Use of point of care sonography by emergency physicians

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EXECUTIVE SUMMARY

Point of care sonography by emergency physicians in the emergency department can be an effective aid in the diagnosis and management of patients presenting with a variety of medical and traumatic conditions. Its use can improve patient outcomes, enhance patient safety, speed patient disposition and save lives.[1–9] CAEP supports the use of point of care sonography.

CURRENT POLICY

The CAEP Position Statement on Ultrasound in the Emergency Department was last published in May of 2006.[10] Since that time, the use of point of care sonography in Canada and around the world has increased dramatically, with newer applications identified and supporting evidence being published at an ever-increasing rate.

INTRODUCTION

The use of point of care sonography in the emergency department has expanded substantially in the last three decades. It has become a routine and integral part of care provided by emergency physicians not only in Canada, but in many other countries as well. Moreover, emergency medicine training programs now incorporate point of care sonography training. This position statement serves as an update on CAEP's previous recommendations with regards to the use of point of care sonography in Canada. Furthermore, CAEP acknowledges that emergency medicine and point of care sonography are continually evolving and that any recommendation in this position statement may not accurately reflect current practice.

RECOMMENDATIONS

1. ***Availability***

   Emergency departments choosing to utilize point of care sonography should strive to have sonographic evaluation by emergency physicians trained in its use available 24 hours a day.

2. ***Resources***

   In emergency departments choosing to utilize point of care sonography, equipment should be immediately available in the emergency department and possess appropriate functionality and quality for sonographic evaluations.

3. ***Scope of Practice***

   The use of point of care sonography by appropriately trained emergency physicians is within their scope of practice. Sonography can be used in—*but is not limited to*—the clinical situations listed below. When using sonography as a diagnostic tool, the clinician should be attempting to answer a specific predetermined question.

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Basic Applications

- Cardiac arrest[9–12]
- Assessing for pericardial effusion[9,13–16]
- Thoracoabdominal trauma[3,17–20]
- Early pregnancy[4,6–8,21–23]
- Abdominal aortic aneurysm[24,25]
- Central vascular access[2,26–38]

Advanced Applications

- Evaluation of left ventricular function[39–42]
- Volume depletion[43–45]
- Jugular venous distention[46,47]
- Undifferentiated hypotension, shortness of breath, chest pain[13,48,49]
- Gallbladder disease[50–60]
- Hydronephrosis, bladder volume[61–66]
- DVT[67–71]
- Thoracic pathology (pneumothorax, pleural effusion)[72–83]
- Ocular pathology and elevated intraocular pressure[84–90]
- Testicular pain[91,92]
- Joint effusion and tendon rupture[93,94]
- Peripheral vascular access[95,96]
- Procedures that benefit from the assistance of ultrasound:
  - Thoracentesis[97–104]
  - Paracentesis[105–107]
  - Pericardiocentesis,[108–110] lumbar puncture[111]
  - Cutaneous[112,113] and peritonsillar abscess[114] drainage
  - Foreign body removal[115–117]
  - Pediatric bladder catheterization[118]
  - Joint aspiration[80,81]
  - Temporary pacemaker placement[119]
  - Regional anesthesia[120]
  - Confirmation of endotracheal tube placement[121]

4. ***Training***

   Emergency physicians should possess appropriate training (including hands-on experience) in image acquisition and interpretation, indications for imaging, and limitations of point of care sonographic imaging. Specific training requirements should be established and monitored by emergency departments based on available evidence[19,20,122–125] and accepted standards suggested by experts in the discipline.[126–128] The Royal College of Physicians and Surgeons of Canada and the Canadian College of Family Physicians have both recognized point of care sonography as a key skill in the practice of Emergency Medicine and have incorporated it into their most recent Objectives of Training. Training of practicing emergency physicians can be obtained through a number of established courses and training pathways offered across Canada and North America. Numerous excellent textbooks are also available for self-study.[129–131]

5. ***Leadership***

   Local leaders should be designated and responsible for development and maintenance of the emergency ultrasound program.

6. ***Self-Governance***

   Emergency departments should adopt specific guidelines for the use of point of care sonography. These guidelines should address, but not be limited to, equipment maintenance, documentation, training, quality assurance, and program oversight.

7. ***Documentation***

   Point of care sonographic findings should be documented in writing.

   - Image capture may be used for quality improvement but is not mandatory.
   - Documentation should only include findings relevant to the specific indication for the scan.
   - Scans that are indeterminate should be so documented and not used in clinical decision-making.

