

Following are bedside tips one learns with experience. So as to guide the newcomer who should not repeat the same mistakes, the answers are backed by literature. The evidence may not be robust but in the experience of the editors, these may be worth trying.

1. Can you convince me that one should use CPAP and avoid mechanical ventilation?

Intubation is the single major preventable factor contributing to bronchopulmonary dysplasia. It has been shown that even a single positive pressure breath can initiate the inflammatory cascade and cause lung damage. In addition, CPAP can conserve surfactant and maintain FRC. On the other hand, with intubation, we add a lot of dead space and resistance-this leads to loss of FRC unless adequate PEEP is provided.

2. Do you think, if I start early successful CPAP my need of referral will decrease?

Definitely. CPAP is most likely to be successful if started early, without waiting for blood gas abnormalities. Early CPAP prevents atelectasis, conserves surfactant and will minimize the stimulation of inflammatory cascade. Hence, lot of babies may be managed on CPAP alone and would not have to be referred.

Lanieta Koyamaibole et al. An Evaluation of Bubble-CPAP in a Neonatal Unit in a Developing Country: Effective Respiratory Support That Can Be Applied By Nurses. Journal of Tropical Pediatrics 2006 52(4):249-253.

Buckmaster et al. Continuous Positive Airway Pressure Therapy for infants with Respiratory Distress in Non-Tertiary Care Centres: A Randomized, Controlled Trial. Pediatrics 2007; 120;509-518.

3. If I keep these babies with me on CPAP, can I also give surfactant to them and extubate them back to CPAP?

Definitely. INSURE technique is to Intubate only for the purpose of giving Surfactant and Extubate. In fact, this technique is less damaging to the lungs than keeping the babies intubated. Units giving surfactant should have back-up ventilation services or good transport facilities in case of CPAP/INSURE failure.

Stevens TP, Harrington EW, Blennow M, So11 RF. Early surfactant administration with brief ventilation vs selective surfactant and continued mechanical ventilation for preterm infants with or at risk for RDS. Cochrane Database Syst Rev. 2007 (4): CD 003063.

4. Is it essential to have a ventilator back-up in every unit with CPAP (to manage babies who fail CPAP?)

Ventilator back-up should be available but not necessarily in the same unit. If ventilator is not available in the unit, the unit should have arrangements for transport/pick-up and referral to another near-by unit with ventilation facilities.

5. In your opinion, how does indigenous CPAP fare when compared to branded (F&P), bubble CPAP and ventilator derived CPAP?

Indigenous CPAP needs a humidifier, and a Y connector to blend air and oxygen. It will also need an interface. It should not be used with 100% oxygen or cold gases. Comparison of these is not reported but as they work on the same principle, the ultimate pressure will be the same if correctly used.

Studies comparing the different systems have found that no single system is superior to others. Successful CPAP therapy is obtained by a proper fitting interface and having care givers who are proficient in trouble shooting and taking care of a neonate on CPAP.

E. Bancalari and T del Moral. Continuous positive airway pressure: early, late, or stay with synchronized intermittent mandatory ventilation? Journal of Perinatology (2006) 26 ,S33-S37.

6. What are the practical problems/issues one would face initially while using indigenous CPAP?

Maintaining effective humidification and blending of oxygen and air are the main bottlenecks.

7. I am planning to buy a CPAP machine. Should I purchase a machine providing CPAP alone or one with additional facility to provide ventilation? Should I go for an Indian-make CPAP machine?

A ventilator will cost at least 3 times that of CPAP machine alone. A dedicated CPAP machine will make the ventilator available for another baby needing IMV. So, it will be more cost-effective to buy a stand-alone CPAP machine. Indian make CPAP machines are cheaper but have suffered from lack of generation of consistent pressures, reliable compressor and good quality interface. However, all the manufacturers have been constantly improving their models based on user feedback. Hence, it may be a good idea to have a demo of the latest model being offered and test-use it before buying. Make sure that you are being provided a humidifier, reliable blender and a sturdy compressor (if you do not have central air supply) capable of working continuously for a week.

8. What are the bare minimum needs for monitoring oxygen therapy on CPAP?

A Pulse oximeter and a FiO₂ monitor. Keep the SpO₂ between 90-94%: for babies below 1 kg even saturations of 85% may be acceptable.

