CHAPTER 127

Wheezing in Infants and Children

Gabrielle Freire
Allan Evan Shefrin
Roger Zemek

REFERENCES

1. Weinberger SE, Cockrill BA, Mandel J: *Principles of Pulmonary Medicine*. 6th ed. Philadelphia, PA: Elsevier Inc.; 2013.
2. Weiss LN: The diagnosis of wheezing in children. *Am Fam Physician* 77: 1109, 2008. [PMID: 18481558]
3. Mellis C: Respiratory noises: how useful are they clinically? *Pediatr Clin North Am* 56: 1, 2009. [PMID: 19135578]
4. Leung AKC, Cho H: Diagnosis of stridor in children. *Am Fam Physician* 60: 2289, 1999. [PMID: 10593320]
5. West J: *Respiratory Physiology: The Essentials*. 7th ed. Philadelphia, PA: Lippincott Williams & Wilkins; 2005.
6. West J: *Pulmonary Pathophysiology: The Essentials*. 6th ed. Philadelphia, PA: Lippincott Williams & Wilkins; 2003.
7. Martinez FD, Wright AL, Taussig LM, Holberg CJ, Halonen M, Morgan WJ: Asthma and wheezing in the first six years of life. *N Engl J Med* 332: 133, 1995. [PMID:7800004]
8. Bisgaard H, Szefler S: Prevalence of asthma-like symptoms in young children. *Pediatr Pulmonol* 42: 723, 2007. [PMID: 17598172]
9. http://ginasthma.org/2018-pocket-guide-for-asthma-management-and-prevention/ (Global Initiative for Asthma: 2018 Pocket Guide for Asthma Management and Prevention. 2018:19-27.) Accessed August 28, 2018.
10. https://www.nhlbi.nih.gov/files/docs/guidelines/asthgdln.pdf (Busse WW, Boushey HA, Camargo CA, et al: Expert panel report 3: guidelines for the diagnosis and management of asthma. National Heart, Lung, and Blood Institute, National Astham Education and Preveintion Program. 2007.) Accessed August 28, 2018.
11. Becker A, Bérubé D, Chad Z, et al: Diagnosis of asthma. *CMAJ* 173(6 Suppl): S15, 2005. [PMID: 31154574]
12. Fuchs S, Gausche-Hill M, Yamamoto L: *APLS: The Pediatric Emergency Medicine Resource*. 4th ed. Boston, MA: Jones & Bartlett; 2007.
13. Hall CB, Weinberg GA, Blumkin AK, et al: Respiratory syncytial virus-associated hospitalizations among children less than 24 months of age. *Pediatrics* 132: e341, 2013. [PMID: 23878043]
14. Johnson JI, Ratard R: Respiratory syncytial virus-associated hospitalizations in Louisiana. *J La State Med Soc* 164: 268, 2012. [PMID: 23362592]
15. Ralston SL, Lieberthal AS, Meissner HC, et al: Clinical practice guideline: the diagnosis, management, and prevention of bronchiolitis. *Pediatrics* 134: e1474, 2014.
