



Use of self-inflating bags for neonatal resuscitation[☆]

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Abstract

Background: Lung inflation is the most important, and most difficult step in newborn resuscitation. A wide variety of devices are used to achieve lung inflation, but there are relatively few data to guide clinicians in their choice of device.

Methods: We tested the ability of instructors and trained candidates on a newborn life support course to deliver initial inflation breaths to a test lung, using a pressure limited blow-off valve, a 240-ml self-inflating bag and a 500-ml self-inflating bag in sequence.

Results: Use of a 240-ml self-inflating bag was associated with shorter initial inflations of 1.8 s mean (95% CI 1.60–1.99 s), compared with 2.42 s (2.24–2.61 s), 2.40 s (2.08–2.71 s) for 500-ml self-inflating bags and “Tom Thumb” T piece, respectively. Delivery of breaths within a target pressure range of 30 ± 5 cm H₂O was significantly better using a T piece than either self-inflating bag (proportion within target range 0.05 (95% CI 0–0.11), 0.17 (95% CI 0.12–0.23), 0.89 (95% CI 0.83–0.94) for 240-ml and 500-ml self-inflating bags and “Tom Thumb” T piece, respectively. Excessive pressure delivery with both sizes of self-inflating bag was frequent.

Conclusions: These data do not support use of 240-ml or 500-ml self-inflating bags for resuscitation of newborn term infants. A variable pressure T piece blow-off system may be the easiest device to use for newborn resuscitation and the most reliable at delivering desired pressures for set times.

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1. Introduction

Neonatal resuscitation depends on achieving adequate lung inflation. Based on studies from the 1970s and the published Consensus from the International Liaison Committee on Resuscitation (ILCOR), current UK guidance recommends that initial lung inflation pressure in newborn term infants should be 30 cm, sustained over 2–3 s [1–4]. Paediatricians use a range of devices to achieve lung inflation in neonatal resuscitation (table) [5]. Relatively little research is available to guide their choice of device [5].

Devices in use to achieve lung inflation in neonatal resuscitation

240-ml self-inflating bag
500-ml self-inflating bag
“Tom Thumb” variable pressure blow-off valve
“Neopuff” variable pressure blow-off valve
Anaesthetic bag and Ayres T piece

The Newborn Life Support (NLS) course is designed to equip novices in neonatal resuscitation with practical skills and prepare them for clinical practice. It has been administered by the Resuscitation Council of the United Kingdom since 1999 and is similar in its inception to the Newborn Resuscitation programme (NRP) in the United States [4,6]. Instructors are selected by performing well on the course, having significant experience of neonatal resuscitation and an aptitude to teach. All instructors have undergone a 3-day instructor course and further mentored training.

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We set out to test the hypothesis that trained Newborn Life Support candidates and instructors could deliver initial inflation breaths conforming to UK recommendations using the three devices commonly used in our region. We also wished to compare the performance of instructors and trained candidates.

2. Methods

Candidates and instructors attending an NLS course were enrolled voluntarily in the study. They were asked them to deliver “initial inflation breaths as you have been shown on the course” to the apparatus. If candidates sought clarification, it was confirmed that this meant 2–3 s inflations.

Candidates and instructors delivered breaths using each of a self-inflating 500-ml bag with integral 40 cm H₂O blow-off valve (Laerdal Medical, Stavanger, Norway), a 240-ml self-inflating bag with 40 cm H₂O blow-off valve (Laerdal Medical, Stavanger, Norway) and a “Tom Thumb” (Viamed, Keighley, West Yorkshire, UK) blow-off valve set at 30 cm H₂O with oxygen flow of 6 l/min. Breathes were delivered to an isolated test lung which the candidates could not see. Thus, the candidates had no visual clues as to the degree of lung inflation. Between the gas delivery device and the test lung (Ingmar Medical, Liverpool, UK) we placed a Respicap (Allied Health care products, St. Louis, MO) ventilator testing device linked to a laptop computer whose screen was visible only to one of us (S.O.). The ventilator testing device sampled recorded pressure and flow every 200 ms. The compliance of the test lung was varied for each device.

All connections were sealed; the ability of participants to achieve a mask to face seal was not tested.

Data on flow and pressure from the last completely recorded breath of the first four the candidate delivered was selected as representing each candidate’s performance with a device/compliance combination. Each candidate had only one attempt at each device compliance combination. At the analysis stage, a small number of observations (8%) had to be discarded when data review showed that a leak in the experimental setup had occurred invalidating the recordings. In data analysis, a breath was defined as ceasing when there was a persistent absence of inflation pressure. Calculations of breath duration and pressure characteristics were made in a spreadsheet and summary data for each breath analysed in a random effects (repeated measures) model using Stata v. 8.2 (Stata Corp., 2004). This is an extension of a linear regression model that accounts for the expected variation within subject correlation of repeated measures.

