

Manual Resuscitators: Some Inconvenient Truths

The Old Testament appears to describe the successful application of mouth-to-mouth resuscitation of a child, some 2,900 years ago (II Kings 4:34). According to O'Donnell and colleagues,¹ the Babylonian Talmud describes a similar event 2,300 years ago: "One may give a woman (about to give birth) all assistance possible.... One may violate the Sabbath on her account." What is meant by "being of assistance"? "Holding up the young, blowing air into its nostrils, and leading it to its mother's breast, so that it may suck."

In the ensuing centuries, a dizzying array of techniques to aid in resuscitating the newborn have been described. Looking through the "retro-spectroscope"* we can now appreciate that some of these techniques were not particularly efficacious. They included: swinging the infant upside down; squeezing the chest; raising and lowering the arms while an assistant compresses the chest; rhythmic traction of the tongue; tickling the chest, mouth, or throat; yelling; shaking; dilating the rectum with a raven's beak or a corn cob; immersion in cold water, sometimes alternating with immersion in hot water; rubbing, slapping, or pinching; electric shocks; nebulized brandy (my personal favorite); a hyperbaric chamber in which pressure was increased 1–3 psi every few minutes, to mimic labor; insufflation of oxygen into the stomach; and, last but certainly not least, insufflation of tobacco smoke into the rectum.¹

We appear to have come a long way, baby.[†] Of course, the technology for resuscitation of newborns has vastly improved, but we continue to have variation in techniques and opinions about the best methods and equipment.

Today, newborns require resuscitation more frequently than any other patient population within the hospital setting,² and one of the more common interventions is positive-pressure ventilation with a manual resuscitator.

Worldwide, in 2003, nearly 10 million newborns required some type of resuscitation.³ The most commonly used manual resuscitators fall into 2 categories: flow-inflating bag, and self-inflating bag.

SEE THE ORIGINAL STUDY ON PAGE 1665

In this issue of *RESPIRATORY CARE*, Johnston and Aziz⁴ do us a service by adding to a growing body of evidence about the performance of self-inflating-bag resuscitators in neonatal scenarios. Johnston and Aziz prove, to my satisfaction, that when used with neonates, a Laerdal-style self-inflating bag can deliver a very high oxygen concentration, even without a reservoir. They found that with a pre-term-size resuscitator (240 mL) and a test lung set to mimic a low-birth-weight infant, as little as 2 L/min of oxygen into the bag maintained the fraction of delivered oxygen (F_{DO_2}) at > 0.95 .

However, a lot of clinicians have been trained to believe that with a Laerdal-style bag $F_{DO_2} > 0.50$ is not possible without a reservoir. The confusion here is typical when dealing with neonatal and pediatric respiratory therapy equipment performance. Much of the conventional wisdom about F_{DO_2} with resuscitators is from the adult literature. It is certainly true that with an adult patient, if a large resuscitation bag that does not have a reservoir is squeezed vigorously with 1 or 2 hands, F_{DO_2} will be approximately 0.40–0.50, even if the inlet oxygen flow into the bag is 15 L/min.

The manufacturer of the resuscitators that Johnston and Aziz studied had already figured out that even without a reservoir the Laerdal neonatal resuscitator can deliver a very high F_{DO_2} . And, as Johnston and Aziz note,⁴ the manufacturer had previously published a table of F_{DO_2} values very similar to those from Johnston and Aziz. What is troubling about the findings from Johnston and Aziz is that they contradict the published recommendations of the American Academy of Pediatrics in the *Textbook of Neonatal Resuscitation*, which recommends limiting F_{DO_2} , if necessary, by removing the reservoir during newborn resuscitation.³ Thus, with a Laerdal-style bag without a reservoir we may be delivering a much higher F_{DO_2} than we think. That risk supports the use of an oxygen blender in the delivery room, so we more carefully control F_{IO_2} . But blenders are costly and not available in all delivery rooms.

* The retro-spectroscope is a powerful tool, but one that can be misused in the hands of the untrained. This thought exercise allows us to smugly look back at historical practices that now seem to range from silly to preposterous. From our lofty perch on the hilltops of the present we sometimes forget to consider what the view may have been from the valleys of the past.

