AARC Clinical Practice Guideline

Application of Continuous Positive Airway Pressure to Neonates via Nasal Prongs, Nasopharyngeal Tube, or Nasal Mask—2004 Revision & Update

NCPAP 1.0 PROCEDURE:
The application of continuous positive airway pressure to neonates and infants by nasal prongs (NCPAP), nasopharyngeal tube (NP-CPAP), or infant nasal mask (NM-CPAP) administered with a commercially available circuit used in conjunction with a continuous flow source, infant ventilator, or a suitably equipped multipurpose ventilator.

NCPAP 2.0 DESCRIPTION/DEFINITION:
Continuous positive airway pressure (CPAP) is the application of positive pressure to the airways of the spontaneously breathing patient throughout the respiratory cycle.[1-4] For the most part, neonates are preferential nose breathers, which easily facilitates the application of nasal CPAP.[5-7] This is accomplished by inserting nasopharyngeal tubes, affixing nasal prongs, or fitting a nasal mask to the patient.[8-11] The device provides heated and humidified continuous or variable flow from a circuit connected to a continuous gas source, mechanical ventilator designed for neonates, or a suitably equipped multipurpose ventilator, set in the CPAP mode.[8-19]

CPAP maintains inspiratory and expiratory pressures above ambient pressure, which results in an increase in functional residual capacity (FRC) and improvement in static lung compliance, and decreased airway resistance in the infant with unstable lung mechanics.[1,3,14-23] This allows a greater volume change per unit of pressure change (ie, greater tidal volume for a given pressure change) with subsequent reduction in the work of breathing and stabilization of minute ventilation ($\dot{V}_E$).[13,24-28] CPAP increases mean airway pressure, and the associated increase in FRC should improve ventilation-perfusion relationships and potentially reduce oxygen requirements.[24,25,29-33] Additionally CPAP may expand, or stent, upper airway structures preventing collapse and upper airway obstruction.[20,28,34,35]

NCPAP 3.0 SETTINGS:
NCPAP, NP-CPAP, and NM-CPAP are applied by trained personnel in acute and subacute care hospitals.

NCPAP 4.0 INDICATIONS:

4.1 Abnormalities on physical examination—the presence of increased work of breathing as indicated by an increase in respiratory rate of > 30% of normal, substernal and suprasternal retractions, grunting, and nasal flaring;[13,20-23,28,33,34,36] the presence of pale or cyanotic skin color and agitation[30,32,33,37]

4.2 Inadequate arterial blood gas values—the inability to maintain a $P_{aO_2} > 50$ torr with F_{IO_2} of ≤ 0.60 provided $\dot{V}_E$ is adequate as indicated by a P_{aCO_2} level of 50 torr and a pH ≥ 7.25[13-15,38]

4.3 The presence of poorly expanded and/or infiltrated lung fields on chest radiograph[25,37,38]

4.4 The presence of a condition thought to be responsive to CPAP and associated with one or more of the clinical presentations in 4.1-4.3[11,19,24]

- **4.4.1** Respiratory distress syndrome[13-15,38]
- **4.4.2** Pulmonary edema[13,39]
- **4.4.3** Atelectasis[19,37,40]
- **4.4.4** Apnea of prematurity[6,23,33,41-45]
- **4.4.5** Recent extubation[17,46-52]
- **4.4.6** Tracheal malacia or other similar abnormality of the lower airways[13,53-57]
- **4.4.7** Transient tachypnea of the newborn[13,37]

4.5 Early intervention in conjunction with surfactant administration for very low birthweight infants at risk for developing respiratory distress syndrome.[11,13,19,58-64]

4.6 The administration of controlled concentrations of nitric oxide in spontaneously breathing infants.[63]

NCPAP 5.0 CONTRAINDICATIONS:

5.1 Although NCPAP, NP-CPAP, and NM-CPAP have been used in bronchiolitis, this application may be contraindicated.[66,67]

5.2 The need for intubation and/or mechanical ventilation as evidenced by the presence of

5.2.1 Upper airway abnormalities that make NCPAP, NP-CPAP, or NM-CPAP ineffective or potentially dangerous (eg, choanal atresia, cleft palate, tracheoesophageal fistula)[57]

5.2.2 Severe cardiovascular instability and impending arrest

5.2.3 Unstable respiratory drive with frequent apneic episodes resulting in desaturation and/or bradycardia

5.2.4 Ventilatory failure as indicated by the inability to maintain $P_{aCO_2} < 60$ torr and pH > 7.25[31,38]

5.3. Application of NCPAP, NP-CPAP, or NM-CPAP to patients with untreated congenital diaphragmatic hernia may lead to gastric distention and further compromise of thoracic organs.[57]

NCPAP 6.0 HAZARDS/COMPLICATIONS:

6.1 Hazards and complications associated with equipment include the following

6.1.1 Obstruction of nasal prongs from mucus plugging or kinking of nasopharyngeal tube may interfere with delivery of CPAP and result in a decrease in F_{IO_2} through entrainment of room air via opposite naris or mouth.