Castillo A, Sola A, Baquero H et al. Pulse oxygen saturation levels and arterial oxygen tension values in newborns receiving oxygen therapy in the NICU: Is 85% to 93% an acceptable range. Pediatrics 2008; 121(5):882-9.

9. Can I use CPAP without X-ray?

X-ray is needed at three stages- initially to confirm the diagnosis, to look for adequate lung expansion and to detect complications such as air leaks and hyperinflation. At least one CXR would be required initially for establishing the diagnosis and to assess lung inflation. 6 to 8 spaces on the CXR is adequate inflation. In case of sudden deterioration, one needs to rule out pneumothorax. A mobile portable x-ray is a must, if we need to give CPAP.

10. Do I need blood gas machine if I have to start CPAP?

Ideally yes, but most babies with mild to moderate disease can be managed without it also. A continuous pulse oximetry to get an idea about oxygenation however, would be mandatory. If baby has good respiratory efforts and normal blood pressure and capillary filling time, one may presume that pCO₂ and pH are normal. High CO₂ in

spontaneously breathing neonates with mild to moderate distress would occur either because of poor respiratory efforts or an air leak-both of which, can be diagnosed clinically.

Hence, blood gas machine is not mandatory while giving CPAP but it helps to pick up high PCO₂ and acid base disturbances. Low CO₂ is uncommon in babies on CPAP. High PCO₂ may occur but to prevent this one need's to assess the respiratory efforts closely.

11. **Is humidification, a must for nasal CPAP as one is not bypassing upper airways?**

Humidification and warming of inspiratory gases is the most important aspect of nasal CRAP. In normally breathing infants the flows are very low compared to the gas flows that occur when giving CPAP. High flow gases dry the mucosa, decrease muco-ciliary function and increase the airway resistance. It is ideal to deliver the gases at 37°C and at 100% relative humidity for best efficacy of CPAP.

Pollett HF, Reid WD. Prevention of obstruction of nasopharyngeal CPAP tubes by adequate humidification of inspired gases. Can Anaesth Soc J. 1977 Sep;24(5):615-7.

Worsnop CJ, Miseski S, Rochford PD. The routine use of humidification with nasal continuous positive airway pressure. Intern Med J. 2010;40:650-56.

12. **Is it advisable to use CPAP without a blender?**

No, one should not use CPAP with 100% oxygen. Either an electrical or mechanical blender or a Y connection to mix oxygen and air (in this case, FiO₂ monitor should be available) should be used.

13. **CPAP is usually recommended for VLBW neonates with respiratory distress or post-extubation or for apnea of prematurity. Can I use CPAP for bigger or term neonates with respiratory distress?**

CPAP is effective and can be used successfully in term babies with respiratory distress due to various etiologies like TTNB, MAS and pneumonia. Term babies may be more irritable and vigorous; hence keeping the prongs in place is more difficult

14. **What is closing volume? How it is relevant in a patient of HMD on CPAP?**

The closing volume (CV) is the lung volume, at which dynamic compression and closure of the airways begins especially in the dependent lung regions. Once airways

close, gases cannot reach or come out of the alveoli. Closing capacity (CC) = CV + RV (Residual volume-volume of gas remaining in lung at the end of forced expiration). The CC is higher in infants than adults because of decreased elastic recoil of the lung. Hence, preterms breathe from an end-expiratory lung volume which is close to the CC. Even during quiet (tidal) breathing, it is possible for lung volumes to be less than the FRC, especially in independent parts of the lung.

In HMD, the FRC is decreased, hence: the difference between CC and FRC further increases. This exaggerates VQ mismatch. The aim of CPAP/ PEEP is to increase the FRC so that it is more than CC.

15. How to select the appropriate size of the nasal cannula for babies with different birth weights?

Choose a prong that fits the nares snugly.

When using Fisher and Paykel prongs, follow the guide available with the kit. The guide consists of a transparent sheet with various sizes of nostril and columella printed on it as two horizontal rows respectively. Match for the appropriate size of nostril and columella. The available possible combinations of these two measurements are indicated by lines joining the two rows. The best fitting size is then taken.

