例如瓣膜功能不全）则较难通过急诊超声心动图进行评估，应通过常规超声心动图评估。

右心室扩大

在急性大面积肺栓塞时，右心室扩张、功能或收缩力下降。血液动力学显著异常的肺栓塞患者，左心室可能充盈不足，处于高动力状态。右心室扩大及功能下降对肺栓塞有重要的预后价值，与显著升高的院内死亡率相关，也是早期预后不良的最好预测指标之一[18-21]。对于怀疑肺栓塞的患者，急诊超声心动图有利于选择下一步检查、鉴别诊断以及重症患者的治

疗决策[18-22]。鉴于大多数肺栓塞患者的溶栓治疗可以适当延迟，一旦怀疑患者发生肺栓塞时，推荐利用常规超声心动图进一步评估右心室大小和功能[23,24]。

急诊超声心动图可以通过观察右室扩张（RV/LV 大于 1:1）、右室收缩功能下降、或有时发现的漂移血栓等来发现血液动力学异常的肺栓塞。虽然次大面积肺栓塞也可以导致右心室扩大、收缩功能下降，但这两个指标即使在常规经胸心脏超声中对诊断肺栓塞的敏感性也是相对较低的（分别为 29%和 51%，联合使用时敏感性可达 52%-56%）[21,23]。正如在 ACC/ASE 合理使用标准中所述，经胸心脏超声敏感性不够，无法用来排除肺栓塞诊断[25]。同样，急诊超声心动图检查如果阳性对于重症患者有诊断价值，但显然无法用于排除这一重要的诊断，或者对血液动力学稳定的患者的危险分层也没有太大帮助。常规超声心动图可用于危险分层，但应选用其他影像检查（如 CTA）来排除肺栓塞[18,22-24]。另外，急诊医生应该清楚，RV/LV 升高并不是肺栓塞所特有，急性和慢性右室形态异常可以发生在慢性阻塞性肺病（COPD）、阻塞性睡眠呼吸暂停（OSA）、肺动脉高压、右室心梗等患者。

容量评估

代表中心静脉压的右房压力可通过测量下腔静脉直径及其随呼吸的变化而估计[26-28]。具体是观察矢状面上膈肌下下腔静脉在呼吸周期中的直径变化。吸气时，胸腔内负压导致管腔内负压，血液回流至心脏。胸外下腔静脉顺应性促使其直径在正常的吸气过程中变小。血管内容量减少的患者，相对于容量正常或者增加的患者，其下腔静脉吸气时直径与呼气时直径的比例变化更大，因此，可以迅速评估血管内容量。观察到吸气时下腔静脉明显塌陷，可及时发现低血容量的患者[29]。

临床应用

急诊超声心动图的临床适应症

大量文献支持急诊超声心动图适用于多种常见的临床情况，并可能影响临床决策和治疗。急诊超声心动图的使用也随着技术和患者需求在变化，本共识主要反映目前的临床实践。下面分别阐述相关临床情况及可采用的急诊超声心动图检查技术。

心脏创伤

近 20 多年来急诊超声心动图已经成为钝器伤、穿通伤患者评估不可缺少的一部分，大量的研究和文献促使急诊超声心动图作为创伤急诊超声评估（Focused Assessment with Sonography in Trauma, FAST）检查的一部分被纳入美国创伤生命支持培训和治疗程序[2,5]。创伤后进行 FAST 检查旨在检出心包、胸腔以及腹腔积液，从而判断是否有活动性出血。急诊超声心动图（FOCUS）作为 FAST 检查的一部分，用于评估心包积液（以及可能即刻需要外科处理的心脏损伤）。此外，急诊超声心动图还可以评估心室整体的收缩运动是否正常。急诊超声心动图可以缩短对心胸部外伤的患者进行必要诊治所需的时间，从而改善需要急诊开胸或剖腹手术治疗的患者预后[30,31]。临床试验显示在创伤诊断评估中实施急诊超声心动图可以减少发病率，并可以降低穿通伤患者死亡率[6,7,30,31]。因此，急诊超声心动图已经成为创伤中心对创伤患者的标准措施之一。

除了检出心包积液，我们还可以根据室壁运动减弱、心肌收缩力下降发现心脏挫伤，但由于我们往往对患者潜在的疾病问题不很清楚，而且局部室壁运动异常的评估也比较有难度，因此这一诊断往往相对困难。很多情况下这些患者需要进行常规超声心动图随访，从而量化收缩功能受损的程度并监测其随时间的变化。

心脏骤停

心脏骤停患者需要立即启动高级心脏生命支持（ACLS）治疗程序，并迅速评估潜在的可治疗或可逆转的心脏骤停原因。此时实施急诊超声心动图的目的是改善心肺复苏的结局，通过 1）识别心脏有序收缩，帮助医生区别心搏停止（asystole）、无脉电活动（PEA）和假性 PEA；2）确认导致心脏骤停的心脏方面的原因；以及 3）在床旁引导急救治疗措施[10,32-35]。