6.1.2 Inactivation of airway pressure alarms

6.1.2.1 Increased resistance created by turbulent flow through the small orifices of nasal prongs and nasopharyngeal tubes can maintain pressure in the CPAP system even when decannulation has occurred. This can result in failure of low airway pressure/disconnect alarms to respond.[7]

6.1.2.2 Complete obstruction of nasal prongs and nasopharyngeal tubes results in continued pressurization of the CPAP system without activation of low or high airway pressure alarms.[69]

6.1.3 Activation of a manual breath (commonly available on infant ventilators) may cause gastric insufflation and patient discomfort particularly if the peak pressure is set inappropriately high.[70]

6.1.4 Insufficient gas flow to meet inspiratory demand resulting in a fluctuating baseline pressure and an increase in the work of breathing[11]

6.1.5 Excessive flow results in overdistension from increased work of breathing due to incomplete exhalation and inadvertent PEEP levels[71]

6.1.6 Decannulation or malpositioning of prongs or nasopharyngeal tubes causing fluctuating or reduced CPAP levels

6.1.7 Aspiration or accidental swallowing of small pieces of the detachable circuit or nasal device assembly[72]

6.1.8 Nasal excoriation, scarring, pressure necrosis, and septal distortion[73,74]

6.1.9 Skin irritation of the head and neck from improperly secured bonnets or CPAP head harnesses

6.2 Hazards and complications associated with the patient's clinical condition include

6.2.1 Lung overdistention leading to

6.2.1.1 Air leak syndromes[75-81]

6.2.1.2 Ventilation-perfusion mismatch[82]

6.2.1.3 CO_2 retention and increased work of breathing[7,30,83]

6.2.1.4 Impedance of pulmonary blood flow with a subsequent increase in pulmonary vascular resistance and decrease in cardiac output[39,84]

6.2.2 Gastric insufflation and abdominal distention potentially leading to aspiration[34,81,85]

6.2.3 Nasal mucosal damage due to inadequate humidification[18]

NCPAP 7.0 LIMITATIONS OF DEVICE:

7.1 NCPAP, NP-CPAP, and NM-CPAP applications are not benign procedures, and operators should be aware of the possible hazards and complications and take all necessary precautions to ensure safe and effective application.

7.2 Mouth breathing during NCPAP, NP-CPAP, and NM-CPAP may result in loss of desired pressure and decrease in delivered oxygen con-

centration.[14,86-89] However, most studies demonstrate effective NCPAP without mouth closure.[11]

7.3 NCPAP harnesses and attachment devices are often cumbersome and difficult to secure and may cause agitation and result in inadvertent decannulation.[7,11,86]

7.4 Excessive head rotation or neck extension may alter the position of NP-CPAP tube placement or obstruct upper airway structures resulting in diminished or altered pressure, flow, and effective CPAP.[11,48]

7.5 Severe RDS, septicemia during NCPAP administration, and pneumothorax are risk factors associated with NCPAP failure.[68,79,90]

NCPAP 8.0 ASSESSMENT OF NEED:
Determination that valid indications are present by physical, radiographic, and laboratory assessments.

NCPAP 9.0 ASSESSMENT OF OUTCOME:
CPAP is initiated at levels of 4-5 cm H_2O and may be gradually increased up to 10 cm H_2O to provide the following[13,25,30,33,59,86,91]

9.1 Stabilization of F_{IO_2} requirement ≤ 0.60 with P_{aO_2} levels > 50 torr and/or the presence of clinically acceptable noninvasive monitoring of oxygen (P_{tcO_2}), while maintaining an adequate $\dot{V}_E$ as indicated by P_{aCO_2} of 50-60 torr or less and pH ≥ 7.25[19,29,64,92-94]

9.2 Reduction in the work of breathing as indicated by a decrease in respiratory rate by 30-40% and a decrease in the severity of retractions, grunting, and nasal flaring[33,37,69]

9.3 Improvement in lung volumes and appearance of lung as indicated by chest radiograph[19,69]

9.4 Improvement in patient comfort as assessed by bedside caregiver

9.5 Clinically significant reduction in apnea, bradycardia, and cyanosis episodes

NCPAP 10.0 RESOURCES:

10.1 Equipment

10.1.1 Endotracheal tubes (positioned in the nasopharynx and secured by taping, with placement verified by laryngoscopy or palpation) or commercially available nasal prongs, bilateral nasopharyngeal tubes, or specially designed nasal masks with accompanying harness and accessories may be used for CPAP administration.[11,17,19,50,97]

10.1.1.1 Unilateral nasopharyngeal prongs may be less effective in preventing extubation failure than bilateral short prongs.[17,98,99]

10.1.2 Continuous flow air-oxygen gas source; commercially available continuous-flow infant ventilators equipped with CPAP mode; CPAP flow driver with fluidic nasal interface, or suitably equipped multipurpose ventilator, with integrated or adjunct low and high airway pressure alarms, oxygen concentration analyzer with low and high alarms, loss of power and gas source alarms[14,19,100,101]

10.1.2.1 A continuous gas flow source requires a mechanical pressure limiting device, or a flow or threshold resistor, which includes the use of an underwater threshold resistor, eg Bubble CPAP[102]

10.1.3 Lightweight CPAP or ventilator circuits with servo-regulated humidification system[18]

10.1.4 Continuous noninvasive oxygenation monitoring by pulse oximetry or transcutaneous monitor with high and low alarm capabilities is recommended (continuous transcutaneous CO_2 monitoring may also be utilized).[101,102]

10.1.5 Continuous electrocardiographic and respiratory rate monitor, with high and low alarm capabilities, is recommended.

10.1.6 Suction source, suction regulator, and suction catheters for periodic suctioning to assure patency of nasal passages and of endotracheal tubes used for NP-CPAP are necessary.[103]

10.1.7 Resuscitation apparatus with airway manometer and masks of appropriate size must be available.

10.1.8 Gastric tube for periodic decompression of stomach and chest tubes should be available.

10.2 Personnel: The application of NCPAP, NP-CPAP, and NM-CPAP should be performed under the direction of a physician by trained personnel who hold a recognized credential

(eg, CRT, RRT, RN) and who competently demonstrate

10.2.1 Proper use, understanding, and mastery of the technical aspects of CPAP devices, mechanical ventilators, and humidification systems

10.2.2 Knowledge of ventilator management and understanding of neonatal airway anatomy and pulmonary physiology

10.2.3 Patient assessment skills, with an understanding of the interaction between the CPAP device and the patient and the ability to recognize and respond to adverse reactions and complications

10.2.4 Knowledge and understanding of artificial airway management, training in the procedures of placing endotracheal tubes in the nasopharynx

10.2.5 The ability to interpret monitored and measured blood gas values and vital signs

10.2.6 The application of Standard Precautions[104]

10.2.7 Proper use, understanding, and mastery of emergency resuscitation equipment and procedures

10.2.8 The ability to assess, evaluate, and document outcome (Section 9.0)

NCPAP 11.0 MONITORING:

11.1 Patient-ventilator system checks should be performed at least every 2 to 4 hours and include documentation of mechanical settings, alarms, and patient assessments as recommended by the AARC CPG Patient-Ventilator System Checks (MV-SC) and the CPG Humidification During Mechanical Ventilation (HMV).[105,106]

11.2 Oxygen and carbon dioxide monitoring, including

11.2.1 Periodic sampling of blood gas values by arterial, capillary, or venous route[107,108]

11.2.2 Continuous noninvasive blood gas monitoring by transcutaneous O_2 and CO_2 monitors[33,108,109]

11.2.3 Continuous noninvasive monitoring of oxygen saturation by pulse oximetry[33,110,111]

11.3 Continuous monitoring of electrocardiogram and respiratory rate[31,33]

11.4 Continuous monitoring of proximal airway pressure (P_{aw}), PEEP, and mean airway pressure ($\overline{P}_{aw}$)[31,33]

11.5 Continuous monitoring of F_{IO_2}[25,58,112]

11.6 Periodic physical assessment of breath sounds and signs of increased work of breathing (see Section 4.1)[16,58,112]

11.7 Periodic evaluation of chest radiographs[25,52,112]

11.8 Periodic assessment of nasal septum

NCPAP 12.0 FREQUENCY:

NCPAP, NP-CPAP, and NM-CPAP are intended for continuous use and discontinued when the patient's clinical condition improves as indicated by successful outcome assessments (Section 9.0).

NCPAP 13.0 INFECTION CONTROL:

No special precautions are necessary, but Standard Precautions[104] as described by the Centers for Disease Control should be employed.