While using the Hudson prongs	
Weight of baby	Size of prong
<700 grams	0
700-1200 grams	1
1200-2000 grams	2
2000-3000 grams	3
3000-4000 grams	4
>4000 grams	5

Argylle nasal prongs - sizes are related to birth weight of the baby. Three sizes are available-one for <1000gms, second for 1000-1500gms and third one for >1500gms.

Note that sometimes in ELBW babies, the prongs of a particular brand will not fit even though selected according to the weight/size criteria. In that case, try out the prongs of another brand and it will often fit. Also, after one or two weeks, the nostrils often distend and one may have to change to the next higher size.

16. What care should be taken of the prongs and nose while the baby is on nasal CPAP?

The biggest nasal prong, that comfortably fits the nostril, should be used. The weight of the prong should not fall on the nostrils. While selecting prongs it is important to select appropriate size so as to snugly fit into the nasal cavity and have appropriate internares distance. While a tight one will cause pressure necrosis, the loose one will result in large air leaks. While inserting, it is important to see the symmetry and direction. The prongs should be moistened with saline before insertion. In a supine baby, the prongs should be inserted in the cephalad direction, 15-20 degree downward to an imaginary perpendicular line drawn to body's long axis. The bridge of the prongs should not abut the columella and must not cause blanching of the skin.

The nasal prongs must be removed every 4-6 h and nose inspected for secretions and normal saline should be instilled. The skin should be cleaned with sterile water and nasal prongs should be cleaned as per the manufacturers' instructions. (with distilled water) every 4 to 6 hours.

It is very important to periodically inspect nasal mucosa for hyperemia; columella and alae nasi for blanching at least 4 hourly. If the prongs are required for >3-4 days it may be prudent to change them and sterilize by putting them in glutaraldehyde solution before reapplication.

17. Can I use bi-nasal flow oxygen cannula for providing CPAP?

It is difficult to obtain a tight fitting bi-nasal cannula, so most often adequate CPAP will not be generated. These cannulae are meant for delivering low flow oxygen. However if the outer diameter of nasal cannula is 3 mm and flows of 2 L/min are given, CPAP can be generated.

Paoli AG, Morley C, Davis PG. Nasal CPAP for neonates; What do we know in 2003? Arch Dis Child Fetal and Neonatal Ed 2003,88:F-168

But note that nasal flow oxygen cannula can generate very variable and unpredictable

CPAP (even up to 8 cm H₂O). Although CPAP can be generated, it has been shown that the work of breathing is increased because of high resistance. Hence, the ultimate chance of success will be less. In addition, adequate humidification will be very difficult to achieve with nasal cannulas.

On the other hand, short bi-nasal prongs (Hudson, Argyle, INCA, IFD) being used as patient interface along with a pressure source have been demonstrated to provide best CPAP.

De Paoli AG, Davis PG, Faber B, Morely CJ. Devices and pressure sources for administration of NCPAP in preterm neonates. Cochrane Database of systematic reviews 2008, CD 002977.

A device such as vapotherm had been used to deliver high flow nasal cannula CPAP but the experience is limited to few centres in the world.

18. What should be the patient position during CPAP?

Infants receiving CPAP can be placed in any position that promotes comfort and optimal airway posturing for the infant. It is recommended that infants be repositioned at least every 3 to 6 hours.

The prone position is often the preferred position. There is, however, no evidence in the literature that the prone position is superior to the supine or side-lying positions for non-ventilated premature infants.

Infants in any position need to be properly supported, whether with a neck roll in the supine and side-lying positions or with a prone roll in the prone position. Care must be taken to ensure optimal airway positioning and intactness of the CPAP system during any position change. Also, the infant should have the developmental boundaries while in the supine and side-lying positions, which promote flexion, containment, and comfort

19. What is the status of providing CPAP via endotracheal tube?

Endotracheal tube CPAP has the advantage of ease of fixation, ability to achieve high pressure with low flows, minimal leak and ease of switching over to mechanical ventilation when needed.