当患者没有心室收缩，而心电图也显示心搏停止时，即使采取积极的 ACLS，其生存率仍然很低。如果患者在到急诊之前进行了院前 ACLS，而急诊超声心动图仍提示心室没有收缩活动、心电图也无心搏迹象时，生存率则可能微乎其微[34,36]。

真正的 PEA 是指虽然有电活动，但心室没有收缩，而假性 PEA 则是指心脏超声显示有心室收缩，但不能触及脉搏[32,34,35]。因此，确定假性 PEA 的诊断对于诊断和预后都非常重要。发生假性 PEA 的患者仍然有可观察到的心输出量（虽然很低），且生存率较高，其原因可能是发生心脏骤停的原因常常可以找到并予以治疗[32-35,37,38]。有众多文献支持急诊超声心动图可以识别发生 PEA 的原因及假性 PEA（见“低血压/休克”章节），目前的研究主要关注患者的预后。使用急诊超声心动图识别 PEA 的病因，对心肺复苏基本没有干扰（或干扰很小）但可以缩短开始治疗和恢复自主循环的时间[32-35]。急诊超声心动图仅推荐用于 PEA 和心电图显示无心搏电活动的患者，对室性心律失常则不应该由于使用急诊超声心动图而延误治疗。这些患者应该在病情相对稳定后进行常规超声心动图，进一步寻找潜在的心脏结构异常，如肥厚型心肌病、右室发育不良等[33]。

低血压/休克

急诊超声心动图在低血压患者中的应用与其在心脏骤停中的应用类似。当患者低血压的原因尚不清楚需要进行鉴别诊断时，急诊超声心动图可以判断休克是否是心源性的。休克需要尽早给予积极干预以预防低灌注造成的器官功能衰竭，因此将心源性休克与其他原因造成的休克鉴别开来十分重要。如前所述，急诊超声心动图检查可以评估心包积液、心脏整体功能、右室大小以及下腔静脉直径/是否塌陷以了解中心静脉压。在适宜的临床病例中，急诊超声心动图可以在床旁指导医生进一步的治疗、优化诊断步骤以及评估治疗效果[38-40]。

急诊超声心动图检查可以提供很多重要的信息，包括是否存在心包积液、积液量及其与血液动力学不稳定的关系，并有利于更快地实施心包穿刺并提高其成功率和减少并发症[37,41]。围心脏骤停期评估右室大小有助于医生根据临床表现以及急诊超声心动图检查结果判断是否是大面积肺栓塞，并考虑溶栓治疗（见此前的“右心室扩大”章节）[18,25]。需要重申的是，即使没有上述这些发现，也不能轻易排除具有临床意义的肺栓塞，但是一旦在血流动力学不稳定的患者中发现右心室扩大，这一诊断则往往能挽救生命[18]。研究证明，急诊超声心动图可准确评估心脏整体收缩功能[16,17]。如果发现左室心功能较差但仍可被探测到，则提示需要正性肌力药物或机械支持。对于围心脏骤停期的患者，用急诊超声心动图评估心室收缩可以提示经皮或经静脉起搏是否成功[42,43]。最后，左室高动力状态结合临床表现可提示低血容量、脓毒血症或大面积肺栓塞等诊断。

在某些少见但危急的情况，如安置起搏器导致心室穿孔，用急诊超声心动图发现心包积液有利于及时手术修补。然而在复苏后，进行仔细的常规超声心动图检查则有利于继续监测心脏功能以及评估复苏措施对血液动力学的影响。休克患者如发生下腔静脉塌陷，则提示需进行腹部超声评估腹腔是否有出血[44,45]。

呼吸困难/气短

呼吸困难是进行常规超声心动图检查的Ⅰ类适应症。当患者出现急性呼吸困难、气短时，进行急诊超声心动图检查的主要目的是排除心包积液、明确左室整体收缩功能以及评估右室大小，后者往往提示是否有造成血液动力学改变的肺栓塞，以上这些已在前文予以讨论。

然而，呼吸困难的全面评估要求进行常规超声心动图检查，评价心脏舒张功能、肺动脉压力、心包情况以及是否存在瓣膜疾病[25,46]。虽然急诊超声心动图检查可以发现明显的瓣膜狭窄或反流（这些情况通常需要二维超声和彩色多普勒来评估），仍然应该进行详细的常规超声心动图检查以提供全面、定量的分析[47,48]。