13.1 Disposable nasal CPAP kits are recommended and are intended for single-patient use.

13.2 Routine disposable circuit changes are unnecessary for infection control purposes when the humidifying device is other than an aerosol generator.[113]

13.3 External surfaces of ventilator should be cleaned according to the manufacturer's recommendations when the device has remained in a patient's room for a prolonged period, when soiled, when it has come in contact with potentially transmittable organisms, and after each patient use.

13.4 Sterile suctioning procedures should be strictly adhered to.[5,51]

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REFERENCES

1. Duncan AW, Oh TE, Hillman DR. PEEP and CPAP. Anaesth Intensive Care 1986;14(3):236-250.

2. ACCP-ATS Joint Committee on Pulmonary Nomenclature. Pulmonary terms and symbols. Chest 1975;67(5):583-593.
3. Sedin G. CPAP and mechanical ventilation. Int J Technol Assess Health Care 1991;7(Suppl 1):31-40.
4. Branson RD. PEEP without endotracheal intubation. Respir Care 1988;33(7):598-610.
5. Miller MJ, Martin RJ, Carlo WA, Fouke JM, Strohl KP, Fanaroff AA. Oral breathing in newborn infants. J Pediatr 1985;107(3):465-469.
6. Martin RJ, Carlo WA. Role of the upper airway in the pathogenesis of apnea in infants. Respir Care 1986;31(7):615-621.
7. Czervinske M, Durbin CG Jr, Gal TJ. Resistance to gas flow across 14 CPAP devices for newborns. Respir Care 1986;31(1):18-21.
8. Caliumi-Pellegrini G, Agostino R, Orzalesi M, Nodari S, Marzetti G, Savignoni PG, Bucci G. Twin nasal cannula for administration of continuous positive airway pressure to newborn infants. Arch Dis Child 1974;49(3):228-230.
9. Kattwinkel J, Fleming D, Cha CC, Fanaroff AA, Klaus MH. A device for administration of continuous positive airway pressure by the nasal route. Pediatrics 1973;52(1):131-134.
10. Wung J-T, Driscoll JM, Epstein RA, Hyman AI. A new device for CPAP by nasal route. Crit Care Med 1975;3(2):76-78.
11. De Paoli AG, Morley C, Davis PG. Nasal CPAP for neonates: what do we know in 2003? Arch Dis Child Fetal Neonatal Ed 2003;88(3):F168-F172.
12. So B-H, Shibuya K, Tamura M, Watanabe H, Kamoshita S. Clinical experience in using a new type of nasal prong for administration of N-CPAP. Acta Paediatr Jpn 1992;34(3):328-333.
13. Jonson B, Ahlström H, Lindroth M, Svenningsen NW. Continuous positive airway pressure; modes of action in relation to clinical applications. Pediatr Clin North Am 1980;27(3):687-699.
14. Moa G, Nilsson K. Nasal continuous positive airway pressure: experiences with a new technical approach. Acta Paediatr 1993;82(2):210-211.
15. Kamper J, Ringsted C. Early treatment of idiopathic respiratory distress syndrome using binasal continuous positive airway pressure. Acta Paediatr Scand 1990;79:581-586.