But, Endotracheal CPAP increases resistance markedly, so the work of breathing will

increase tremendously. In view of this, the Cochrane meta-analysis forbids use of ET CPAP as a weaning mode and recommends direct extubation from low rate IMV rather than after a trial of ET CPAP. Such a strategy increases the chances of successful extubation and also reduces chances of post extubation apnea. In fact, in another review, Cochrane recommends extubation from IMV to nasal CPAP instead of head box oxygen as this reduces the chances of adverse events and extubation failure.

Davis PG, Henderson-Smart DJ. Extubation from low rate intermittent positive airways pressure versus extubation after a trial of ET CPAP in intubated preterm infants. Cochrane Database Syst Rev. 2001; (4): CD001078.

Davis PG, Henderson-Smart DJ. NCPAP immediately after extubation for preventing morbidity in preterm infants. Cochrane Database Syst Rev 2003; (2): CD000143.

A 3 minute pre-extubation trial of ET-CPAP has been shown to increase the chance of extubation success in one study but needs further corroboration.

Kamlin CO, Davis PG, Morely CJ. Predicting successful extubation of VLBW infants.. Arch Dis Child Fetal Neonatal ed. 2006, May 2006; 91(3): F180-183.

20. Bi-nasal prongs are difficult to procure and are costly. Can I use an endotracheal tube inserted up to nasopharynx?

Nasopharyngeal tubes can provide effective CPAP and are easier to fix compared to short binasal prongs. However, in case of nasopharyngeal tube, the resistance is much higher and air leak through the contralateral nostril is likely to diminish the applied pressure. Moreover nursing care is impossible as there is no way to periodically monitor nasopharynx.

Better oxygenation, respiratory rates, and weaning success was reported with a short binasal device when compared with a single prong nasopharyngeal CPAP.

De Paoli AG, Davis PG, Faber B, Morely CJ. Devices and pressure sources for administration of NCPAP in preterm neonates.. Cochrane Database of systematic reviews 2008... CD 002977.

21. How to select the appropriate size of the nasopharyngeal cannula, particularly when using cut ET tube - is it the same size as that for intubation?

Either the same size as that required for intubation or one size smaller.

22. How frequently should we do suctioning while using (a) nasal cannula and (b) nasopharyngeal cannula?

The suction is not routinely required in case of short binasal prongs. But periodic monitoring is must. If secretions are visible on periodic monitoring, gentle suction should be performed. In cases of nasopharyngeal prongs there is no way to inspect nasopharynx, so one has to perform suction every 4 hourly at least.

23. What is the best pressure to start with and how to regulate CPAP pressure?

For most lung diseases, the starting CPAP is 5cms of water. For apnea of prematurity, the starting pressure is 4cms water.

When using bubble CPAP, an increase or decrease in CPAP is done by increasing or decreasing the depth of immersion of expiratory limb in the bubble chamber. The water level should be kept constant.

Chest retractions, grunting and lung inflation <6 spaces on the X-ray are the indications for increasing CPAP pressure. Hyperinflated chest, lung inflation >8 spaces and flat diaphragm are indications for decreasing CPAP pressure.

After initiating CPAP, the decision to increase CPAP should be based on clinical signs. Presence of grunt, retractions and even tachypnea are indicative of inadequate support. SpO₂ values and blood gases can be useful adjuncts in decision making, in cases where mild tachypnea is present. One should not wait for X-ray to take decisions for increasing CPAP. FiO₂, should be adjusted to keep SpO₂ in range of 87-93%. CPAP pressure and FiO₂, generally go hand in hand eg. 5 cm water-50%, 7cm water-70% and so on. If there is mismatch eg. FiO₂, 30% and CPAP of 7 cm water, this means we are wrong somewhere. X rays are helpful to diagnose over-inflation by the presence of >8 posterior intercostal spaces, flat diaphragm and horizontal ribs. During weaning, as the FiO₂, requirements come down, CPAP should be brought down.

24. Besides the set pressure, what are the other factors which affect the delivered pressure to the baby on CPAP?

For a given set pressure, increasing the flow rate of the gases will cause an increase in the delivered pressure of CPAP. So while changing the CPAP pressures on a given patient, the flow rate of the gases must be kept constant. The flow rate required depends on the

CPAP generating system and other factors such as any leaks in the system and whether the mouth is closed or not.