16. Thompson M, Vodicka TA, Blair PS, Buckley DI, Heneghan C, Hay AD: Duration of symptoms of respiratory tract infections in children: systematic review. *BMJ* 347: f7027, 2013. [PMID: 24335668]
17. Willwerth BM, Harper MB, Greenes DS: Identifying hospitalized infants who have bronchiolitis and are at high risk for apnea. *Ann Emerg Med* 48: 441, 2006. [PMID: 16997681]
18. Purcell K, Fergie J: Concurrent serious bacterial infections in 2396 infants and children hospitalized with respiratory syncytial virus lower respiratory tract infections. *Arch Pediatr Adolesc Med* 156: 322, 2002. [PMID: 11929363]
19. Schuh S, Lalani A, Allen U, et al: Evaluation of the utility of radiography in acute bronchiolitis. *J Pediatr* 150: 429, 2007. [PMID: 17382126]
20. Basile V, Di Mauro A, Scalini E, et al: Lung ultrasound: a useful tool in diagnosis and management of bronchiolitis. *BMC Pediatr* 15: 63, 2015. [PMID: 25993984]
21. Caiulo VA, Gargani L, Caiulo S, et al: Lung ultrasound in bronchiolitis: comparison with chest x-ray. *Eur J Pediatr* 170: 1427, 2011. [PMID: 21468639]
22. Varshney T, Mok E, Shapiro AJ, Li P, Dubrovsky AS: Point-of-care lung ultrasound in young children with respiratory tract infections and wheeze. *Emerg Med J* 33: 603, 2016. [PMID: 27107052]
23. Gadomski AM, Brower M: Bronchodilators for bronchiolitis. *Cochrane database Syst Rev* 12: CD001266, 2010. [PMID: 21154348]
24. Hartling L, Fernandes RM, Bialy L, et al: Steroids and bronchodilators for acute bronchiolitis in the first two years of life: systematic review and meta-analysis. *BMJ* 342: d1714, 2011. [PMID: 21471175]
25. Hartling L, Bialy LM, Vandermeer B, et al: Epinephrine for bronchiolitis. *Cochrane Database Syst Rev* 6: CD003123, 2011. [PMID: 21678340]
26. Plint AC, Johnson DW, Patel H, et al: Epinephrine and dexamethasone in children with bronchiolitis. *N Engl J Med* 360: 2079, 2009. [PMID: 19439742]
27. Kua KP, Lee SWH: Systematic review and meta-analysis of the efficacy and safety of combined epinephrine and corticosteroid therapy for acute bronchiolitis in infants. *Front Pharmacol* 8: 396, 2017. [PMID: 28690542]
28. Fernandes RM, Bialy LM, Vandermeer B, et al: Glucocorticoids for acute viral bronchiolitis in infants and young children. *Cochrane Database Syst Rev* 6: CD004878, 2013.
29. Essouri S, Laurent M, Chevret L, et al: Improved clinical and economic outcomes in severe bronchiolitis with pre-emptive nCPAP ventilatory strategy. *Intensive Care Med* 40: 84, 2014. [PMID: 24158409]
30. Ganu SS, Gautam A, Wilkins B, Egan J: Increase in use of non-invasive ventilation for infants with severe bronchiolitis is associated with decline in intubation rates over a decade. *Intensive Care Med* 38: 1177, 2012. [PMID: 22527081]
31. Milesi C, Essouri S, Pouyau R, et al: High flow nasal cannula (HFNC) versus nasal continuous positive airway pressure (nCPAP) for the initial respiratory management of acute viral bronchiolitis in young infants: a multicenter randomized controlled trial (TRAMONTANE study). *Intensive Care Med* 43: 209, 2017. [PMID: 28124736]
32. Mansbach JM, Clark S, Christopher NC, et al: Prospective multicenter study of bronchiolitis: predicting safe discharges from the emergency department. *Pediatrics* 121: 680, 2008. [PMID: 18381531]
33. Ducharme FM, Dell SD, Radhakrishnan D, et al: Diagnosis and management of asthma in preschoolers: a Canadian Thoracic Society and Canadian Paediatric Society position paper. *Can Respir J* 20: 353, 2015.
34. Sanders DL, Gregg W, Aronsky D: Identifying asthma exacerbations in a pediatric emergency department: a feasibility study. *Int J Med Inform* 76: 557, 2007. [PMID: 16647876]
35. Papiris S, Kotanidou A, Malagari K, Roussos C: Clinical review: severe asthma. *Crit Care* 6: 30, 2002. [PMID: 11940264]
36. Kaza V, Bandi V, Guntupalli KK: Acute severe asthma: recent advances. *Curr Opin Pulm Med* 13: 1, 2007. [PMID: 17133117]
37. Guill MF: Asthma update: clinical aspects and management. *Pediatr Rev* 25: 335, 2004. [PMID: 15466134]
38. Chien JW, Ciufo R, Novak R, et al: Uncontrolled oxygen administration and respiratory failure in acute asthma. *Chest* 117: 728, 2000. [PMID: 10712998]
39. Perrin K, Wijesinghe M, Healy B, et al: Randomised controlled trial of high concentration versus titrated oxygen therapy in severe exacerbations of asthma. *Thorax* 66: 937, 2011. [PMID: 21597111]