8. ***Quality Improvement***

   A strong quality improvement program is integral to the safe practice of emergency department point of care sonography and should be incorporated into the overall emergency department quality improvement program.[128]

9. ***Continuing Medical Education***

   Continuing education and experience in point of care sonography is strongly encouraged.[128]

10. ***Research***

    Research in the field of point of care sonography is strongly encouraged.

CONCLUSION

Within the practice of emergency medicine, the use of *point of care sonography* by emergency physicians in the emergency department is an effective aid in the management of patients presenting with any one of a variety of medical and traumatic conditions. The practice of point of care sonography in Canada continues to evolve and expand, and builds on a proven history in other countries. *It is well acknowledged that point of care sonography is different from the sonographic imaging performed in the radiology department by technologists and radiologists. It is not meant to alter the established indications for, or replace the use of, comprehensive diagnostic imaging studies performed by Diagnostic Imaging.*

REFERENCES

1. Bassler D, Snoey ER, Kim J. Goal-directed abdominal ultrasonography: impact on real-time decision making in the emergency department. *J Emerg Med* 2003;24:375-8, doi:10.1016/S0736-4679(03)00032-5.
2. *Making health care safer: a critical analysis of patient safety practices*. Prepared for: Agency for Healthcare Research and Quality. Prepared by: University of California at San Francisco (UCSF)—Stanford University Evidence-based Practice Center. Available at: www.ahrq.gov (accessed January 2009).
3. Blaivas M, Sierzenski P, Theodoro D. Significant hemoperitoneum in blunt trauma victims with normal vital signs and clinical examination. *Am J Emerg Med* 2002;20:218-21, doi:10.1053/ajem.2002.32637.
4. Burgher SW, Tandy TK, Dawdy MR. Transvaginal ultrasonography by emergency physicians decreases patient time in the emergency department. *Acad Emerg Med* 1998;5:802-7, doi:10.1111/j.1553-2712.1998.tb02507.x.
5. Durham B. Emergency medicine physicians saving time with ultrasound. *Am J Emerg Med* 1996;14:309-13, doi:10.1016/S0735-6757(96)90184-9.
6. Durston WE, Carl ML, Guerra W, et al. Ultrasound availability in the evaluation of ectopic pregnancy in the ED: comparison of quality and cost-effectiveness with different approaches. *Am J Emerg Med* 2000;18:408-17, doi:10.1053/ajem.2000.7310.
7. Rodgerson JD, Heegaard WG, Plummer D, et al. Emergency department right upper quadrant ultrasound is associated with a reduced time to diagnosis and treatment of ruptured ectopic pregnancies. *Acad Emerg Med* 2001;8:331-6, doi:10.1111/j.1553-2712.2001.tb02110.x.
8. Shih CH. Effect of emergency physician-performed pelvic sonography on length of stay in the emergency department. *Ann Emerg Med* 1997;29:348-51, doi:10.1016/S0196-0644(97)70346-9.
9. Tayal VS, Kline JA. Emergency echocardiography to detect pericardial effusion in patients in PEA and near-PEA states. *Resuscitation* 2003;59:315-8, doi:10.1016/S0300-9572(03)00245-4.
10. McNaughton T, McConahy M, Lam J, et al. *CJEM* 2006;8:170-1.
11. Blaivas M, Fox JC. Outcome in cardiac arrest patients found to have cardiac standstill on the bedside emergency department echocardiogram. *Acad Emerg Med* 2001;8:616-21, doi:10.1111/j.1553-2712.2001.tb00174.x.
12. Salen P, O'Connor R, Sierzenski P, et al. Can cardiac sonography and capnography be used independently and in combination to predict resuscitation outcomes? *Acad Emerg Med* 2001;8:610-5, doi:10.1111/j.1553-2712.2001.tb00172.x.
13. Blaivas M. Incidence of pericardial effusion in patients presenting to the emergency department with unexplained dyspnea. *Acad Emerg Med* 2001;8:1143-6, doi:10.1111/j.1553-2712.2001.tb01130.x.
14. Plummer D, Dick C, Ruiz E, et al. Emergency department two-dimensional echocardiography in the diagnosis of nontraumatic cardiac rupture. *Ann Emerg Med* 1994;23:1333-42, doi:10.1016/S0196-0644(94)70361-2.
15. Plummer D, Brunette D, Asinger R, Ruiz E. Emergency department echocardiography improves outcome in penetrating cardiac injury. *Ann Emerg Med* 1992;21:709-12, doi:10.1016/S0196-0644(05)82784-2.
16. Rozycki GS, Feliciano DV, Ochsner MG, et al. The role of ultrasound in patients with possible penetrating cardiac wounds: a prospective multicenter study. *J Trauma* 1999;46:543-51, doi:10.1097/00005373-199904000-00002.
17. Boulanger BR, McLellan BA, Brenneman FD, et al. Prospective evidence of the superiority of a sonography-based algorithm in the assessment of blunt abdominal injury. *J Trauma* 1999;47:632-7, doi:10.1097/00005373-199910000-00005.
18. Ma OJ, Mateer JR. Trauma ultrasound examination versus chest radiography in the detection of hemothorax. *Ann Emerg Med* 1997;29:312-5, doi:10.1016/S0196-0644(97)70341-X.
19. Scalea TM, Rodriguez A, Chiu WC, et al. Focused Assessment with Sonography for Trauma (FAST): results from an international consensus conference. *J Trauma* 1999;46:466-72, doi:10.1097/00005373-199903000-00022.
20. Rose JS. Ultrasound in abdominal trauma. *Emerg Med Clin North Am* 2004;22:581-99, doi:10.1016/j.emc.2004.04.007.
21. Durham B, Lane B, Burbridge L, Balasubramaniam S. Pelvic ultrasound performed by emergency physicians for the detection of ectopic pregnancy in complicated first-trimester pregnancies. *Ann Emerg Med* 1997;29:338-47, doi:10.1016/S0196-0644(97)70345-7.
22. Mateer JR, Valley VT, Aiman EJ, et al. Outcome analysis of a protocol including bedside endovaginal sonography in patients at risk for ectopic pregnancy. *Ann Emerg Med* 1997;27:283-9, doi:10.1016/S0196-0644(96)70260-3.
23. Mateer JR, Aiman EJ, Brown MH, Olson DW. Ultrasonographic examination by emergency physicians of patients at risk for ectopic pregnancy. *Acad Emerg Med* 1995;2:867-73, doi:10.1111/j.1553-2712.1995.tb03099.x.
24. Kuhn M, Bonnin RL, Davey MJ, et al. Emergency department ultrasound scanning for abdominal aortic aneurysm: accessible, accurate, and advantageous. *Ann*