† Younger readers may be mercifully unfamiliar with the major advertising campaign for the first cigarette designed for and marketed to women in the late 1960s. "You've come a long way baby" was the slogan used to convince women that they could express their equality and rights by smoking their own brand of cigarettes. The campaign was very effective; by 1987, lung cancer surpassed breast cancer as the leading cause of cancer deaths among women.

The findings from Johnston and Aziz are an example of the sometimes confusing nature of the conventional wisdom and “urban myth” about the relative merits of self-inflating versus flow-inflating bags. The casual reader could easily be confused by claims and counter-claims about the superiority of one type of bag. I was once casually debating this with a physician colleague who told me he didn’t care what the research showed, he would always know that flow-inflating bags were superior. Many respiratory therapists (RTs) have told me this also. So goes the debate. Will Rogers, one of my favorite Americans once said, “It isn’t what we don’t know that gives us trouble, it’s what we know that ain’t so.”

To sort the wheat from the chaff about the relative merits of resuscitators, I suggest that we first must carefully consider the patient population and define what matters about how the bags perform in the target clinical scenario. In neonatal and pediatric use I would suggest that there are 2 important considerations in resuscitator bag performance: oxygen-delivery variability, and ventilation variability.

Oxygen Delivery

One of the most widely reported findings is that under certain conditions a self-inflating bag cannot deliver a high F_{DO_2} .^{5,6} The delivery of oxygen during manual ventilation has 3 distinct conditions:

- F_{DO_2} while squeezing the bag
- F_{DO_2} while the bag is attached to the patient during spontaneous ventilation
- F_{DO_2} while the mask is near but not touching the patient’s face (“blow-by” or “free-flow” oxygen delivery)

Much of the confusion about F_{DO_2} during manual squeezing of the bag is related to the extrapolation of adult findings to pediatric practice. It is clear that some self-inflating-bag designs deliver lower F_{DO_2} when vigorously squeezed with 1 or 2 hands during simulated adult resuscitation. Studies of bag performance in adult models of resuscitation have focused on the bag’s ability to give large breaths.⁷ But with a neonate this is not how a self-inflating bag ought to be used. The ventilating pressure and volume should be carefully limited with a pressure-relief valve, or, better yet, a manometer, to avoid over-distention lung injury. A much smaller tidal volume (V_T) is used, which reduces the risk of the bag entraining room air while the bag’s elastic recoil causes refilling. This explains why some investigators have been able to produce very high F_{DO_2} with self-inflating bags on neonatal lung models. They were using volumes and pressures that would be used on a real neonate.

Another source of confusion is the proclivity of some pundits to lump all brands of self-inflating bag together

while pontificating about the relative merits of one type bag or another. But, of course, not all brands of self-inflating bag perform the same.^{8,9}

Another source of divergent views on bag performance is construction of research models that do not actually measure what they attempt to assess, or do not use the bag in a rational clinical way. More than one set of investigators have measured oxygen flow in L/min going into the self-inflating bag and coming out of the bag’s patient connection without it being connected to a patient.¹⁰⁻¹³ Not surprisingly, owing to the design of a Laerdal-style bag, the oxygen flow out of the patient connector was about 18–24% of the flow rate going into the back end of the bag. But to then equate that to lower F_{DO_2} during free-flow oxygen delivery is a stretch for me. The low inspiratory flow demands of neonatal patients make it very easy to give very high F_{IO_2} with a relatively low flow blown at the face. Dawson and colleagues showed this in an in vitro study of free-flow oxygen delivery to a spontaneously breathing neonatal lung model with a mannequin head.¹⁴

The conventional wisdom is that the Laerdal-style self-inflating bag must be slightly squeezed to ensure consistent free-flow oxygen delivery,^{15,16} because the duck-bill valve in the bag’s patient connector opens only in one direction, when there is a pressure gradient across the valve. The theory goes that the duck-bill valve will not open enough without the squeeze to create a small pressure gradient. Nevertheless, I have repeatedly visually examined this type of valve during flow into a bag of 10 L/min, and the valve clearly was open.

That observation notwithstanding, some hospitals minimize the possibility of inadequate free-flow oxygen delivery with this style bag by using the other end of the bag for free-flow delivery. Nam et al¹⁷ showed that increasing the length of the corrugated-tubing reservoir on a Laerdal-style resuscitator increased the F_{DO_2} . At my institution we use self-inflating bags with corrugated-tubing reservoirs and ensure that the internal volume of the tubing is equal to or greater than the internal volume of the resuscitation bag. Thus, when the bag re-inflates after being squeezed, it fills almost completely with oxygen from the reservoir tubing.