40. McFadden ER: Acute severe asthma. *Am J Respir Crit Care Med* 168: 740, 2003. [PMID: 14522812]
41. Sinex JE: Pulse oximetry: principles and limitations. *Am J Emerg Med* 17: 59, 1999.
42. Hutton P, Clutton-Brock T: The benefits and pitfalls of pulse oximetry. *BMJ* 307: 457, 1993. [PMID: 8400922]
43. Barton CW, Wang ESJ: Correlation of end-tidal CO2 measurements to arterial Paco2 in nonintubated patients. *Ann Emerg Med* 23: 560, 1994. [PMID: 8135434]
44. Abramo TJ, Wiebe RA, Scott SM, Primm PA, Mcintyre D, Mydler T: Noninvasive capnometry in a pediatric population with respiratory emergencies. *Pediatr Emerg Care* 12: 252, 1996. [PMID: 8858646]
45. Langhan ML, Zonfrillo MR, Spiro DM: Quantitative end-tidal carbon dioxide in acute exacerbations of asthma. *J Pediatr* 152: 829, 2008. [PMID: 8858646]
46. Rogers M: *Textbook of Pediatric Intensive Care*. 3rd ed. (Nichols D, ed.). Baltimore, MD: Williams & Wilkins; 1996.
47. Kerem E, Canny G, Tibshirani R, et al: Clinical-physiologic correlations in acute asthma of childhood. *Pediatrics* 87: 481, 1991. [PMID: 2011424]
48. Arnold DH, Gebretsadik T, Minton PA, Higgins S, Hartert TV: Clinical measures associated with FEV1 in persons with asthma requiring hospital admission. *Am J Emerg Med* 25: 425, 2007. [PMID: 17499661]
49. Chalut DS, Ducharme FM, Davis GM: The Preschool Respiratory Assessment Measure (PRAM): a responsive index of acute asthma severity. *J Pediatr* 137: 762, 2000. [PMID: 11113831]
50. Baxt WG, Smith SR, Hodge D: Prospective application of an asthma severity rule [5] (multiple letters). *Acad Emerg Med* 9: 868, 2002. [PMID: 12153902]
51. Ducharme FM, Chalut D, Plotnick L, et al: The Pediatric Respiratory Assessment Measure: a valid clinical score for assessing acute asthma severity from toddlers to teenagers. *J Pediatr* 152: 476, 2008. [PMID: 18346499]
52. Gershel JC, Goldman HS, Stein RE, Shelov SP, Ziprkowski M: The usefulness of chest radiographs in first asthma attacks. *N Engl J Med* 309: 336, 1983. [PMID: 6866069]
53. Swischuk LE: Asthma attack: is a chest x-ray necessary? *Pediatr Emerg Care* 21: 468, 2005. [PMID: 16027583]
54. Xie M, Zhang X, Zhang X, Wang W, Hua K: Can we evaluate the levator ani after Kegel exercise in women with pelvic organ prolapse by transperineal elastography? A preliminary study. *J Med Ultrason* 45: 437, 2018. [PMID: 29349582]
55. Iorio G, Capasso M, Prisco S, et al: Lung ultrasound findings undetectable by chest radiography in children with community-acquired pneumonia. *Ultrasound Med Biol* 44: 1687, 2018. [PMID: 29759424]
56. Trinavarat P, Riccabona M: Potential of ultrasound in the pediatric chest. *Eur J Radiol* 83: 1507, 2014. [PMID: 24844730]
57. Balk DS, Lee C, Schafer J, et al: Lung ultrasound compared to chest X-ray for diagnosis of pediatric pneumonia: a meta-analysis. *Pediatr Pulmonol* 2018 April 26 [Epub ahead of print].
58. Dankoff S, Li P, Shapiro AJ, Varshney T, Dubrovsky AS: Point of care lung ultrasound of children with acute asthma exacerbations in the pediatric ED. *Am J Emerg Med* 35: 615, 2017. [PMID: 28063721]
59. Hodding JH, Kraus DM: *Pediatric & Neonatal Dosage Handbook*. 21st ed. (Taketomo CK, ed.). Hudson, OH: Lexicop; 2014.