Emerg Med 2000;36:219-23, doi:10.1067/mem.2000.108616.

25. Tayal VS, Graf CD, Gibbs MA. Prospective study of accuracy and outcome of emergency ultrasound for abdominal aortic aneurysm over two years. *Acad Emerg Med* 2003;10:867-71, doi:10.1111/j.1553-2712.2003.tb00630.x.
26. Hind D, Calvert, McWilliams R, et al. Ultrasonic locating devices for central venous cannulation: meta-analysis. *BMJ* 2003;327:361-4, doi:10.1136/bmj.327.7411.361.
27. Hrics P, Wilber S, Blanda MP, Gallo U: Ultrasound-assisted internal jugular vein catheterization in the, editor. *Am J Emerg Med* 1998;16:401-3.
28. Hilty WM, Hudson PA, Levitt MA, Hall JB. Real-time ultrasound-guided femoral vein catheterization during cardiopulmonary resuscitation. *Ann Emerg Med* 1997;29:331-7, doi:10.1016/S0196-0644(97)70344-5.
29. Atkinson P, Boyle A, Robinson S, Campbell-Hewson G. Should ultrasound guidance be used for central venous catheterization in the emergency department? *Emerg Med J* 2005;22:158-64, doi:10.1136/emj.2003.011288.
30. Abboud PAC, Kendall JL. Ultrasound guidance for vascular access. *Emerg Med Clin North Am* 2004;22:749-73, doi:10.1016/j.emc.2004.04.003.
31. Pronovost P, Needham D, Berenholtz S, et al. An intervention to decrease catheter-related bloodstream infections in the ICU. *N Engl J Med* 2006;355:2725-32, doi:10.1056/NEJMoa061115.
32. McGee DC, Gould MK. Preventing complications of central venous catheterization. *N Engl J Med* 2003;348:1123-33, doi:10.1056/NEJMra011883.
33. Miller AH, Roth BA, Mills TJ, et al. Ultrasound guidance versus the landmark technique for the placement of central venous catheters in the emergency department. *Acad Emerg Med* 2002;9:800-5, doi:10.1111/j.1553-2712.2002.tb02168.x.
34. Milling T, Holden C, Melniker L, et al. Randomized controlled trial of single-operator vs. two-operator ultrasound guidance for internal jugular central venous cannulation. *Acad Emerg Med* 2006;13:245-7, doi:10.1111/j.1553-2712.2006.tb01686.x.
35. Leung J, Duffy M, Finckh A. Real-time ultrasonographically guided internal jugular vein catheterization in the emergency department increases success rates and reduces complications: a randomized, prospective study. *Ann Emerg Med* 2006;48:540-7, doi:10.1016/j.annemergmed.2006.01.011.
36. Sabbaj A, Hedges JR. Ultrasonographic guidance for internal jugular vein cannulation: an educational imperative, a desirable practice alternative. *Ann Emerg Med* 2006;48:548-50, doi:10.1016/j.annemergmed.2006.04.015.
37. Blaivas M, Brannam L, Fernandez E. Short-axis versus long-axis approaches for teaching ultrasound-guided vascular access on a new inanimate model. *Acad Emerg Med* 2003;10:1307-11, doi:10.1111/j.1553-2712.2003.tb00002.x.
38. Shiver S, Blaivas M, Lyon M. A prospective comparison of ultrasound-guided and blindly placed radial arterial catheters. *Acad Emerg Med* 2006;13:1275-9, doi:10.1111/j.1553-2712.2006.tb00289.x.