16. Chernick V. Continuous distending pressure in hyaline membrane disease: of devices, disadvantages, and a daring study. Pediatrics 1973;52(1):114-115.
17. De Paoli AG, Davis PG, Faber B, Morley CJ. Devices and pressure sources for administration of nasal continuous positive airway pressure (NCPAP) in preterm neonates. Cochrane Database Syst Rev 2002;(4):CD002977.
18. Lee SY, Lopez V. Physiological effects of two temperature settings in preterm infants on nasal continuous airway pressure ventilation. J Clin Nurs 2002;11(6):845-847.
19. Polin RA, Sahni R. Newer experience with CPAP. Semin Neonatol 2002;7(5):379-389.
20. Miller RW, Pollack MM, Murphy TM, Fink RJ. Effectiveness of continuous positive airway pressure in the treatment of bronchomalacia in infants: a bronchoscopic documentation. Crit Care Med 1986;14(2):125-127.
21. Higgins RD, Richter SE, Davis JM. Nasal continuous positive airway pressure facilitates extubation of very low birth weight neonates. Pediatrics 1991;88(5):999-1003.
22. Jonson B, Ahlstrom H, Lindroth M, Svenningsen NW. Continuous positive airway pressure: modes of action in relation to clinical applications. Pediatr Clin North Am 1980;27(3):687-799.
23. Speidel BD, Dunn PM. Effect of continuous positive airway pressure on breathing pattern of infants with respiratory-distress syndrome. Lancet 1975;1(7902):302-304.
24. Schulze A, Madler H-J, Gehrhardt B, Schaller P, Gmyrek D. Titration of continuous positive airway pressure by the pattern of breathing: analysis of flow-volume-time relationships by a noninvasive computerized system. Pediatr Pulmonol 1990;8(2):96-103.
25. Landers S, Hansen TN, Corbet AJS, Stevener MJ, Rudoph AD. Optimal constant positive airway pressure assessed by arterial alveolar difference for CO_2 in hyaline membrane disease. Pediatr Res 1986;20(9):884-889.
26. Miller MJ, DiFiore JM, Strohl KP, Martin RJ. Effects of nasal CPAP on supraglottic and total pulmonary resistance in preterm infants. J Appl Physiol 1990;68(1):141-146.
27. Durand M, McCann E, Brady JP. Effect of continuous positive airway pressure on the ventilatory response to CO2 in preterm infants. Pediatrics 1983;71(4):634-638.
28. Locke R, Greenspan JS, Shaffer TH, Rubenstein SD, Wolfson MR. Effect of nasal CPAP on thoracoabdominal motion in neonates with respiratory insufficiency. Pediatr Pulmonol 1991;11(3):259-264.
29. Fox WW, Gewitz MH, Berman LS, Peckham GJ, Downes JJ. The P_{aO_2} response to changes in end expiratory pressure in the newborn respiratory distress syndrome. Crit Care Med 1977;5(5):226-229.
30. Bonta BW, Uauy R, Warshaw JB, Motoyama EK. Determination of optimal continuous positive airway pressure for the treatment of IRDS by measurement of esophageal pressure. J Pediatr 1977;91(3):449-454.
31. Chatburn RL. Similiarities and differences in the managment of acute lung injury in neonates (IRDS) and in adults (ARDS). Respir Care 1988;33(7):539-553.