60. Qureshi F, Zaritsky A, Welch C, Meadows T, Burke BL: Clinical efficacy of racemic albuterol versus levalbuterol for the treatment of acute pediatric asthma. *Ann Emerg Med* 46: 29, 2005. [PMID: 15988423]
61. Cates CJ, Crilly JA, Rowe BH: Holding chambers (spacers) versus nebulisers for beta-agonist treatment of acute asthma. *Cochrane database Syst Rev* 2: CD000052, 2006.
62. Doan Q, Shefrin A, Johnson D: Cost-effectiveness of metered-dose inhalers for asthma exacerbations in the pediatric emergency department. *Pediatrics* 127: e1105, 2011. [PMID: 21464192]

63. Travers AH, Milan SJ, Jones AP, et al: Addition of intravenous beta(2)-agonists to inhaled beta(2)-agonists for acute asthma. *Cochrane Database Syst Rev* 12: CD010179, 2012. [PMID: 23235685]
64. Indinnimeo L, Chiappini E, del Giudice MM: Guideline on management of the acute asthma attack in children by Italian Society of Pediatrics. *Ital J Pediatr* 44: 46, 2018. [PMID: 29625590]
65. Rowe BH, Vethanayagam D: The role of inhaled corticosteroids in the management of acute asthma. *Eur Respir J* 30: 1035, 2007. [PMID: 18055700]
66. Rowe BH, Spooner CH, Ducharme FM, Bretzlaff JA, Bota GW: Corticosteroids for preventing relapse following acute exacerbations of asthma. *Cochrane Database Syst Rev* 3: CD000195, 2007.
67. Zemek R, Plint A, Osmond MH, et al: Triage nurse initiation of corticosteroids in pediatric asthma is associated with improved emergency department efficiency. *Pediatrics* 129: 671, 2012. [PMID: 22430452]
68. Normansell R, Kew KM, Mansour G: Different oral corticosteroid regimens for acute asthma. *Cochrane Database Syst Rev* 5: CD011801, 2016. [PMID: 27176676]
69. Paniagua N, Lopez R, Munoz N, et al: Randomized trial of dexamethasone versus prednisone for children with acute asthma exacerbations. *J Pediatr* 191: 190, 2017. [PMID: 29173304]
70. Butler K, Cooper WO: Adherence of pediatric asthma patients with oral corticosteroid prescriptions following pediatric emergency department visit or hospitalization. *Pediatr Emerg Care* 20: 730, 2004.
71. Altamimi S, Robertson G, Jastaniah W, et al: Single-dose oral dexamethasone in the emergency management of children with exacerbations of mild to moderate asthma. *Pediatr Emerg Care* 22: 786, 2006. [PMID: 17198210]
72. Gordon S, Tompkins T, Dayan PS: Randomized trial of single-dose intramuscular dexamethasone compared with prednisolone for children with acute asthma. *Pediatr Emerg Care* 23: 521, 2007. [PMID: 17726409]
73. Shefrin AE, Goldman RD: Use of dexamethasone and prednisone in acute asthma exacerbations in pediatric patients. *Can Fam Physician* 55: 704, 2009.
74. Edmonds ML, Milan SJ, Camargo CA Jr, Pollack CV, Rowe BH: Early use of inhaled corticosteroids in the emergency department treatment of acute asthma. *Cochrane Database Syst Rev* 12: CD002308, 2012.