39. Jones AE, Craddock PA, Tayal VS, Kline KS. Diagnostic accuracy of left ventricular function for identifying sepsis among emergency department patients with nontraumatic symptomatic undifferentiated hypotension. *Shock* 2005;24:513-7, doi:10.1097/01.shk.0000186931.02852.5f.
40. Moore CL, Rose GA, Tayal VS, et al. Determination of left ventricular function by emergency physician echocardiography of hypotensive patients. *Acad Emerg Med* 2002;9:186-93, doi:10.1111/j.1553-2712.2002.tb00242.x.
41. Pershad J, Myers S, Plouman C, et al. Bedside limited echocardiography by the emergency physician is accurate during evaluation of the critically ill patient. *Pediatrics* 2004;114:e667-71, doi:10.1542/peds.2004-0881.
42. Randazzo MR, Snoey ER, Levitt MA, Binder K. Accuracy of emergency physician assessment of left ventricular ejection fraction and central venous pressure using echocardiography. *Acad Emerg Med* 2003;10:973-7, doi:10.1111/j.1553-2712.2003.tb00654.x.
43. Lyon M, Blaivas M, Brannam L. Sonographic measurement of the inferior vena cava as a marker of blood loss. *Am J Emerg Med* 2005;23:45-50, doi:10.1016/j.ajem.2004.01.004.
44. Yanagawa Y, Nishi K, Sakamoto T, Okada Y. Early diagnosis of hypovolemic shock by sonographic measurement of inferior vena cava in trauma patients. *J Trauma* 2005;58:825-9, doi:10.1097/01.TA.0000145085.42116.A7.
45. Kosiak W, Swieton D, Piskunowicz M. Sonographic inferior vena cava/aorta diameter index, a new approach to the body fluid status assessment in children and young adults in emergency ultrasound—preliminary study. *Am J Emerg Med* 2008;26:320-5, doi:10.1016/j.ajem.2007.07.012.
46. Lipton B. Estimation of central venous pressure by ultrasound of the internal jugular vein. *Am J Emerg Med* 2000;18:432-4, doi:10.1053/ajem.2000.7335.
47. Jang T, Aubin C, Naunheim R, Char D. Ultrasonography of the internal jugular vein in patients with dyspnea without jugular venous distention on physical examination. *Ann Emerg Med* 2004;44:160-8, doi:10.1016/j.annemergmed.2004.03.014.
48. Jones AE, Tayal VS, Sullivan DM, Kline JA. Randomized, controlled trial of immediate versus delayed goal-directed ultrasound to identify the cause of nontraumatic hypotension in emergency department patients. *Crit Care Med* 2004;32:1703-8, doi:10.1097/01.CCM.0000133017.34137.82.
49. Rose JS, Bair AE, Mandavia D, Kinser DJ. The UHP protocol: a novel ultrasound approach to the empiric evaluation of the undifferentiated hypotensive patient. *Am J Emerg Med* 2001;19:299-302, doi:10.1053/ajem.2001.24481.
50. Scruggs W, Fox JC, Potts B, et al. Accuracy of ED bedside ultrasound for the identification of gallstones: retrospective analysis of 575 studies. *West J Med* 2008;9:1-5.
51. Jehle D, Davis E, Evans T, et al. Emergency department sonography by emergency physicians. *Am J Emerg Med* 1989;7:605-11, doi:10.1016/0735-6757(89)90283-0.
52. Durston W, Carl M, Guerra W, et al. Comparison of quality and ost-effectiveness in the evaluation of symptomatic cholelithiasis with different approaches to ultrasound availability in the ED. *Am J Emerg Med* 2001;19:260-9, doi:10.1053/ajem.2001.22660.