胸痛

在评估血液动力学明显异常的肺栓塞（已予以讨论）或筛查可能的主动脉夹层等危及生命的胸痛综合征时，进行急诊超声心动图检查会有所帮助。

对于主动脉夹层患者，夹层的范围及其并发症等相关信息需要由常规超声心动图检查提供，而急诊超声心动图检查的主要用途是在怀疑有主动脉夹层的患者，检查是否存在心包积液或胸腔积液以及测量主动脉根部的直径。当主动脉根部直径超过 4cm 时往往提示 A 型夹层，并提示疑似是夹层的诊断，但重要的是如果急诊超声心动图，甚至常规超声心动图检查结果阴性时，并不能排除主动脉夹层，此时应当进一步进行其他影像检查以明确诊断和分型。

当胸痛患者疑似急性心肌缺血而静息心电图不能明确诊断时，胸痛是进行常规超声心动图检查的Ⅰ类适应症[25,49]。鉴于节段性室壁运动异常和室壁厚度的分析是对技术要求较高，因此，这种情况下急诊超声心动图不作为首选，应由经验丰富的超声心动图专业人员进行全面详细的常规超声心动图检查来评估节段性室壁运动异常。

培训及实践

ASE 和 ACEP 均已发布关于医师和超声技术人员使用心脏超声和超声心动图培训的指南及相关文献。由于常规超声心动图的培训不同于急诊超声心动图，两个学会均有必要保持其各自的培训规程的整体性并保证对这些影像技术合理可靠的使用。

常规超声心动图培训指南由 ASE 起草并记录在 ACC/AHA 超声心动图临床能力声明的意见书中。这些培训指南适用于开展常规超声心动图的医师和相关人员[25,48]。

所有的急诊超声检查（包括 FAST 和急诊超声心动图检查 FOCUS）培训指南由 ACEP 起草并记录在该学会的急诊超声指南意见书中[1-3]。

所有的“最低”培训病例数都是为保证该培训层级上的受训者采得并判读足够多的超声影像以学习到可能出现的各种诊断。因此，急诊超声心动图学员和完整常规超声心动图学员都应该学习涵盖一定广度的、在该培训层级上应识别的各类疾病案例（包括阳性病例和阴性病例）。如果未达到该培训层级所要求的最小病例数，学员应当使用涵盖本文档中阐述的各种疾病的教学性病例库来辅助学习，即便在已经达到训练数量时也应如此。急诊超声心动图的操作标准应当与该医院开展的所有其他诊断影像检查的质量监控过程相一致。任何使用急诊超声心动图检查进行临床决策的项目都必须对图像质量进行内部和外部的质量评估，后者主要通过与病理和手术结果、临床结局及最终诊断进行比较分析，最好每年一次。保证急诊超声心动图检查的质量非常重要，这可以通过与其他检查结果（如 CT、常规超声心动图等）进行相关分析，也可以请有经验的专家（受过亚专科培训或有超声心动图或急诊超声认证的医生）再次阅读超声。推荐有条件的单位应尽可能与常规超声心动图实验室合作进行培训。

其次，急诊超声心动图和常规超声心动图专业人员都应当接受继续教育。ASE 和 ACEP 均要求能力评估，包括现行操作能力评估和教学培训，这两个组织都致力于专业的高标准以及组织的高效率。

设备选择

超声设备的选择主要涉及成本、便携性、图像质量以及使用者的水平。如果使用者能够操作并分析高级心脏超声成像仪器，那么全功能、高档的操作平台是合适的。便携的超声仪

器相对较小，使用更容易，价格低廉。由于其尺寸较小，因此适用于任何急救场合并有可能在院前急救时作为诊断检查使用[50]。在急诊科，与仅仅依靠查体相比，医生使用便携式超声可显著提高心血管结构异常的检出率率，从而可以提高诊断的准确性[51-56]。但是，如果常常需要采用同一超声设备对其他部位进行超声检查，这会极大地影响到设备的选择，因为不是每一台心脏超声诊断仪都能与其他超声影像的探头适配。

急诊超声心动图图像存档及报告

由于急诊超声心动图对患者诊疗以及治疗方案和随后的诊断性测试的选择等临床决策有很大的影响，它在急诊科的使用明显增长，因此，图像存档在医院常规运营中实属必要，而且非常重要。医院内所有用于急诊超声心动图检查的超声设备都应该具有在可离线观看和存档的某一媒体上存储图像的功能。急诊超声心动图检查应当记录在医疗文书中，并基于每个医院各自的文件储存系统提供纸质或电脑报告。在患者离开急诊之前，应有完整的纸质或者电子版检查报告，除非患者的病情急需立即转院（此时可以提供口头报告、随后再提供纸质或者电子报告）。正式报告应当与实时结果尽量一致，如有内容变动，应当及时通知医疗记录人员，并告知患者或者患者的医生。