75. Griffiths B, Ducharme FM: Combined inhaled anticholinergics and short-acting beta2-agonists for initial treatment of acute asthma in children. *Cochrane Database Syst Rev* 8: CD000060, 2013. [PMID: 23966133]
76. Teoh L, Cates CJ, Hurwitz M, Acworth JP, van Asperen P, Chang AB: Anticholinergic therapy for acute asthma in children. *Cochrane Database Syst Rev* 4: CD003797, 2012. [PMID: 22513916]
77. Gourgoulianis KI, Chatziparasidis G, Chatziefthimiou A, Molyvdas PA: Magnesium as a relaxing factor of airway smooth muscles. *J Aerosol Med* 14: 301, 2001. [PMID: 11693841]
78. Kew KM, Kirtchuk L, Michell CI: Intravenous magnesium sulfate for treating adults with acute asthma in the emergency department. *Cochrane Database Syst Rev* 5: CD010909, 2014. [PMID: 24865567]
79. Schuh S, Zemek R, Plint A, et al: Magnesium use in asthma pharmacotherapy: a Pediatric Emergency Research Canada Study. *Pediatrics* 129: 852, 2012. [PMID: 22508922]
80. Mohammed S, Goodacre S: Intravenous and nebulised magnesium sulphate for acute asthma: systematic review and meta-analysis. *Emerg Med J* 24: 823, 2007. [PMID: 18029512]
81. Powell CVE: The role of magnesium sulfate in acute asthma: does route of administration make a difference? *Curr Opin Pulm Med* 20: 103, 2014. [PMID: 24264055]
82. Powell CVE, Kolamunnage-Dona R, Lowe J, et al: MAGNEsium Trial In Children (MAGNETIC): a randomised, placebo-controlled trial and economic evaluation of nebulised magnesium sulphate in acute severe asthma in children. *Health Technol Assess* 17: v-vi, 1, 2013. [PMID: 24144222]
83. Goodacre S, Cohen J, Bradburn M, Gray A, Benger J, Coats T: Intravenous or nebulised magnesium sulphate versus standard therapy for severe acute asthma (3Mg trial): a double-blind, randomised controlled trial. *Lancet Respir Med* 1: 293, 2013. [PMID: 24429154]
84. Griffiths B, Kew KM: Intravenous magnesium sulfate for treating children with acute asthma in the emergency department. *Cochrane database Syst Rev* 4: CD011050, 2016. [PMID: 27126744]
85. Normansell R, Knightly R, Milan SJ, Knopp-Sihota JA, Rowe BH, Powell C: Inhaled magnesium sulfate in the treatment of acute asthma in children. *Paediatr Respir Rev* 26: 31, 2018. [PMID: 29456076]
86. Su Z, Li R, Gai Z: Intravenous and nebulized magnesium sulfate for treating acute asthma in children: a systematic review and meta-analysis. *Pediatr Emerg Care* 2016 October 4 [Epub ahead of print].
87. Denmark TK, Crane HA, Brown L: Ketamine to avoid mechanical ventilation in severe pediatric asthma. *J Emerg Med* 30: 163, 2006. [PMID: 16567251]
88. Jat KR, Chawla D: Ketamine for management of acute exacerbations of asthma in children. *Cochrane Database Syst Rev* 11: CD009293, 2012. [PMID: 23152273]
89. Wong JJ, Lee JH, Turner DA, Rehder KJ: A review of the use of adjunctive therapies in severe acute asthma exacerbation in critically ill children. *Expert Rev Respir Med* 8: 423, 2014. [PMID: 24993063]
90. Maddox RP, Seupaul RA: Is ketamine effective for the management of acute asthma exacerbations in children? *Ann Emerg Med* 63: 309, 2014.
91. Hendaus MA, Jomha FA, Alhammadi AH: Is ketamine a lifesaving agent in childhood acute severe asthma? *Ther Clin Risk Manag* 12: 273, 2016.
92. Chan-Yeung M, Abboud R, Tsao MS, Maclean L: Effect of helium on maximal expiratory flow in patients with asthma before and during induced bronchoconstriction. *Am Rev Respir Dis* 113: 433, 1976. [PMID: 1267250]
93. Rodrigo GJ, Castro-Rodriguez JA: Heliox-driven beta2-agonists nebulization for children and adults with acute asthma: a systematic review with meta-analysis. *Ann Allergy Asthma Immunol* 112: 29, 2014. [PMID: 24331390]
94. Baker MD: Theophylline toxicity in children. *J Pediatr* 109: 538, 1986. [PMID: 3746549]
95. Powell EC, Reynolds SL, Rubenstein JS: Theophylline toxicity in children: a retrospective review. *Pediatr Emerg Care* 9: 129, 1993. [PMID: 8346082]
96. Nair P, Milan SJ, Rowe BH: Addition of intravenous aminophylline to inhaled beta(2)-agonists in adults with acute asthma. *Cochrane Database Syst Rev* 12: CD002742, 2012.