53. Schlager D, Lazzareschi G, Whiten D, Sanders AB. A prospective study of ultrasonography in the ED by emergency physicians. *Am J Emerg Med* 1994;12:185-9, doi:10.1016/0735-6757(94)90244-5.

54. Lanoix R, Leak LV, Gaeta T, Gernsheimer JR. A preliminary evaluation of emergency ultrasound in the setting of an emergency medicine training program. *Am J Emerg Med* 2000;18:41-5, doi:10.1016/S0735-6757(00)90046-9.

55. Kendall JL, Shimp RJ. Performance and interpretation of focused right upper quadrant ultrasound by emergency physicians. *J Emerg Med* 2001;21:7-13, doi:10.1016/S0736-4679(01)00329-8.

56. Blaivas M, Harwood RA, Lambert MJ. Decreasing length of stay with emergency ultrasound examination of the gallbladder. *Acad Emerg Med* 1999;6:1020-3, doi:10.1111/j.1553-2712.1999.tb01186.x.

57. Blaivas M, Adhikari S. Diagnostic utility of cholescintigraphy in emergency department patients with suspected acute cholecystitis: comparison with bedside RUQ ultrasonography. *J Emerg Med* 2007;33:47-52, doi:10.1016/j.jemermed.2007.02.044.

58. Miller AH, Pepe PE, Brockman CR, Delaney KA. ED ultrasound in hepatobiliary disease. *J Emerg Med* 2006;30:69-74, doi:10.1016/j.jemermed.2005.03.017.

59. Rosen CL, Brown DF, Chang Y, et al. Ultrasonography by emergency physicians in patients with suspected cholecystitis. *Am J Emerg Med* 2001;19:32-6, doi:10.1053/ajem.2001.20028.

60. Rowland JL, Kuhn M, Bonnin RLL, et al. Accuracy of emergency department ultrasonography. *Emerg Med* 2001;13:305-13, doi:10.1046/j.1035-6851.2001.00233.x.

61. Watkins S, Bowra J, Sharma P, et al. Validation of emergency physician ultrasound in diagnosing hydronephrosis in ureteral colic. *Emerg Med Australas* 2007;19:188-95, doi:10.1111/j.1742-6723.2007.00925.x.

62. Gaspari RJ, Horst K. Emergency ultrasound and urinalysis in the evaluation of flank pain. *Acad Emerg Med* 2005;12:1180-3, doi:10.1111/j.1553-2712.2005.tb01494.x.

63. Henderson SO, Hoffner RJ, Aragona JL, et al. Bedside emergency department ultrasonography plus radiography of the kidneys, ureters and bladder vs. intravenous pyelography in the evaluation of suspected ureteral colic. *Acad Emerg Med* 1998;5:666-71, doi:10.1111/j.1553-2712.1998.tb02483.x.

64. Chan H. Noninvasive bladder volume measurement. *J Neurosci Nurs* 1993;25:309-13, doi:10.1097/01376517-199310000-00007.

65. Rowland JL, Kuhn M, Bonnin RLL, et al. Accuracy of emergency department ultrasonography. *J Emerg Med* 2001;13:305-13, doi:10.1046/j.1035-6851.2001.00233.x.

66. Mandavia DP, Aragona J, Chan L, et al. Ultrasound training for emergency physicians—a prospective study. *Acad Emerg Med* 2000;7:1008-14, doi:10.1111/j.1553-2712.2000.tb02092.x.

67. Burnside P, Brown D, Kline J. Systematic review of emergency physician-performed ultrasonography for lower extremity deep venous thrombosis. *Acad Emerg Med* 2008;15:493-8, doi:10.1111/j.1553-2712.2008.00101.x.

68. Blaivas M, Lambert MJ, Harwood RA, et al. Lower-extremity doppler for deep venous thrombosis—can emergency physicians be accurate and fast? *Acad Emerg Med* 2000;7:120-6, doi:10.1111/j.1553-2712.2000.tb00512.x.

69. Theodoro D, Blaivas M, Duggal S, et al. Real-time B-mode ultrasound in the ED saves time in the diagnosis of deep vein thrombosis (DVT). *Am J Emerg Med* 2004;22:197-200, doi:10.1016/j.ajem.2004.02.007.

70. Jacoby J, Cesta M, Axelband J, et al. Can emergency medicine residents detect acute deep venous thrombosis with a limited, two-site examination? *J Emerg Med* 2007;32:197-200, doi:10.1016/j.jemermed.2006.06.008.