My colleagues and I have tested the F_{DO_2} of this bag configuration, and a number of other oxygen-delivery devices, in an analog of a spontaneously breathing neonatal patient.¹⁸ Our model included a lung simulator that mimics neonatal spontaneous breathing (ASL 5000, Ingmar Medical, Pittsburgh, Pennsylvania), and an analog of a baby face fabricated from the soft rubber skin of the head of a neonatal resuscitation mannequin, which included openings for the mouth and nares. F_{DO_2} was sampled at the simulated hypopharynx. Table 1 shows the F_{DO_2} with the various devices, including self-inflating bag and flow-inflating bag, both attached to the face via mask, and held near the face, at 2 distances. With the self-inflating bag we used the corrugated-tubing reservoir to

Table 1. F_{DO_2} With Self-Inflating and Flow-Inflating Resuscitators and Various Oxygen Delivery Devices

Device and Condition	F_{DO_2} (mean \pm SD)
Nasal Cannula	
O ₂ at 0.25 L/min	0.33 \pm 0.01
O ₂ at 0.50 L/min	0.40 \pm 0.01
O ₂ at 1.0 L/min	0.53 \pm 0.02
O ₂ at 1.5 L/min	0.73 \pm 0.02
O ₂ at 2.0 L/min	0.84 \pm 0.01
Non-rebreather Mask	
O ₂ at 10 L/min	0.95 \pm 0.01
Simple Mask	
O ₂ at 5 L/min	0.56 \pm 0.01
O ₂ at 7 L/min	0.60 \pm 0.02
O ₂ at 10 L/min	0.60 \pm 0.01
Flow-Inflating Bag With Mask	
On face	0.98 \pm 0.01
5 cm from face	0.59 \pm 0.01
10 cm from face	0.44 \pm 0.01
Flow-Inflating Bag Without Mask	
5 cm from face	0.52 \pm 0.02
10 cm from face	0.46 \pm 0.01
Self-Inflating Bag	
Mask on face	0.98 \pm 0.00
Reservoir tubing 5 cm from face	0.95 \pm 0.01
Reservoir tubing 10 cm from face	0.48 \pm 0.02

F_{DO_2} = fraction of delivered oxygen
(From data in Reference 18.)

deliver free-flow oxygen. Notice that it was possible to give very high F_{DO_2} with either the self-inflating or the flow-inflating bag during spontaneous breathing, either via direct application with a mask or during free-flow delivery. Also note how much the F_{DO_2} dropped when the free-flow device was moved even a small distance away from the face. My group discovered that we could achieve very high F_{DO_2} with simple, relatively inexpensive devices, such as a mask or nasal cannula, in our neonatal model. This is why I have never been a big fan of free-flow oxygen delivery with any type of resuscitation bag. It is highly variable and rather expensive, compared to a simple cannula or mask. I know of hospitals that keep a resuscitator in every room, and they are mostly used to give the patient a “puff” of oxygen as needed (called “wafting” by some authors¹⁹). That seems an expensive way to “waft” oxygen to the patient. I know of other facilities that keep simple small plastic funnels equipped with oxygen tubing for episodic free-flow oxygen delivery. The funnel is simply held inverted over the baby’s face.[‡]

My group also discovered that the flow-inflating bag held the same distance from the face as the corrugated-

‡ The inverted funnel was described as an oxygen-delivery device as far back as the 19th century.²⁰

tubing reservoir of the self-inflating bag produced markedly lower F_{DO_2} . We believe this was because the inner diameter of the patient connector of the bag is so much smaller than the inner diameter of the corrugated tubing.