报告应该涵盖以下内容：

1. 检查日期和时间
2. 患者姓名及 ID 号
3. 患者年龄（出生日期）和性别
4. 检查指证
5. 检查者的姓名
6. 检查发现
7. 检查的局限性及后续检查推荐
8. 检查印象
9. 检查结果判读者的姓名
10. 报告签署日期和时间
11. 数据存储方式

急诊超声心动图的整合与发展

使用急诊超声心动图需要掌握该技术的适用范围和局限性。其局限性来自于检查本身及读图医生的培训情况。瓣膜病、舒张功能不全以及节段性室壁运动异常等心脏异常往往最终需要常规超声心动图检查。情况允许时，急诊超声心动图检查发现的异常应进一步通过常规超声心动图检查以及其他检查和会诊来确认。但是，急诊超声心动图检查可以发现一些病理情况，指导复苏治疗并挽救生命。最后，急诊超声心动图检查医生应当与心脏超声专科医生相互配合，充分使用这一项有价值的检查手段，致力于诊断的及时准确以及治疗的合理性。

Focused Cardiac Ultrasound in the Emergent Setting: A Consensus Statement of the American Society of Echocardiography and American College of Emergency Physicians

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The use of ultrasound has developed over the last 50 years into an indispensable first-line test for the cardiac evaluation of symptomatic patients. The technologic miniaturization and improvement in transducer technology, as well as the implementation of educational curriculum changes in residency training programs and specialty practice, have facilitated the integration of focused cardiac ultrasound into practice by specialties such as emergency medicine. In the emergency department, focused cardiac ultrasound has become a fundamental tool to expedite the diagnostic evaluation of the patient at the bedside and to initiate emergent treatment and triage decisions by the emergency physician. (J Am Soc Echocardiogr 2010;23:1225-30.)

Keywords: Echocardiography, Emergency department, Focused cardiac ultrasound, Resuscitation

This consensus statement by the American Society of Echocardiography (ASE) and the American College of Emergency Physicians (ACEP) delineates the important role of focused cardiac ultrasound (FOCUS) in patient care and treatment and emphasizes the complementary role of FOCUS to that of comprehensive echocardiography. We outline the clinical applications where FOCUS could be used, as part of the evolving relationship between echocardiography laboratories and emergency departments. Although cardiac ultrasound as performed by emergency physicians in emergency departments is often performed in the context of other focused ultrasound applications (examining the hypotensive patient for abdominal aortic aneurysms, ruptured ectopic pregnancy, or intraperitoneal hemorrhage as a result of trauma), the scope of this consensus statement is limited to cardiac applications of the FOCUS examination. Accordingly, the important role of comprehensive transthoracic echocardiography and transesophageal echocardiography in the emergency department will not be discussed in detail in this article.

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FOCUSED CARDIAC ULTRASOUND VERSUS COMPREHENSIVE ECHOCARDIOGRAPHY

The principal role for FOCUS is the time-sensitive assessment of the symptomatic patient.[1-5] This evaluation primarily includes the assessment for pericardial effusion and the evaluation of relative chamber size, global cardiac function, and patient volume status (Table 1). Intravascular volume status may be assessed by left ventricular (LV) size, ventricular function, and inferior vena cava (IVC) size and respiratory change. In addition, FOCUS is used to guide emergent invasive procedures, such as pericardiocentesis, or evaluate the position of transvenous pacemaker placement.[3,5]

Other pathologic diagnoses (intracardiac masses, LV thrombus, valvular dysfunction, regional wall motion abnormalities, endocarditis, aortic dissection) may be suspected on FOCUS, but additional evaluation, including referral for comprehensive echocardiography or cardiology consultation, is recommended. Further hemodynamic assessment of intracardiac pressures, valvular pathology, and diastolic function requires additional training in comprehensive echocardiography techniques.

Comprehensive echocardiographic examination or other imaging modalities are recommended in any case in which the focused findings and clinical presentations are discordant. Clinical scenarios and the information obtained from the focused use of cardiac ultrasound in emergent situations are distinctly different from those where comprehensive echocardiography are used, and both types of studies have a role in optimizing patient care as will be outlined in the

Abbreviations

ACEP = American College of Emergency Physicians

ACLS = Advanced Cardiac Life Support

ASE = American Society of Echocardiography

FOCUS = Focused cardiac ultrasound

IVC = Inferior vena cava

LV = Left ventricular

PEA = Pulseless electrical activity

RV = Right ventricular

following sections. The role of emergency ultrasound, including FOCUS and other core emergency ultrasound applications, also is discussed in ACEP's Emergency Ultrasound Imaging Compendium.[3]

FOCUSED CARDIAC ULTRASOUND EXAMINATION FINDINGS

Pericardial Effusion

Studies have shown a high degree of sensitivity and specificity in the detection of pericardial effusions in both medical and trauma patients using FOCUS.[6-10] Imaging in multiple views or windows provides the most accurate detection of pericardial effusion. It is important to recognize that pericardial tamponade is a clinical diagnosis that includes the visualization of pericardial fluid, blood, or thrombus, in addition to clinical signs including hypotension, tachycardia, pulsus paradoxus, and distended neck veins.