71. Jang T, Docherty M, Aubin C, et al. Resident-performed compression ultrasonography for the detection of proximal deep vein thrombosis: fast and accurate. *Acad Emerg Med* 2004;11:319-22, doi:10.1111/j.1553-2712.2004.tb02220.x.

72. Chan SSW. Emergency bedside ultrasound to detect pneumothorax. *Acad Emerg Med* 2003;10:91-4, doi:10.1111/j.1553-2712.2003.tb01984.x.

73. Blaivas M, Lyon M, Duggal S, et al. A prospective comparison of supine chest radiography and bedside ultrasound for the diagnosis of traumatic pneumothorax. *Acad Emerg Med* 2005;12:844-9, doi:10.1111/j.1553-2712.2005.tb00960.x.

74. Fill SL, Edmisten T, Holtzman G, et al. The occult pneumothorax: an increasing diagnostic entity in trauma. *Am Surg* 1999;65:254-8.

75. Goodman TR, Traill ZC, Phillips AJ, et al. Ultrasound detection of pneumothorax. *Clin Radiol* 1999;54:736-9, doi:10.1016/S0009-9260(99)91175-3.

76. Henry M, Arnold T, Harvey J. BTS guidelines for the management of spontaneous pneumothorax. *Thorax* 2003;58:39-52, doi:10.1136/thorax.58.suppl_2.ii39.

77. Jaffer U. Best evidence topic reports: transthoracic ultrasonography to diagnosis pneumothorax in trauma. *Emerg Med J* 2005;22:504-9, doi:10.1136/emj.2005.026542.

78. Kirkpatrick AW, Sirois M, Laupland KB, et al. Hand-held thoracic sonography for detecting post-traumatic pneumothoraces. *J Trauma* 2004;57:288-95, doi:10.1097/01.TA.0000133565.88871.E4.

79. Knudston JL, Dort JM, Helmer SD, et al. Surgeon-performed ultrasound for pneumothorax in the trauma suite. *J Trauma* 2004;56:527-30, doi:10.1097/01.TA.0000114529.99353.22.

80. Lichtenstein D, Meziere G, Biderman P, et al. The comet tail artifact: an ultrasound sign ruling out pneumothorax. *Intensive Care Med* 1999;25:383-8, doi:10.1007/s001340050862.

81. Lichtenstein D, Meziere G, Biderman P, et al. The lung point: an ultrasound sign specific to pneumothorax. *Intensive Care Med* 2000;26:1434-40, doi:10.1007/s001340000627.

82. Lichtenstein D, Meziere G, Lascols N, et al. Ultrasound diagnosis of occult pneumothorax. *Crit Care Med* 2005;33:1231-8, doi:10.1097/01.CCM.0000164542.86954.B4.

83. Zhang M, Liu ZH, Yang JX, et al. Rapid detection of pneumothorax by ultrasonography in patients with multiple trauma. *Crit Care* 2006;10:R112, doi:10.1186/cc5004.

84. Legome E, Pancu D. Future applications for emergency ultrasound. *Emerg Med Clin North Am* 2004;22:817-27, doi:10.1016/j.emc.2004.04.011.

85. Lewin MR, Williams SR. Ultrasonographic diagnosis of retinal detachment in the emergency department [letter to the editor]. *Ann Emerg Med* 2005;45:97-8, doi:10.1016/j.annemergmed.2004.07.456.

86. Blaivas M, Theodoro D, Sierzenski PR. A study of bedside ocular ultrasonography in the emergency department. *Acad Emerg Med* 2002;9:791-9, doi:10.1111/j.1553-2712.2002.tb02166.x.

87. Blaivas M, Theodoro D, Sierzenski PR. Elevated intracranial pressure detected by bedside emergency ultrasonography of the optic nerve sheath. *Acad Emerg Med* 2003;10:376-81, doi:10.1111/j.1553-2712.2003.tb01352.x.

88. Geeraerts T, Launey Y, Martin L, et al. Ultrasonography of the optic nerve sheath may be useful for detecting raised intracranial pressure after severe brain injury. *Intensive Care Med* 2007;33:1704-11, doi:10.1007/s00134-007-0797-6.

89. Hasbun R, Abrahams J, Jekel J, et al. Computed tomography of the head before lumbar puncture in adults with suspected meningitis. *N Engl J Med* 2001;354:1727-33, doi:10.1056/NEJMoa010399.