32. Gregory GA, Kitterman JA, Phibbs RH, Tooley WH, Hamilton WK. Treatment of the idiopathic respiratory-distress syndrome with continuous positive airway pressure. N Engl J Med 1971;284(24):1332-1339.
33. Speidel BD, Dunn PM. Effect of continuous positive airway pressure on breathing pattern of infants with respiratory-distress syndrome. Lancet 1975;1(7902):302-304.
34. Kiciman NM, Andreasson B, Bernstein G, Mannino FL, Rich W, Henderson C, Heldt GP. Thoracoabdominal motion in newborns during ventilation delivered by endotracheal tube or nasal prongs. Pediatr Pulmonol 1998;25(3):175-181.
35. Gaon P, Lee S, Hannan S, Ingram D, Milner AD. Assessment of effect of nasal continuous positive pressure on laryngeal opening using fibre optic laryngoscopy. Arch Dis Child Fetal Neonatal Ed 1999;80(3):F230-F232.
36. Saunders RA, Milner AD, Hopkin IE. The effects of continuous positive airway pressure on lung mechanics and lung volumes in the neonate. Biol Neonate 1976;29(3-4):178-186.
37. Jonzon A. Indications for continuous positive airway pressure and respirator therapy. Int J Technol Assess Health Care 1991;7 Suppl 1:26-30.
38. Ho JJ, Subramaniam P, Henderson-Smart DJ, Davis PG. Continuous distending airway pressure for respiratory distress syndrome in preterm infants. Cochrane Database Syst Rev 2000;(4):CD002271.
39. Roberton NRC. Prolonged continuous positive airways pressure for pulmonary oedema due to persistent ductus arteriosus in the newborn. Arch Dis Child 1974;49(7):585-587.
40. Donn SM, Sinha SK. Invasive and noninvasive neonatal mechanical ventilation. Respir Care 2003;48(4):426-439; discussion 439-441.
41. McNamara F, Sullivan CE. Obstructive sleep apnea in infants and its management with nasal continuous positive airway pressure. Chest 1999;116(1):10-16.
42. Kattwinkel J. Neonatal apnea: pathogenesis and therapy. J Pediatr 1977;90(3):342-347.
43. Kurz H. Influence of nasopharyngeal CPAP on breathing pattern and incidence of apnoeas in preterm infants. Biol Neonate 1999;76(3):129-133.
44. Miller MJ. Carlo WA, Martin RJ. Continuous positive airway pressure selectively reduces obstructive apnea in preterm infants. J Pediatr 1985;106(1):91-94.
45. Martin RJ, Nearman HS, Katona PG, Klaus MH. The effect of a low continuous positive airway pressure on the reflex control of respiration in the preterm infant. J Pediatr 1977;90(6):976-981.
46. Engelke SC, Roloff DW, Kuhns LR. Postextubation nasal continuous positive airway pressure: a prospective controlled study. Am J Dis Child 1982;136(4):359-361.
47. Higgins RD, Richter SE, Davis JM. Nasal continuous positive airway pressure facilitates extubation of very low birth weight neonates. Pediatrics 1991;88:999-1003.
48. Jackson JK, Vellucci J, Johnson P, Kilbride HW. Evidence-based approach to change in clinical practice: introduction of expanded nasal continuous positive airway pressure use in an intensive care nursery. Pediatrics 2003;111(4 Pt 2):e542-e547.
49. Davis PG, Henderson-Smart DJ. Nasal continuous positive airways pressure immediately after extubation for preventing morbidity in preterm infants. Cochrane Database Syst Rev 2003;(2):CD000143.
50. Dimitriou G, Greenough A, Kavvadia V, Laubscher B, Alexiou C, Pavlou V, Mantagos S. Elective use of nasal continuous positive airways pressure following extubation of preterm infants. Eur J Pediatr 2000;159(6):434-439.
51. Bachman TE. Evidence-based medicine: NCPAP in weaning preterm infants from ventilators. Neonatal Intensive Care 2000;13(1):15-19.
52. Davis P, Jankov R, Doyle L, Henschke P. Randomised, controlled trial of nasal continuous positive airway pressure in the extubation of infants weighing 600 to 1250 g. Arch Dis Child Fetal Neonatal Ed 1998;79(1):F54-F57.
53. Neijens HJ, Kerrebijn KF, Smalhout B. Successful treatment with CPAP of two infants with bronchomalacia. Acta Paediatr Scand 1978;67:293-296.
54. Miller RW, Pollack MM, Murphy TM, Fink RJ. Effectiveness of continuous positive airway pressure in the treatment of bronchomalacia in infants: a bronchoscopic documentation. Crit Care Med 1986;14(2):125-127.
55. Katz ES, Gauda E, Crawford T, Ogunlesi F, Lefton-Greif MA, McGrath-Morrow S, Marcus CL. Respiratory flutter syndrome: an underrecognized cause of respiratory failure in neonates. Am J Respir Crit Care Med 2001;164(7):1161-1164.
56. Weigle CG. Treatment of an infant with tracheobronchomalacia at home with a lightweight, high-humidity, continuous positive airway pressure system. Crit Care Med 1990;18(8):892-894.
57. Thompson JE, Farrell E, McManus M. Neonatal and pediatric airway emergencies. Respir Care 1992;37(6):582-599.
58. De Klerk AM, De Klerk RK. Nasal continuous positive airway pressure and outcomes of preterm infants. J Paediatr Child Health 2001;37(2):161-167.