Although FOCUS may be used to visualize delayed right ventricular diastolic expansion and right atrial or ventricular diastolic collapse representing increased pericardial pressures, there are additional two-dimensional and Doppler findings obtained in a comprehensive exam that can confirm or refute the degree of suspected hemodynamic compromise and provide a means of serially monitoring its progress.[10-12] In addition, small, more focal pericardial effusions can be difficult to recognize with FOCUS, and a comprehensive echocardiogram or other diagnostic imaging testing is indicated whenever the clinical suspicion for the presence of effusion is high and the FOCUS could not demonstrate it.

In trauma patients, hemodynamically significant pericardial effusions may be small or focal and the hemorrhage may exhibit evidence of clot formation, yet the degree of hemodynamic instability may be pronounced. In such hemodynamically unstable patients, a comprehensive echocardiogram will typically not be obtained before initial treatment is provided.

When emergency pericardiocentesis is indicated, ultrasound can provide guidance by first imaging the fluid collection from the subxiphoid/subcostal or other transthoracic windows to define the best trajectory for needle insertion.[13-15] If the diagnosis of a pericardial effusion that could be drained percutaneously can be made at the bedside expeditiously, ultrasound-guided pericardiocentesis in these critically ill patients has been shown to have fewer complications and a higher success rate than if done without ultrasound guidance.[12,13] Injection of agitated saline may be helpful in localizing needle placement during this procedure.[14]

Global Cardiac Systolic Function

FOCUS can be used for global assessment of LV systolic function. This assessment relies on overall assessment of endocardial excursion and myocardial thickening, using multiple windows, including the parasternal, subcostal, and apical views. It is important to note that FOCUS is performed to assess global function and differentiates patients into "normal" or minimally impaired function versus "depressed" or significantly impaired function. This descriptive nomenclature when used by non-echocardiographers has good correlation with echocardiographer interpretations.[16] The goal of the focused exam is to facilitate clinical decision-making to decide if a patient with acute shortness of breath or chest pain has impaired systolic contractility and thus would benefit from pharmacologic therapies or other interventions.[17] Evaluation of segmental wall motion abnormalities and other causes of shortness of breath (e.g., valvular dysfunction) can be challenging and should be assessed by performing a comprehensive echocardiogram.

Table 1 Goals of the focused cardiac ultrasound in the symptomatic emergency department patient

Assessment for the presence of pericardial effusion
Assessment of global cardiac systolic function
Identification of marked right ventricular and left ventricular enlargement
Intravascular volume assessment
Guidance of pericardiocentesis
Confirmation of transvenous pacing wire placement

Right Ventricular Enlargement

In an acute massive pulmonary embolus, the right ventricle can be dilated and have reduced function or contractility. In patients with hemodynamically significant pulmonary embolus, the left ventricle can be underfilled and hyperdynamic. The presence of right ventricular (RV) enlargement and dysfunction in patients with pulmonary embolus is prognostically important and associated with significantly higher in-hospital mortality, as well as being one of the best predictors of poor early outcome.[18-21] The role of FOCUS in patients with suspected pulmonary embolus is to prioritize further testing, alter differential diagnosis assessments, and assist with treatment decisions in the *severely* compromised patient.[18-22] Because the use of thrombolytic therapy in most patients can safely be delayed, it is recommended to further assess the size and function of the RV using comprehensive echocardiography once the suspicion for the presence of pulmonary embolism is established.[23,24]

FOCUS can be used to identify hemodynamically significant pulmonary emboli by observing right ventricular dilatation (>1:1 RV/LV ratio), decreased right ventricular systolic function, or occasionally by visualizing free-floating thrombus. Although an acute submassive pulmonary embolus can result in RV enlargement and dysfunction, the sensitivity of these findings even on comprehensive transthoracic echocardiography is limited (29% and 51%, respectively, 52%–56% using both criteria combined).[21,23] As stated in the American College of Cardiology/ASE appropriateness criteria document, transthoracic echocardiography is not sufficiently sensitive to rule out pulmonary embolism.[25] Likewise, FOCUS may be helpful if positive in the compromised patient but is clearly not sufficient to rule this important diagnosis out or to risk stratify patients with stable hemodynamics. Comprehensive echocardiography can be used to risk stratify patients, whereas other imaging modalities (e.g., computed tomographic angiography) should be the diagnostic modality of choice to exclude the diagnosis.[18,22-24] In addition, emergency physicians should be aware that an increased RV:LV ratio is not specific for pulmonary embolus and that acute and chronic RV abnormalities may exist in patients with chronic obstructive pulmonary disease, obstructive sleep apnea, pulmonary hypertension, and right-sided myocardial infarction, among others.