Ventilation Variability

So why not simply use a flow-inflating bag for all newborn resuscitation or bedside manual ventilation of infants in the intensive care unit? This is certainly being done at centers around the country and the world. I first became concerned about this practice when, over a period of years, I repeatedly observed myself and other clinicians fumbling around trying to maintain positive end-expiratory pressure (PEEP) during manual ventilation with a flow-inflating bag. Most are designed with a hole in the bag, which is occluded with the thumb during exhalation, to create PEEP. After pondering this arrangement, I realized that the actual PEEP delivered is the result of a nearly mystical combination of the flow coming to the bag, the flow exiting the bag through the hole, and the position of my thumb, which of course I could not really hold constant, since I usually had to occlude the hole completely during inspiration. It often took repeated adjustments of the flow to find the right combination of flow rate and thumb occlusion. I was even more dismayed as I discovered in my journeys that some clinicians were using flow-inflating bags without a manometer, thus rendering moot the idea of controlling PEEP in a therapeutic range. Call me crazy, but I think that PEEP assessment via visual inspection of the chest is somewhat unreliable. I gradually became very disenchanted with the flow-inflating bag, despite the fact that my initial training and experience with manually ventilating real patients was with an Ayres-T-piece-style resuscitator, under the loving tutelage of a great Navy anesthesiologist named Pete Conrardy.

My concerns about flow-inflating bags were also heightened as our community became more aware of the causes of iatrogenic lung injury: lung over-distention and lack of PEEP. I speculated that self-inflating bags might be easier to use, since the operator was not managing as many variables at one time. Along with ensuring a patent airway and watching chest rise (or, better yet, using a manometer) when using a flow-inflating bag, you must also manage another complex variable: the relationship between the flow rates into and out of the bag.

These concerns led me and my colleagues to study ventilation variability with self-inflating bags versus flow-inflating bags. In all our studies we used a self-inflating bag equipped with a spring-loaded PEEP valve, and a flow-inflating bag that had a hole for manual control of PEEP. In repeated laboratory scenarios we found that the flow-inflating bag produced more variable V_T and PEEP than the self-inflating bag.²¹⁻²³ These tests were done on

nurses and RTs, and we found the effect in all populations studied. We used manometers with both types of bag.

Other reports have also suggested high ventilation variability with self-inflating bags. Resende et al²⁴ found considerable variability in the ventilation of premature lambs with a self-inflating bag administered by experienced neonatologists. Median V_T was 17.8 mL/kg, and 38% of cases had $V_T > 20$ mL/kg. That study was limited by the fact that no manometer was used and that the bag's automatic pressure-relief mechanism was disabled.

Oddie et al²⁵ reported that the self-inflating bag they tested gave more breaths with excessive pressure than did the flow-inflating bag they tested. But the pressure-relief valve of the self-inflating bag was set higher than that of the flow-inflating bag. The flow-inflating bag tested was the Tom Thumb brand, which is marketed in Europe and has a factory-preset pressure-relief setting. Oddie et al also did not allow the clinicians any visual cues, nor did they use a manometer.

Hussey et al²⁶ reported an in vitro comparison of neonatal ventilation with a self-inflating versus a flow-inflating bag. They reported significantly higher airway pressures with the self-inflating bag. Unfortunately, the "playing field" was not level, since the flow-inflating bag was equipped with a manometer but the self-inflating bag was not; instead it had a preset pressure-relief valve, reportedly set at 40 cm H₂O. Participants were told to target a ventilating pressure of 20 cm H₂O, which of course was more challenging without a manometer. This underscores the need to use a manometer when ventilating a neonate, no matter what type of resuscitator is used.

Mondolfi et al²⁷ reported an in vitro study of self-inflating versus flow-inflating bags, with a lung simulator and a relatively inexperienced pediatric emergency-room staff. Those clinicians performed much better with the self-inflating bag than with the flow-inflating bag. Notably, there was a lot of "excessive" PEEP (defined as > 10 cm H₂O for > 10 s) in the flow-inflating-bag group. That certainly fits my experience and clinical observations about creating PEEP with a flow-inflating bag. Others have reported that it takes more training and experience to become comfortable with a flow-inflating bag than with a self-inflating bag.²⁸

Kanter²⁹ studied several types of clinicians' manual ventilation abilities with a neonatal manikin. Along with the rather pleasant finding that the experienced RTs produced more consistent ventilation than other clinical disciplines, Kanter reported that the self-inflating bag delivered better minute ventilation than the flow-inflating bag. There was an overall tendency to over-ventilate and use excessive pressure. Technical difficulties with the flow-inflating bag resulted in reduced ventilation.