59. Hegyi T, Hiatt IM. The effect of continuous positive airway pressure on the course of respiratory distress syndrome: the benefits on early initiation. Crit Care Med 1981;9(1):38-41.
60. Verder H, Albertsen P, Ebbesen F, Greisen G, Robertson B, Bertelsen A, et al. Nasal continuous positive airway pressure and early surfactant therapy for respiratory distress syndrome in newborns of less than 30 weeks' gestation. Pediatrics 1999;103(2):E24.
61. Pieper CH, Smith J, Maree D, Pohl FC. Is nCPAP of value in extreme preterms with no access to neonatal intensive care? J Trop Pediatr 2003;49(3):148-152.
62. Dunn MS, Reilly MC. Approaches to the initial respiratory management of preterm neonates. Paediatr Respir Rev 2003;4(1):2-8.
63. Horbar JD, Badger GJ, Carpenter JH, Fanaroff AA, Kilpatrick S, LaCorte M, et al; Members of the Vermont Oxford Network. Trends in mortality and morbidity for very low birth weight infants, 1991-1999. Pediatrics 2002;110(1 Pt 1):143-151.
64. Elgellab A, Riou Y, Abbazine A, Truffert P, Matran R, Lequien P, Storme L. Effects of nasal continuous positive airway pressure (NCPAP) on breathing pattern in spontaneously breathing premature newborn infants. Intensive Care Med 2001;27(11):1782-1787.
65. Lindwall R, Frostell CG, Lonnqvist PA. Delivery characteristics of a combined nitric oxide nasal continuous positive airway pressure system. Paediatr Anaesth 2002;12(6):530-536.
66. Beasley JM, Jones SEF. Continuous positive airway pressure in bronchiolitis. Br Med J (Clin Res Ed)1981;283(6305):1506-1508.
67. Smith PG, el-Khatib MF, Carlo WA. PEEP does not improve pulmonary mechanics in infants with bronchiolitis. Am Rev Respir Dis 1993;147(5):1295-1298.
68. Jeena P, Pillay P, Adhikari M. Nasal CPAP in newborns with acute respiratory failure. Ann Trop Paediatr 2002;22(3):201-207.
69. Pandit PB, Courtney SE, Pyon KH, Saslow JG, Habib RH. Work of breathing during constant- and variable-flow nasal continuous positive airway pressure in preterm neonates. Pediatrics 2001;108(3):682-685.
70. Ryan CA, Finer NN, Peters KL. Nasal intermittent positive-pressure ventilation offers no advantages over nasal continuous positive airway pressure in apnea of prematurity. Am J Dis Child 1989;143(10):1196-1198.
71. Sampietro VI, Azevedo MP, Resende JG. [Measurement of airflow resistance in prongs of nasal continuous positive airway pressure for newborns.] J Pediatr (Rio J) 2000;76(2):133-137. [Article in Portuguese] English translation available at http://www.jped.com.br/conteudo/00-76-02-133/ing.asp. Accessed August 16, 2004.
72. Peck DJ, Tulloh RM, Madden N, Petros AJ. A wandering nasal prong: a thing of risks and problems. Paediatr Anaesth 1999;9(1):77-79.
73. Loftus BC, Ahn J, Haddad J Jr. Neonatal nasal deformities secondary to nasal continuous positive airway pressure. Laryngoscope 1994;104(8 Pt 1):1019-1022.
74. Robertson NJ, McCarthy LS, Hamilton PA, Moss AL. Nasal deformities resulting from flow driver continuous positive airway pressure. Arch Dis Child Fetal Neonatal Ed 1996;75(3):F209-F212.
75. Yu VYH, Liew SW, Roberton NRC. Pneumothorax in the newborn: changing pattern. Arch Dis Child 1975;50(6):449-453.
76. Chernick V. Lung rupture in the newborn infant. Respir Care 1986;31(7):628-633.
77. Gessler P, Toenz M, Gugger M, Pfenninger J. Lobar pulmonary interstitial emphysema in a premature infant on continuous positive airway pressure using nasal prongs. Eur J Pediatr 2001;160(4):263-264.
78. de Bie HM, van Toledo-Eppinga L, Verbeke JI, van Elburg RM. Neonatal pneumatocele as a complication of nasal continuous positive airway pressure. Arch Dis Child Fetal Neonatal Ed 2002;86(3):F202-F203.
79. Gurakan B, Tarcan A, Arda IS, Coskun M. Persistent pulmonary interstitial emphysema in an unventilated neonate. Pediatr Pulmonol 2002;34(5):409-411.
80. Makhoul IR, Smolkin T, Sujov P. Pneumothorax and nasal continuous positive airway pressure ventilation in premature neonates: a note of caution. ASAIO J 2002;48(5):476-479.
81. Leone RJ Jr, Krasna IH. 'Spontaneous' neonatal gastric perforation: is it really spontaneous? J Pediatr Surg 2000;35(7):1066-1069.
82. Schlobohm RM, Falltrick RT, Quan SF, Katz JA. Lung volumes, mechanics, and oxygenation during spontaneous positive-pressure ventilation: the advantage of CPAP over EPAP. Anesthesiology 1981;55(4):416-422.
83. Goldman SL, Brady JP, Dumpit FM. Increased work of breathing associated with nasal prongs. Pediatrics 1979;64(2):160-164.
84. Nelson RM, Egan EA, Eitzman DV. Increased hypoxemia in neonates secondary to the use of continuous positive airway pressure. J Pediatr 1977;91(1):87-91.
85. Garland JS, Nelson DB, Rice T, Neu J. Increased risk of gastrointestinal perforations in neonates mechanically ventilated with either face mask or nasal prongs. Pediatrics 1985;76(3):406-410.