Volume Assessment

Right atrial pressures, representing central venous pressure, can be estimated by viewing size and respiratory change in the diameter of the IVC.[26-28] This is done by viewing the vena cava below the diaphragm in the sagittal plane and observing the change in the IVC diameter during the respiratory cycle. During inspiration, negative intrathoracic pressure causes negative intraluminal pressure and increases venous return to the heart. The compliance of the extrathoracic IVC causes the diameter to decrease with normal inspiration. In patients with low intravascular volume, the inspiration to expiration diameter ratios change more than in those patients who have normal or high intravascular volume, and therefore a quick assessment of intravascular volume can be made. IVC evaluation can be particularly helpful in those patients with a significant respiratory collapse during inspiration, permitting prompt identification of the hypovolemic patient.[29]

CLINICAL APPLICATIONS

Clinical Indications for Focused Cardiac Ultrasound

There are a number of common clinical scenarios where FOCUS has substantial literature support and potential to affect clinical decision making and patient care. Use will continue to evolve with technology and the changing needs of the patient. This consensus statement reflects current clinical practice. The following sections review the clinical conditions and applicable techniques of FOCUS.

Cardiac Trauma

FOCUS has been an integral part of the evaluation of the blunt and penetrating trauma patient for more than 20 years. Extensive research and literature support have led to the incorporation of FOCUS into the American Trauma Life Support training and treatment algorithm as part of the Focused Assessment with Sonography in Trauma or FAST exam.[2,5] The FAST exam aims to identify active hemorrhage post-trauma by evaluating for the presence of fluid around the heart, in the thoracic cavity, and in the peritoneum. FOCUS is part of the FAST exam and is used to evaluate for the presence of pericardial effusion (and thus the identification of possible cardiac injury that may require immediate surgical attention). In addition, the presence or absence of organized ventricular contractility can be assessed. Performing emergent FOCUS as part of the FAST exam has improved outcomes by decreasing the time required to diagnose and treat traumatic cardiac and thoracic injury in those patients requiring emergent thoracotomy or laparotomy.[30,31] Not only have trials shown decreased morbidity by incorporating FOCUS into trauma diagnostic evaluations, but use of FOCUS in penetrating trauma has also been shown to have a mortality benefit.[6,7,30,31] The use of FOCUS in trauma patients has since become standard of care in trauma centers.

In addition to the identification of pericardial effusions, cardiac contusions can be identified by depressed wall motion and decreased myocardial contractility. This diagnosis can be difficult, however, because the trauma patient's underlying medical condition is often not known and the evaluation of segmental wall motion abnormalities is challenging. In many cases, these patients will have follow-up comprehensive echocardiograms so that the degree of contractile dysfunction can be quantified and monitored over time.

Cardiac Arrest

The patient in cardiac arrest requires initiation of Advanced Cardiac Life Support (ACLS) treatment algorithms and rapid diagnostic evaluation for potentially treatable or reversible causes of cardiac arrest. The goal of FOCUS in the setting of cardiac arrest is to improve the outcome of cardiopulmonary resuscitation by 1) identifying organized cardiac contractility to help the clinician distinguish among asystole, pulseless electrical activity (PEA), and pseudo-PEA; 2) determining a cardiac cause of the cardiac arrest; and 3) guiding lifesaving procedures at the bedside.[10,32-35]

In a patient with no ventricular cardiac contraction and an asystolic electrocardiogram, the survival rate is low despite aggressive ACLS resuscitation. In patients presenting to the emergency department with asystolic rhythms and no ventricular contractility by FOCUS after attempts at resuscitation with pre-hospital ACLS, survival is unlikely.[34,36]

True PEA is defined as the clinical absence of ventricular contraction despite the presence of electrical activity, whereas pseudo-PEA is defined as the presence of ventricular contractility visualized on cardiac ultrasound in a patient without palpable pulses.[32,34,35] Therefore, making the diagnosis of pseudo-PEA can be of diagnostic and prognostic importance. Patients with pseudo-PEA have some observable, although minimal, cardiac output and have a higher survival rate, in part because there are often identifiable and treatable causes of their arrest.[32-35,37,38] Although there is ample literature to support that causes of PEA and pseudo-PEA can be identified with FOCUS (see "Hypotension/Shock" section), research is now focused on patient outcomes. Identification of causes of PEA arrest by FOCUS with zero or minimal interruption in cardiopulmonary resuscitation improves outcomes by decreasing time to treatment and to return of spontaneous circulation.[32-35] FOCUS is only recommended in PEA and asystolic rhythms and should not delay lifesaving treatment of ventricular arrhythmias. These patients should be stabilized, and a comprehensive echocardiogram, looking for potential specific structural abnormalities such as hypertrophic cardiomyopathy or RV dysplasia, can be performed at a later point.[33]