The required flow rate can be objectively seen in bubble CPAP and rate can be adjusted to generate adequate underwater bubbles at the expiratory limb. For ventilator generated CPAP, the required exact flow rate is still debatable. A circuit flow of gases at 4-8L/min may be sufficient if there are no leaks through the nose or mouth.

Kahn DJ, Habib RH, Courtney SE. Effects of flow amplitude on intra prong pressures during bubble versus ventilator - generated nasal continuous positive airway pressure in premature neonates. Pediatrics 2008, 122:1009-13.

25. Please provide practical tips related to bubble generation in under water CPAP system?

Bubble generation in the CPAP system is related to flow, leaks in the circuit and airway of the patient. The bubbles should be seen both during inspiratory and expiratory phases of respiration. Excess bubbling happens with higher flow rates often generating more pressure at patient interface than what is intended.

In the absence of bubbling, do the following:

- Connect the circuit to a test lung. If still there is no bubbling increase the flow.
- If bubbling occurs with test lung and not with patient, look for leaks through the mouth or suspect air leaks.

26. What parameters suggest that the baby is getting adequate CPAP while on Bubble CPAP?

Comfortable baby, minimal retractions, good bubbling sounds in the chest, SpO₂ between 87% to 93%, continuous bubbling in the bubble chamber, minimal or no condensation in the inspiratory limb of the circuit and adequate chest expansion on the CXR

27. Should the mouth be closed while giving CPAP?

Closing the mouth with a chin strap or pacifier will raise the pharyngeal pressure, whereas the pharyngeal pressure may fall if mouth is persistently open. However, open mouth also acts as a safety pop-off and helps to vent out any inadvertent increase in

pressure delivered to baby. Hence, there is no need for routine closure of the mouth. However, if the baby is irritable and there is no bubbling in the bubble chamber even with flows >7 to 8 L/min, one may choose to close the mouth. It should be noted that most studies of CPAP have shown success without actively closing the mouth. It is important to realize that the neonates are obligatory nasal breathers. Most often, the cause of open mouth is pain or stress in the neonate. If these issues are addressed, majority of the cases will not need chin strapping.

28. Can I feed my baby on CPAP?

Definitely. We do not withhold feeds for a baby on CPAP. Most babies on CPAP in our units are managed successfully on full feeds.

The common fear is that the CPAP air will distend the stomach. But luckily, in premature infants the tone at upper end of esophagus and at gastro esophageal junction is higher than the usual CPAP pressures. So the air goes preferentially to the airways rather than the esophagus. Occasionally; 'CPAP belly', can occur ; this is most of the times, benign. Hence, while on CPAP, babies must always have an orogastric (OG) tube left in situ with other end open to atmosphere hanging with the canopy above the level of baby. This prevents efflux of feeds through the OG tube. Usually, the OG tube is plugged for 20-30 minutes after feeds.

Omani Ti, Benniga MA, Barnet CP, et al. Characterization of esophageal body and lower esophageal sphincter motor function in the very premature neonate. J Pediatrics 1999, 135:517-21.

In an interesting study, preterm newborn infants (n = 16) with mean age of 27.7 weeks (SD, 1.9) on NCPAP were compared with 20 newborn infants with mean age of 28.2 weeks (SD, 1.2) and not receiving NCPAP. Mean gastric emptying time as estimated by measuring cross-sectional area of the antrum by means of an ultrasound technique was 28 minutes (SD, 1.2) in the NCPAP group and 40 minutes (SD, 17) in the comparison group (P < .05). There were no differences in gastrointestinal complications between the two groups. The study concluded that gastric emptying time was shorter for newborn infants treated with NCPAP. The authors hypothesized that the results were related to the pressure that is exerted on the stomach by the diaphragm.

Gounaris A, Costalos C, Varchalama L, Kokori P, Kolovou E, Alexiou N. Gastric emptying in

very-low-birth-weight infants treated with nasal continuous positive airway pressure. Journal of Pediatrics 2004;145:508-510.

29. What steps should I take to prevent common hazards and complications of nasal CPAP?

The major difficulty in using nasal CPAP is keeping the prongs in proper position. An interface that is light weight and is pivoted to the head and neck by proper fixation ensures that the nasal prongs do not get dislodged with the movement of the baby's head. Taking care of humidification of the gases, frequent suctioning and instillation of normal saline prevents nasal obstruction.