97. Saint GL, Semple MG, Sinha I, Hawcutt DB: Optimizing the dosing of intravenous theophylline in acute severe asthma in children. *Paediatr Drugs* 20: 209, 2018. [PMID: 29302790]
98. Roberts JS, Bratton SL, Brogan TV: Acute severe asthma: differences in therapies and outcomes among pediatric intensive care units. *Crit Care Med* 30: 581, 2002. [PMID: 11990919]
99. Antonelli M, Conti G, Rocco M, et al: A comparison of noninvasive positive-pressure ventilation and conventional mechanical ventilation in patients with acute respiratory failure. *N Engl J Med* 339: 429, 1998. [PMID: 9700176]
100. Deis JN, Abramo TJ, Crawley L: Noninvasive respiratory support. *Pediatr Emerg Care* 24: 331, 2008. [PMID: 18496121]
101. Beers SL, Abramo TJ, Bracken A, Wiebe RA: Bilevel positive airway pressure in the treatment of status asthmaticus in pediatrics. *Am J Emerg Med* 25: 6, 2007. [PMID: 17157675]
102. Yañez LJ, Yunge M, Emilfork M, et al: A prospective, randomized, controlled trial of noninvasive ventilation in pediatric acute respiratory failure. *Pediatr Crit Care Med* 9: 484, 2008. [PMID: 31208033]
103. Werner HA: Status asthmaticus in children: a review. *Chest* 119: 1913, 2001. [PMID: 11399724]
104. Stather DR, Stewart TE: Clinical review: mechanical ventilation in severe asthma. *Crit Care* 9: 581, 2005. [PMID: 16356242]
105. Darioli R, Perret C: Mechanical controlled hypoventilation in status asthmaticus. *Am Rev Respir Dis* 129: 385, 1984. [PMID: 6703497]
106. Mannino DM, Homa DM, Akinbami LJ, Moorman JE, Gwynn C, Redd SC: Surveillance for asthma—United States, 1980-1999. *MMWR Surveill Summ* 51: 1, 2002. [PMID: 12420904]
107. Robertson CF, Rubinfeld AR, Bowes G: Pediatric asthma deaths in Victoria: the mild are at risk. *Pediatr Pulmonol* 13: 95, 1992. [PMID: 1495863]
108. Alnaji F, Zemek R, Barrowman N, Plint A: PRAM score as predictor of pediatric asthma hospitalization. *Acad Emerg Med* 21: 872, 2014. [PMID: 25176153]
109. Scarfone RJ, Zorc JJ, Angsuco CJ: Emergency physicians' prescribing of asthma controller medications. *Pediatrics* 117: 821, 2006. [PMID: 16510663]
110. https://www.nice.org.uk/guidance/ng80 (NICE: Asthma: diagnosis, monitoring and chronic asthma management. *Nice*. 2017.) Accessed August 28, 2018.
111. NHLBI: National Asthma Education and Prevention Program. Expert Panel Report 3 (EPR-3): guidelines for the diagnosis and management of asthma–summary report 2007. *J Allerg Clin Immunol* 120: S94, 2007. [PMID: 18786332]
112. Lehman HK, Lillis KA, Shaha SH, Augustine M, Ballow M: Initiation of maintenance antiinflammatory medication in asthmatic children in a pediatric emergency department. *Pediatrics* 118: 2394, 2006. [PMID: 17142524]
113. Bhogal SK, Zemek RL, Ducharme F: Written action plans for asthma in children. *Cochrane Database Syst Rev* 3: CD005306, 2006. [PMID: 16856090]
114. Zemek RL, Bhogal SK, Ducharme FM: Systematic review of randomized controlled trials examining written action plans in children: what is the plan? *Arch Pediatr Adolesc Med* 162: 157, 2008.
115. Ducharme FM, Zemek RL, Chalut D, et al: Written action plan in pediatric emergency room improves asthma prescribing, adherence, and control. *Am J Respir Crit Care Med* 183: 195, 2011. [PMID: 20802165]