The latter studies highlight a major issue in the debate on bag design. I have little doubt that very experienced clinicians who regularly do manual ventilation can

achieve good results with any style of bag to which they are accustomed. But that is not who is using these resuscitators. They are being used by clinicians with highly variable training and experience. Even clinicians with longevity may do poorly with a bag style they have not been trained to use. Some hospitals depend on agency and temporary contract clinicians to meet episodic spikes in staffing demand, and those clinicians have variable experience and typically very little training and skills-verification in manual ventilation. Also consider the presence of interns and residents in teaching hospitals, and how much training time they have with manual resuscitators. Further consider how seldom some of them actually get to use resuscitators. We seem to be doing a lot less manual ventilation than we used to. The use of closed suction-catheter systems has contributed to this. So has the growing reluctance to disconnect the patient from the ventilator, because we want to avoid zero PEEP and alveolar de-recruitment. So now many clinicians have less experience in manual ventilation. Some of the worst clinical mishaps I have had to deal with in my management career have involved misapplication of resuscitators.

In my opinion, insufficient attention is sometimes paid to the possibility of over-distention in adult populations as well during manual ventilation. Turki et al³⁰ reported that experienced RTs ventilating a test lung with a manual resuscitator produced airway pressures in excess of 100 cm H₂O. We seem to take great pains to limit airway pressure and V_T with mechanical ventilators, but we sometimes pay little attention during manual ventilation with a resuscitation bag.

Other Issues

A long time ago in a galaxy far, far away, I was told that flow-inflating bags are superior to self-inflating bags because they allow the clinician to more deftly *feel* changes in lung compliance.^{31,32} In the anesthesia world this has been called the "educated hand."

One of the earliest descriptions of the "educated hand" was published in 1954, by Cullen et al, and has been used since to promote the idea that an experienced clinician can feel changes in compliance better with a flow-inflating bag than a self-inflating bag.³³ However, it has been known for decades that even experienced anesthesiologists have difficulty maintaining consistent ventilation during manual "bagging."³⁴ Spears et al³¹ showed that only approximately one fourth of anesthesiologists could detect a complete occlusion of the endotracheal tube (ETT) during manual ventilation of a neonatal test lung with a flow-inflating bag. The experienced anesthesiologists detected the changes no more often than did the inexperienced.

Schily et al³⁵ reported nearly opposite findings when they blindfolded and ear-plugged pediatric anesthesiologists and had them ventilate 16 anesthetized and paralyzed neonates prior to abdominal surgery. All auditory signals from the monitors were disabled. The investigators randomly occluded the ETT, and the anesthesiologists were instructed to report every time the ETT was occluded. They concluded that, under certain conditions, > 80% of occluded ETTs can be detected by anesthesiologists with > 8 years of experience. Neither of the latter studies compared the ability to feel compliance changes while using different types of resuscitators.

My group studied clinicians' ability to detect compliance changes by feel, with self-inflating and flow-inflating bags. Experienced RTs specializing in neonatology could not distinguish changes in compliance better with a flow-inflating bag than with a self-inflating bag.³⁶

There are a variety of clinical situations where intubated and non-intubated infants breathe spontaneously through manual resuscitators. Although typically patients do not breath spontaneously through a resuscitator for a prolonged period, the amount of energy (work) required by the patient to move gas through the bag system's series of resistive elements has been of concern to some. Two reports measured resistance through manual resuscitators, and those researchers expressed concern that the resuscitator's valves might impose an unacceptable amount of work on the patient during spontaneous ventilation.^{37,38} While it is beyond the scope of this editorial to address this complex issue, I would like to point out that the speculations about imposed work of breathing need a lot more research to determine how much is too much. In general, it is probably not a good idea to let an infant spontaneously breath through a manual resuscitator for any length of time. If they need prolonged positive-pressure ventilation, they should be on a ventilator. If not, they should be extubated. To my mind, this is not an important consideration in selecting the type of resuscitator.

In terms of limiting the variability of ventilation during manual ventilation, there is newer technology that may offer advantages over flow-inflating or self-inflating bag. The Neopuff (Fisher and Paykel, Auckland, New Zealand) is a flow-controlled, pressure-limiting neonatal resuscitator. The operator controls inspiratory time with the thumb, and the peak inspiratory pressure is controlled by a pressure-relief mechanism. The obvious advantage is that the flow and inspiratory pressure are constant. This appears to produce more consistent ventilating pressure and limits excessive pressure and high PEEP.³⁹ Of course V_T can still vary considerably with the Neopuff,⁴⁰ probably because of variations in the inspiratory time created by the operator's thumb, and poor mask-face seal. However, investigators have reported a danger of higher-than-desired peak inspiratory pressure with the Neopuff if the flow is not set at

the recommended level.⁴¹ In another report, McHale and colleagues reported large V_T variations when various types of clinicians with various levels of experience ventilated a neonatal mannequin with the Neopuff. And the large variations in mean airway pressure and V_T were independent of operator experience. More research needs to be done to determine if the Neopuff really offers neonates an advantage.