An inappropriately chosen large nasal cannula can cause nasal trauma including columella necrosis and long term complication of nasal snubbing. A smaller size cannula may result in leak and CPAP failure. Hence the correct size cannula needs to be chosen, following the guidelines mentioned for that product. Providing higher pressures than required can result in hyperinflation of the chest; if severe, it can result in air leaks (pneumothorax), retention of CO₂, reduction of systemic venous return and rarely impaired renal perfusion. Hence, continuous monitoring of babies on CPAP is a must to prevent these complications.

30. How often do I need to change patient circuit?

Like in case of ventilators, there is no hard evidence. For those ventilated for more than a week, it may be prudent to change the circuit once a week; but for those ventilated for less than a week, there is no need to change the circuit. There is little data about circuit change in neonatal ventilation. But in adults, it is recommended that ventilator circuits should not be changed routinely for infection control purposes. The available evidence suggests no patient harm and considerable cost savings associated with extended ventilator circuit change intervals. However, the maximum duration of time that circuits can be used safely is unknown.

Care of the Ventilator Circuit and Its Relation to Ventilator-Associated Pneumonia. AARC Evidence-Based Clinical Practice Guidelines. Respir Care 2003;48(9): 869-879.

31. Does CPAP predispose to sepsis?

Like any other foreign device, CPAP increases the risk of infection in a baby when

compared to another baby without that device. However, this risk is substantially lesser than that of an intubated baby. The increased risk of infection due to CPAP is suggested to be due to trauma to the flares, increasing the ports of entry for bacteria. Nasal CPAP support at 24 h of age was found to be an independent predictive factor for early onset septicaemia in a prospective study of 462 infants with a gestational age of less than 28 weeks and birth weight of less than 1000 g. In addition, in a case control study, nasal cannula CPAP was significantly associated with gram negative blood stream infections in VLBW infants.

It has however, been highlighted that the rate of infection in the two nurseries involved in the study was twice the national average and, as a consequence, it was questioned whether the results would apply to NICUs with better infection-control practices.

Ronnestad A, Abrahamsen TG, Medbo S, Reigstad H, Lossius K, Kaaresen PI, et al. Septicemia in the first week of life in a Norwegian national cohort of extremely premature infants. Pediatrics 2005;115:e262-8.

Graham PLI, Begg MD, Larson E, Della-Latta P, Allen A, Saiman LM. Risk factors for late onset gram-negative sepsis in low birth weight infants hospitalized in the neonatal intensive care unit. PIDJ 2006;25:113-7.

Aly H, Herson V. Nasal continuous positive airway pressure and gram negative sepsis in low birthweight infants. Pediatr Infect Dis J 2006;25:663-4.

32. What is Heated Humidified High-Flow Nasal Cannula (HHHFNC)? Is it a better form of CPAP?

HHHFNC and CPAP are not one and the same, that is, that HHHFNC is not a form of CPAP. This is primarily because HHHFNC is neither designed nor FDA approved to provide true CPAP. The available evidence to date suggests that some positive airway pressure is indeed generated when using HHHFNC, but that this pressure is inconsistent, unreliable, and unpredictable.

HHHFNC should best be regarded as a potentially valuable respiratory support modality, being easier to use with the possibility of being better tolerated with fewer adverse effects such as local trauma, but also as a potentially dangerous respiratory support modality until concerns regarding infection risk, airway pressure, and other as yet unrecognized possible adverse effects are adequately addressed. To conclude,

1. HHHFNC use is recommended for postextubation support at ≤ 28 weeks of gestation or to transition from nCPAP.
2. It should not be used routinely in neonatal care as a primary modality of respiratory support for RDS until adequate evidence for safety and efficacy becomes available.
3. A clear unit protocol for use needs to be in place to ensure safe management of infants treated with HHHFNC.

CC. Roehr, BA. Yoder, PG. Davis, K Ives. Guidelines for Using Heated, Humidified, High-Flow Nasal Cannulae in Neonatology Oxford Nasal High-Flow Therapy Meeting, 2015. Clin Perinatol 43 (2016) 693–705