Hypotension/Shock

FOCUS for the hypotensive patient is a continuum from its use in cardiac arrest. For patients presenting with undifferentiated hypotension, the primary advantage of FOCUS is in determining whether the shock is cardiogenic. Shock requires aggressive early intervention to prevent organ dysfunction caused by inadequate tissue perfusion. Therefore, the distinction of cardiogenic shock from shock of other causes is extremely important. The FOCUS exam, as previously stated, should evaluate for the presence of pericardial effusion, global cardiac function, right ventricular size, and IVC size/collapsibility as a marker of central venous pressure. In the right clinical context, this evaluation can direct the clinician at the bedside in important next treatment interventions, optimize diagnostic efficiency, and assess the response to performed interventions.[38-40]

FOCUS can give vital information regarding the presence, size, and functional relevance of a pericardial effusion as a cause of hemodynamic instability and can expedite pericardiocentesis with fewer complications and a higher success rate.[37,41] Evaluation of right ventricular size in the peri-arrest patient may lead the clinician to consider thrombolytics if the clinical scenario and the FOCUS findings (see previous section on "Right Ventricular Enlargement") suggest massive pulmonary embolus.[18,25] It is worth reiterating that the absence of these findings cannot be used to exclude the presence of

a clinically significant pulmonary embolism, although identifying an enlarged RV in an unstable patient can lead to lifesaving therapy.[18] Studies have shown that global systolic function can be assessed accurately by FOCUS.[16,17] Identification of poor but detectable LV systolic function indicates a need for further inotropes or mechanical support. In the peri-arrest patient, assessment of ventricular contraction by FOCUS can determine whether transcutaneous or transvenous pacing is capturing successfully.[42,43] Finally, the finding of a hyperdynamic left ventricle can prompt evaluation for hypovolemia or suggest sepsis or massive pulmonary embolus as a diagnosis in the right clinical scenario.

In those rare but catastrophic instances when pacemaker placement results in ventricular perforation, the ability to identify pericardial effusions can expedite operative repair. In the post-resuscitation phase, however, patients can benefit from a comprehensive echocardiogram, which can provide essential information in monitoring cardiac function and in assessing the impact of resuscitative measures on a patient's hemodynamics. In a patient with shock, a collapsed vena cava should prompt an ultrasound evaluation of the peritoneal cavity to look for abdominal hemorrhage.[44,45]

Dyspnea/Shortness of Breath

Dyspnea is a Class I indication for comprehensive echocardiography. For patients presenting with acute dyspnea and shortness of breath, the three main goals for FOCUS in this instance are to rule out pericardial effusion, identify global LV systolic dysfunction, and assess the size of the right ventricle as a proxy for indicating the presence or absence of a hemodynamically significant pulmonary embolus, all discussed above.

However, complete evaluation of dyspnea in patients requires comprehensive echocardiography to evaluate diastolic function and pulmonary artery pressures, as well as to evaluate for pericardial disease and valvular heart disease.[25,46] Although the presence of significantly stenotic valves or regurgitant lesions using two-dimensional and color Doppler techniques may be suggested by a FOCUS, full evaluation requires the quantitative analysis provided by a comprehensive echocardiogram.[47,48]

Chest Pain

The life-threatening chest pain syndromes where FOCUS may be helpful are in the evaluation of patients with a hemodynamically significant pulmonary embolus (discussed above) or in screening patients with suspected aortic dissection.

Whereas comprehensive echocardiography could provide information about the extent of dissection and complications, the role of FOCUS in patients with suspected aortic dissection is to look for pericardial or pleural effusions and to assess the diameter of the aortic root. An aortic root greater than 4 cm is suggestive of type A dissection and should raise the clinical suspicion for disease, although it is important to state that a negative FOCUS or even a negative comprehensive transthoracic echocardiogram does not rule out aortic dissection, and further imaging and diagnostic studies should be considered for definitive diagnosis and characterization.

Chest pain is also a Class I indication for the use of comprehensive echocardiography in patients with chest pain due to suspected acute myocardial ischemia when the baseline electrocardiogram is nondiagnostic.[25,49] Given that segmental wall motion and wall thickening analysis are some of the most technically demanding aspects of echocardiographic interpretation, FOCUS should not be used primarily for this purpose. Comprehensive echocardiography interpreted by experienced readers is recommended for evaluation of segmental wall motion.

TRAINING AND PERFORMANCE

Both the ASE and the ACEP have produced written guidelines and documents on the training of physicians and sonographers using cardiac ultrasound and echocardiography. It is recognized that the training requirements for comprehensive echocardiography are not the same as those for FOCUS, and therefore each society is responsible for maintaining the integrity of their training protocols and for ensuring the responsible practice and use of these imaging techniques.