86. Tanswell AK. Continuous distending pressure in the respiratory distress syndrome of the newborn: who, when, and why? Respir Care 1982;27(3):257-266.
87. Han VKM, Beverley DW, Clarson C, Sumabat WO, Shaheed WA, Brabyn DG, Chance GW. Randomized controlled trial of very early continuous distending pressure in the management of preterm infants. Early Hum Dev 1987;15(1):21-32.
88. Pedersen JE, Nielsen K. Oropharyngeal and esophageal pressure during mono- and binasal CPAP in neonates. Acta Paediatr 1994;83(2):143-149.
89. Chilton HW, Brooks JG. Pharyngeal pressures in nasal CPAP. J Pediatr 1979;94(5):808-810.
90. Boo NY, Zuraidah AL, Lim NL, Zulfiqar MA. Predictors of failure of nasal continuous positive airway pressure in treatment of preterm infants with respiratory distress syndrome. J Trop Pediatr 2000;46(3):172-175.
91. Tanswell AK, Clubb RA, Smith BT, Boston RW. Individualised continuous distending pressure applied within 6 hours of delivery in infants with respiratory distress syndrome. Arch Dis Child 1980;55(1):33-39.
92. Andreasson B, Lindroth M, Svenningsen NW, Drefeldt B, Jonsson GI, Niklason L, Jonson B. Measurement of ventilation and respiratory mechanics during continuous positive airway pressure (CPAP) treatment in infants. Acta Paediatr Scand 1989;78(2):194-204.
93. Kamper J, Wulff K, Larsen C, Lindequist S. Early treatment with nasal continuous positive airway pressure in very low-birth-weight infants. Acta Paediatr 1993;82(2):193-197.
94. Richardson CP, Jung AL. Effects of continuous positive airway pressure on pulmonary function and blood gases of infants with respiratory distess syndrome. Pediatr Res 1978;12(7):771-774.
95. Courtney SE, Pyon KH, Saslow JG, Arnold GK, Pandit PB, Habib RH. Lung recruitment and breathing pattern during variable versus continuous flow nasal continuous positive airway pressure in premature infants: an evaluation of three devices. Pediatrics 2001;107(2):304-308.
96. Davis P, Davies M, Faber B. A randomised controlled trial of two methods of delivering nasal continuous positive airway pressure after extubation to infants weighing less than 1000 g: binasal (Hudson) versus single nasal prongs. Arch Dis Child Fetal Neonatal Ed 2001;85(2):F82-F85.
97. De Paoli AG, Morley CJ, Davis PG, Lau R, Hingeley E. In vitro comparison of nasal continuous positive airway pressure devices for neonates. Arch Dis Child Fetal Neonatal Ed 2002;87(1):F42-F45.
98. Hayes B. Ventilation and ventilators-an update. J Med Eng Technol 1988;12(5):197-218.
99. Mazzella M, Bellini C, Calevo MG, Campone F, Massocco D, Mezzano P, et al. A randomised control study comparing the Infant Flow Driver with nasal continuous positive airway pressure in preterm infants. Arch Dis Child Fetal Neonatal Ed 2001;85(2):F86-F90.
100. Lee KS, Dunn MS, Fenwick M, Shennan AT. A comparison of underwater bubble continuous positive airway pressure with ventilator-derived continuous positive airway pressure in premature neonates ready for extubation. Biol Neonate 1998;73(2):69-75.
101. Severinghaus JW. Transcutaneous blood gas analysis. Respir Care 1982;27(2):152-159.
102. Hay WW Jr, Brockway JM, Ezyaguirre M. Neonatal pulse oximetry: accuracy and reliability. Pediatrics 1989;83(5):717-722.
103. American Association for Respiratory Care. AARC Clinical Practice Guideline: Endotracheal suctioning of mechanically ventilated adults and children with artificial airways. Respir Care 1993;38(5):500-504.
104. Bolyard EA, Tablan OC, Williams WW, Pearson ML, Shapiro CN, Deitchmann SD. Guideline for infection control in healthcare personnel, 1998. Hospital Infection Control Practices Advisory Committee. Infect Control Hosp Epidemiol 1998;19(6):407-463. Erratum in: Infect Control Hosp Epidemiol 1998;19(7):493.
105. American Association for Respiratory Care. AARC Clinical Practice Guideline: Patient-ventilator system checks. Respir Care 1992;37(8):882-886.
106. American Association for Respiratory Care. AARC Clinical Practice Guideline: Humidification during mechanical ventilation. Respir Care 1992;37(8):887-890.
107. American Association for Respiratory Care. AARC Clinical Practice Guideline: Oxygen therapy for adults in the acute care hospital—2002 revision & update. Respir Care 2002;47(6):717-720.
108. Avery GB, Glass P. Retinopathy of prematurity: what causes it? Clin Perinatol 1988;15(4):917-928.
109. American Association for Respiratory Care. AARC Clinical Practice Guideline: Transcutaneous blood gas monitoring for neonatal and pediatric patients. Respir Care 1994:39(12):1176-1179.
110. Salyer JW. Neonatal and pediatric pulse oximetry. Respir Care 2003;48(4):386-396; discussion 397-398.
111. American Association for Respiratory Care. AARC Clinical Practice Guideline: Pulse oximetry. Respir Care 1991;36(12):1406-1409.

112. Speidel BD, Dunn PM. Use of nasal continuous positive airway pressure to treat severe recurrent apnoea in very preterm infants. Lancet 1976;2(7987):658-660.
113. American Association for Respiratory Care. AARC Evidence-Based Clinical Practice Guideline: Care of the ventilator circuit and its relation to ventilator-associated pneumonia. Respir Care 2003;48(9):869-879.