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REFERENCES

- O'Donnell CP, Gibson AT, Davis PG. Pinching, electrocution, ravens' beaks, and positive pressure ventilation: a brief history of neonatal resuscitation. *Arch Dis Child Fetal Neonatal Ed* 2006;91(5): F369-F373.
- Wistwell TE. Neonatal resuscitation. *Respir Care* 2003;48(3):288-294.
- American Academy of Pediatrics. Textbook of neonatal resuscitation, 5th edition. 2006;3-12.
- Johnston KL, Aziz K. The self-inflating resuscitation bag delivers high oxygen concentrations when used without a reservoir: implications for neonatal resuscitation. *Respir Care* 2009;54(12):1665-1670.
- Kissoon N, Nykanen D, Tiffin N, Frewen T, Brasher P. Evaluation of performance characteristics of disposable bag-valve resuscitators. *Crit Care Med* 1991;19(1):102-107.
- Corley M, Ledwidge MK, Glass C, Grap MJ. The myth of 100% oxygen delivery through manual resuscitation bags. *J Emerg Nurs* 1993;19(1):45-49.
- Hess D, Spahr C. An evaluation of volumes delivered by selected adult disposable resuscitators: the effects of hand size, number of hands used and use of disposable medical gloves. *Respir Care* 1990; 35(8):800-805.
- Hess D, Hirsh C, Marquis-D'Amico C, Kacmarek RM. Imposed work of breathing and oxygen delivery during spontaneous breathing with adult disposable manual ventilators. *Anesthesiology* 1994;81(5): 1256-1263.
- Kwei, P, Matzelle C, Wallman D, Ong M, Weightman W. Inadequate preoxygenation during spontaneous ventilation with single patient use self-inflating resuscitation bags. *Anaesth Intensive Care* 2006;34(5):685-686.
- Carter BG, Fairbank B, Tibballs J, Hochmann M, Osborne A. Oxygen delivery using self-inflating resuscitation bags. *Pediatr Crit Care Med* 2005;6(2):125-128.
- Godoy AC, Vieira RJ, Vieira Neto RJ. Oxygen outflow delivered by manually operated self-inflating resuscitation bags in patients breathing spontaneously. *J Bras Pneumol* 2008;34(4):212-216.
- Martell RJ, Soder CM. Laerdal infant resuscitators are unreliable as free-flow oxygen delivery devices. *Am J Perinatol* 1997;14(6):347-351.
- Bakr AF, El Attar A. Oxygen concentrations at the rear and front of the bag in bag valve mask devices during oxygenation of neonates. *Resuscitation* 2005;66(2):217-223.
- Dawson JA, Davis PG, O'Donnell CP, Omar F, Kamlin C, Morley CJ. Free-flow oxygen delivery to newly born infants. *Arch Dis Child Fetal Neonatal Ed* 2007;92(2):F132-F134.