Comprehensive echocardiography training guidelines have been described by the ASE and are documented in the position paper American College of Cardiology/American Heart Association Clinical Competence Statement on Echocardiography. These training guidelines are applicable for those physicians and practitioners who perform comprehensive echocardiography.[25,48]

Emergency ultrasound training guidelines for all emergency ultrasound examinations, including the FAST and FOCUS exams, have been described by the ACEP and are documented in their position paper Emergency Ultrasound Guidelines.[1-3]

For all "minimum" training numbers, it is essential that the trainee has acquired and interpreted ultrasound images that represent the full range of diagnostic possibilities for that training level. Therefore, both FOCUS and comprehensive echocardiography trainees are required to have a case mix of positive and negative studies that include the breadth of pathology expected to be recognized by a given level of training. In the event this is not achieved with the minimum number of cases required for training (and indeed even if it is), trainees should complement their learning by using a library of educational cardiac ultrasound cases that depict the various pathologies outlined in this document. It is also understood that the performance of FOCUS requires standards consistent with the quality assurance processes for all diagnostic imaging performed within the hospital. Any program that uses FOCUS to make clinical decisions must have quality assessment reviews of scan quality both internally and externally comparing interpretations with pathologic and surgical data, as well as clinical outcomes and final diagnoses, preferably on an annual basis. Quality assurance for FOCUS is essential and can be performed by correlating FOCUS findings with non-ultrasound imaging results (i.e., computed tomography), comprehensive echocardiography findings, or with over-read review by qualified experts (physicians with fellowship training or credentialing in either echocardiography or emergency ultrasound). It is recommended that training occur in partnership with a comprehensive echocardiography laboratory whenever possible.

In addition, it is recognized that expertise in both FOCUS and echocardiography requires ongoing continuing education programs. Competency assessment, including ongoing performance assessment reviews and didactic educational programs, are required by both ASE and ACEP. Both organizations are committed to maintaining high standards and are responsible for ensuring maintenance of proficiency in their respective organizations.

Device Selection

The major issues that define compact ultrasound device selection involve cost, portability, image quality, and user expertise. If users are available who can operate and interpret the advanced cardiac imaging tools, a full-featured, high-end platform may be appropriate.

Cart-based or handheld portable devices are smaller, simpler to use, and less expensive. The small size of these platforms allows their use in nearly any emergent setting and has shown potential for pre-hospital diagnostic use.[50] In the emergency department, physician use of portable machines substantially increases the detection of cardiovascular abnormalities over physical examination alone and increases diagnostic accuracy.[51-56] The need to use the same ultrasound platform to image noncardiac structures will have the greatest influence over platform selection, because not all devices suitable for cardiac use will accommodate the transducers required for other imaging applications.

Image Archival and Report Generation for Focused Cardiac Ultrasound

Given that the increasing use of FOCUS in the emergency department is a result of its impact on patient care and clinical decision making in both treatment and follow-up diagnostic testing, image archival is essential during regular hospital operations. All hospital-based ultrasound systems used for FOCUS should possess a method for recording data onto a media format that allows for offline review and archiving. The ultrasound examination should be documented within the medical record and depending on the individual hospital's documentation system can include paper records or computer-generated reports. A written or electronic description of the findings should be completed before the patient leaves the emergency department unless the patient's condition requires emergent transfer to another department, at which time verbal reporting of the findings is acceptable, followed by the written or electronic report at a later time. Official reports should be consistent with the real-time interpretation provided or a notification of substantive changes should be forwarded to medical records, as well as the patient or the patient's physicians as appropriate.

Reports should include the following:

1. Date and time of study
2. Name and hospital ID number of patient
3. Patient age (date of birth) and gender
4. Indication for study
5. Name of the person who performed the study
6. Findings
7. Limitations and recommendations for additional studies
8. Impression
9. Name of the person who interpreted the study
10. Date and time the report was signed
11. Mode of archiving the data

INTEGRATION AND EVOLUTION IN FOCUSED CARDIAC ULTRASOUND

The use of FOCUS requires knowledge of the strengths and limitations of this imaging modality. There are limitations of the FOCUS exam secondary to both the nature of the exam and the training of the individual interpreting the study. Valvular heart disease, diastolic function, and segmental wall motion analysis are examples of cardiac abnormalities that should eventually be assessed by comprehensive echocardiography. Abnormal findings on FOCUS should be referred for comprehensive echocardiography, other testing, or consultation when the situation allows for this to be done safely. However, FOCUS can identify pathologic processes that can guide resuscitative interventions and be lifesaving. In the end, patient care will be assisted by cooperation between these two professional groups that are both dedicated to the rapid and accurate diagnosis and treatment of patients using this valuable technology.

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