90. Hansen HC, Helmke K, Kunze K. Optic nerve sheath enlargement in acute intracranial hypertension. *Neuro-ophthalmology* 1994;14:345-54, doi:10.3109/01658109409024061.

91. Blaivas M, Sierzenski P, Lambert M. Emergency evaluation of patients presenting with acute scrotum using bedside ultrasonography. *Acad Emerg Med* 2001;8:90-3, doi:10.1111/j.1553-2712.2001.tb00563.x.

92. Blaivas M, Sierzenski P. Emergency ultrasonographic evaluation in the evaluation of the acute scrotum. *Acad Emerg Med* 2001;8:85-9, doi:10.1111/j.1553-2712.2001.tb00562.x.

93. Roy S, Dewitz A, Paul I. Ultrasound-assisted ankle arthrocentesis. *Am J Emerg Med* 1999;17:300-1.

94. Smith SW. Emergency physician-performed ultrasonography-guided hip arthrocentesis. *Acad Emerg Med* 1999;6:84-6, doi:10.1111/j.1553-2712.1999.tb00101.x.

95. Blaivas M, Lyon M. The effect of ultrasound guidance on the perceived difficulty of emergency nurse obtained peripheral IV access. *J Emerg Med* 2006;31:407-10, doi:10.1016/j.jemermed.2006.04.014.

96. Brannam L, Blaivas M, Lyon M, Flake M. Emergency nurses' utilization of ultrasound guidance for placement of peripheral intravenous lines in difficult-access patients. *Acad Emerg Med* 2004;11:1361-3, doi:10.1111/j.1553-2712.2004.tb01929.x.

97. Grogan DR, Irwin RS, Channick R, et al. Complications associated with thoracentesis: a prospective, randomized study comparing three different methods. *Arch Intern Med* 1990;150:873-7, doi:10.1001/archinte.1990.00390160119023.

98. Jones PW, Moyers JP, Rogers JT, et al. Ultrasound-guided thoracentesis: is it a safer method? *Chest* 2003;123:418-23, doi:10.1378/chest.123.2.418.

99. Mayo PH, Goltz H, Tafreshi M, Doelken P. Safety of ultrasound-guided thoracentesis in patients receiving mechanical ventilation. *Chest* 2004;125:1059-62, doi:10.1378/chest.125.3.1059.

100. Marks WM, Filly RA, Callen PW. Real-time evaluation of pleural lesions: sonography versus radiography. *Radiology* 1982;142:163-4.

101. Diacon AH, Brutsche MH, Soler M. Accuracy of pleural puncture sites: a prospective comparison of clinical examination with ultrasound. *Chest* 2003;123:436-41, doi:10.1378/chest.123.2.436.

102. Thomsen TW, DeLaPena J, Setnik GS. Thoracentesis. *N Engl J Med* 2006;355:e16, doi:10.1056/NEJMvcm053812.

103. Feller-Kopman D. Ultrasound-guided thoracentesis. *Chest* 2006;129:1709-14, doi:10.1378/chest.129.6.1709.

104. Beaulieu Y, Marik PE. Bedside ultrasonography in the ICU: part 2. *Chest* 2005;128:1766-81, doi:10.1378/chest.128.3.1766.

105. Nazeer SR, Dewbre H, Miller AH. Ultrasound-assisted paracentesis performed by emergency physicians vs. the traditional technique: a prospective, randomized study. *Am J Emerg Med* 2005;23:363-7, doi:10.1016/j.ajem.2004.11.001.

106. Mallory A, Schaefer JW. Complications of diagnostic paracentesis in patients with liver disease. *JAMA* 1978;239:628-30, doi:10.1001/jama.1978.03280340048020.

107. Nicolaou S, Talsky A, Khashoggi K, Venu V. Ultrasound-guided interventional radiology in critical care. *Crit Care Med* 2007;35(5 Suppl):S186-97, doi:10.1097/01.CCM.0000260630.68855.DF.

108. Tsang TS, Freeman WK, Sinak LJ, Seward JB. Echocardiographically-guided pericardiocentesis: evolution and state-of-the-art technique. *Mayo Clin Proc* 1998;73:647-52, doi:10.4065/73.7.647.

109. Tsang TS, Enriquez-Sarano M, Freeman WK, et al. Consecutive 1127 therapeutic echocardiographically guided pericardiocentesis: clinical profile, practice patterns and outcomes spanning 21 years. *Mayo Clin Proc* 2002;77:429-36.

110. Tibbles CD, Porcaro W. Procedural applications of ultrasound. *Emerg Med Clin North Am* 2004;22:797-815, doi:10.1016/j.emc.2004.04.010.