15. Laclerc F, Riou Y, Diependaele JF. Oxygen delivery during resuscitation with self-inflating bags: do not forget a simple but important recommendation. *Pediatr Crit Care Med* 2005;6(2):226-229.
16. Niermeyer S, Kattwinkel J, Van Reempts P, Nadkarni V, Phillips B, Zideman D, et al. International guidelines for neonatal resuscitation: an excerpt from the guidelines 2000 for cardiopulmonary resuscitation and emergency cardiovascular care: an international consensus on science. *Pediatrics* 2000;106(3):E29.
17. Nam SH, Kim KJ, Nam YT, Shim JK. The changes in delivered oxygen fractions using Laerdal resuscitator bag with different types of reservoir. *Yonsei Med J* 2001;42(2):242-246.
18. DiBlasi RM, Crotwell D, Salyer J. F_{DO_2} of various oxygen delivery devices during simulated breathing of an infant (abstract). *Respir Care* 2007;52(11):1625.
19. Davies P, Cheng D, Fox A, Lee L. The efficacy of noncontact oxygen delivery methods. *Pediatrics* 2002;110(5):964-967. Erratum in: *Pediatrics* 2006;118(3):1325.
20. Silverman WA. A cautionary tale about supplemental oxygen: the albatross of neonatal medicine. *Pediatrics* 2004;113(2):394-396.
21. Keenan J, Salyer JW, Ashby T, Withers J, Bee N. Manual ventilation technique variability in a pediatric lung model (abstract). *Respir Care* 1999;44(10):1252.
22. Keenan J, Salyer JW, Ashby T, Withers J, Bee N. Ventilation variability using self-inflating and non self-inflating resuscitation bags in a neonatal lung model (abstract). *Respir Care* 1999;44(10):1253.
23. Salyer J, Foubare D. Ventilation variability using flow-inflating versus self inflating manual resuscitators in a neonatal lung model (abstract). *Respir Care* 2005;50(11):1498.
24. Resende JG, Zaconeta CA, Ferreira AC, Silva CA, Rodrigues MP, Rebello CM, Tavares NP. Evaluation of peak inspiratory pressure, tidal volume, and respiratory rate during ventilation of premature lambs using a self-inflating bag. *J Pediatr (Rio J)* 2006;82(4):279-283.
25. Oddie S, Wyllie J, Scally A. Use of self-inflating bags for neonatal resuscitation. *Resuscitation* 2005;67(1):109-112.
26. Hussey SG, Ryan CA, Murphy BP. Comparison of three manual ventilation devices using an intubated mannequin. *Arch Dis Child Fetal Neonatal Ed* 2004;89(6):F490-F493.
27. Mondolfi AA, Grenier BM, Thompson JE, Bachur RG. Comparison of self-inflating bags with anesthesia bags for bag-mask ventilation in the pediatric emergency department. *Pediatr Emerg Care* 1997;13(5):312-316.
28. O'Donnell CP, Davis PG, Morely CJ. Neonatal resuscitation: review of ventilation equipment and survey of practice in Australia and New Zealand. *J Paediatr Child Health* 2004;40(4):208-212.
29. Kanter RK. Evaluation of mask-bag ventilation in resuscitation of infants. *Am J Dis Child* 1987;141(7):761-763.
30. Turki M, Young MP, Wagers SS, Bates JHT. Peak pressures during manual ventilation. *Respir Care* 2005;50(3):340-344.
31. Spears RS, Yeh A, Fisher DM, Zwass MS. The "educated hand". Can anesthesiologists assess changes in neonatal pulmonary compliance manually? *Anesthesiology* 1991;75(4):693-696.
32. Egbert LD, Bisno D. The educated hand of the anesthesiologist: a study of professional skill. *Anesth Analg* 1967;46(2):195-200.
33. Cullen SC, Comroe JH Jr, Brown EB Jr, Beecher HK, Maloney JV Jr. Problems in ventilation: a panel discussion. *Anesthesiology* 1954;15(4):416-435.
34. Woolmer, R. Ventilation during anaesthesia. *Anaesthesia* 1960;15:66.
35. Schily M, Koumoukelis H, Lerman J, Creighton RE. Can pediatric anesthesiologists detect an occluded tracheal tube in neonates? *Anesth Analg* 2001;93(1):66-70.
36. Salyer J, Foubare D. The myth of "feeling" compliance during manual ventilation. (abstract) *Respir Care* 2005;50(11):1512.
37. Hess D, Simmons M. An evaluation of the resistance to flow through the patient valves of twelve adult manual resuscitators. *Respir Care* 1992;37(5):432-438.
38. Mills PJ, Baptiste J, Preston J, Barnas GM. Manual resuscitators and spontaneous ventilation—an evaluation. *Crit Care Med* 1991;19(11):1425-1431.
39. Finer NN, Rich W, Craft A, Henderson C. Comparison of methods of bag and mask ventilation for neonatal resuscitation. *Resuscitation* 2001;49(3):299-305.
40. O'Donnell CP, Davis PG, Lau R, Dargaville PA, Doyle LW, Morley CJ. Neonatal resuscitation 2: an evaluation of manual ventilation devices and face masks. *Arch Dis Child Fetal Neonatal Ed* 2005;90(5):F392-F396.
41. Hawkes CP, Oni OA, Dempsey EM, Ryan CA. Potential hazard of the Neopuff T-piece resuscitator in the absence of flow limitation *Arch Dis Child Fetal Neonatal Ed* 2009; Apr 8. [Epub ahead of print].

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