111. Nomura J, Leech S, Shenbagamurthi S, et al. A randomized controlled trial of ultrasound-assisted lumbar puncture. *J Ultrasound Med* 2007;26:1341-8.

112. Squire BT, Fox JC, Anderson C. ABSCESS: Applied Bedside Sonography for Convenient Evaluation of Superficial Soft tissue infections. *Acad Emerg Med* 2005;12:601-6, doi:10.1111/j.1553-2712.2005.tb00913.x.

113. Tayal VS, Hasan N, Norton HJ, Tomaszewski CA. The effect of soft-tissue ultrasound on the management of cellulitis in the emergency department. *Acad Emerg Med* 2006;13:384-8, doi:10.1111/j.1553-2712.2006.tb00314.x.

114. Blaivas M, Theodoro D, Duggal S. Ultrasound-guided drainage of peritonsillar abscess by the emergency physician. *Am J Emerg Med* 2003;21:155-8, doi:10.1053/ajem.2003.50029.

115. Hill R, Conron R, Greissinger P, Heller M. Ultrasound for the detection of foreign bodies in human tissue. *Ann Emerg Med* 1997;29:353-6, doi:10.1016/S0196-0644(97)70347-0.

116. Orlinsky M, Knitel P, Feit T, et al. The comparative accuracy of radiolucent foreign body detection using ultrasonography. *Am J Emerg Med* 2000;18:401-3, doi:10.1053/ajem.2000.7315.

117. Blankstein A, Cohen I, Heiman Z, et al. Localization, detection, and guided removal of soft tissue foreign bodies in the hands using sonography. *Arch Orthop Trauma Surg* 2000;120:514-7, doi:10.1007/s004020000173.

118. Witt M, Baumann B, McCans K. Bladder ultrasound increases catheterization success in pediatric patients. *Acad Emerg Med* 2005;12:371-4, doi:10.1111/j.1553-2712.2005.tb01961.x.

119. Aguilera PA, Durham BA, Riley DA. Emergency transvenous cardiac pacing placement using ultrasound guidance. *Ann Emerg Med* 2000;36:224-7, doi:10.1067/mem.2000.108654.

120. Gray A. Ultraosund-guided regional anaesthesia: current state of the art. *Anesthesiology* 2006;104:368-73, doi:10.1097/00000542-200602000-00024.

121. Chun R, Kirkpatrick AW, Sirois M, et al. Where's the tube? Evaluation of hand-held ultrasound in confirming endotracheal tube placement. *Prehosp Disast Med* 2004;19:366-9.

122. Gracias VH, Frankel HL, Gupta R, et al. Defining the learning curve for the focused abdominal sonogram for trauma (FAST) examination: implications for credentialing. *Am Surg* 2001;67:364-8.

123. Shackford SR, Rogers FB, Osler TM, et al. Focused abdominal sonogram for trauma: the learning curve of nonradiologist clinicians in detecting hemoperitoneum. *J Trauma* 1999;46:553-64, doi:10.1097/00005373-199904000-00003.

124. Thomas B, Falcone RE, Vasquez D, et al. Ultrasound evaluation of blunt abdominal trauma: program implementation, initial experience, and learning curve. *J Trauma* 1997;42:384-8, doi:10.1097/00005373-199703000-00004.

125. Gracias VH, Frankel H, Gupta R, et al. The role of positive examinations in training for the focused assessment sonogram in trauma (FAST) examination. *Am Surg* 2002; 68:1008-11.

126. Peterson MA, Lambert MJ. Training and program development. In: Ma OJ, Mateer JR, Blaivas M, editors. *Emergency ultrasound*. New York: McGraw-Hill; 2008. p. 1-14.

127. American College of Emergency Physicians: ACEP Emergency Ultrasound Guidelines 2001. *Ann Emerg Med* 2001;38:470-81, doi:10.1067/mem.2001.118487.

128. Mateer J, Plummer D, Heller M, et al. Model curriculum for physician training in emergency sonography. *Ann Emerg Med* 1994;23:95-102, doi:10.1016/S0196-0644(94)70014-1.

129. Ma OJ, Mateer JR, Blaivas M, editors. *Emergency ultrasound.* 2nd ed. New York: McGraw-Hill; 2008.

130. Heller M, Jehle D. *Ultrasound in emergency medicine.* 2nd ed. West Seneca, NY: Center Page, Inc; 2002.

131. Rosen CL, Wolfe RE, editors. Ultrasound in emergency medicine. *Emerg Med Clin North Am* 2004;22:581-843, doi:10.1016/j.emc.2004.04.007.