3. Results

Ninety-one breaths from 18 subjects (7 instructors, 11 candidates) were suitable for analysis. These comprised 31 using a “Tom Thumb”, 35 breaths using a 500-ml bag and 25 breaths delivered using a 240-ml bag. Results are presented graphically. In Figs. 1 and 2, the left hand column represents experimental breaths delivered by a candidate using a “Tom Thumb” device to a high compliance lung, and columns to the right show the effect of varying one component of the experimental system.

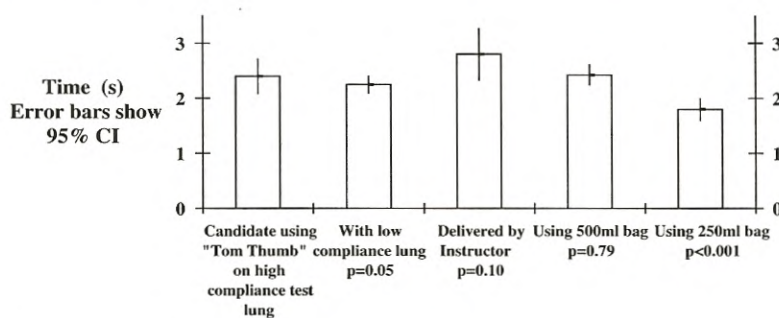


Fig. 1. Effect on duration of inflation breaths (s) by varying device or participant delivering breaths.

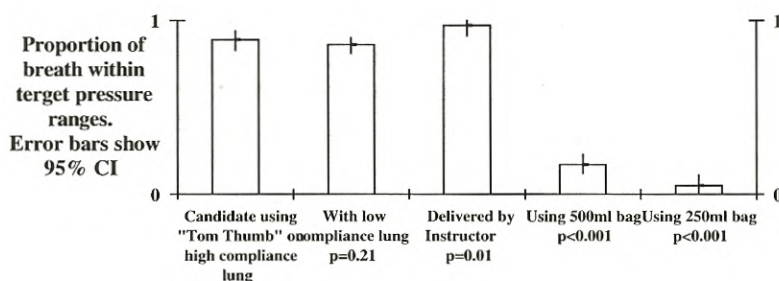


Fig. 2. Effect on proportion of breaths within target pressure range of varying device or participant delivering breaths.

Using a “Tom Thumb” device, candidates achieved a mean inflation time of 2.4 s (Fig. 1). Instructor status, changes to test lung compliance and use of 500-ml bag made no difference to the duration of breaths defined in this way. Use of a 240-ml self-inflating bag was associated with shorter initial inflations of 1.8 s mean (95% CI 1.60–1.99 s), compared with 2.42 s (2.24–2.61 s), 2.40 s (2.08–2.71 s) for 500-ml self-inflating bags and “Tom Thumb” T piece, respectively. Delivery of breaths within a target pressure range of 30 ± 5 cm H₂O was significantly better using a T piece than either self-inflating bag (proportion within the target range 0.05 (95% CI 0–0.11), 0.17 (95% CI 0.12–0.23), 0.89 (95% CI 0.83–0.94) for 240-ml and 500-ml self-inflating bags and “Tom Thumb” T piece, respectively).

The mean proportion of candidate delivered breaths to the high compliance lung using a “Tom Thumb” device within a pressure range 25–34.9 cm H₂O was 0.89 (Fig. 2). Changing the lung compliance made no significant difference although instructor status was associated with a slightly higher proportion reaching target pressures. Use of a 500-ml bag and a 240-ml bag was associated with statistically significantly greater proportions of breaths outside the target pressure range. Additionally, there was a clinical and statistically significant ($p < 0.0001$) difference in the proportion of breaths within the target range when the 240-ml and 500-ml bags were compared.

All breaths with the Tom Thumb were delivered at less than 40 cm H₂O. The self-inflating bags delivered pressures of up to 73 cm H₂O. In 4 of 35 breaths using a 500-ml bag and 15 of 25 breaths delivered using a 240-ml bag delivered pressure exceeded 39.9 cm H₂O at some point, despite the presence of a functioning blow-off valve. The difference in proportions of excessive pressure breaths was clinically and statistically significantly worse using a 240-ml bag compared to a 500-ml bag ($p < 0.0002$). There was no difference in the proportion of self-inflating bag breaths that were of excessive pressure between instructors and candidates (2/12 versus 2/19 for 500-ml bag ($p = 0.62$), 10/16 versus 5/9 for 240-ml bag ($p = 0.73$) for instructors and candidates, respectively).

4. Discussion

This study has demonstrated that neither candidates nor instructors on a newborn life support course are able to deliver breaths conforming reliably to standard criteria when using self-inflating bags. Although breaths delivered with a 500-ml self-inflating bag were of adequate duration much of inspiration was outside the target pressure range. Worryingly we have shown that in relatively stress-free laboratory conditions, where a self-inflating bag is used, both instructors and candidates frequently deliver breaths of excessive pressure according to current guidelines.

The participants in our study were those who would actually be carrying out neonatal resuscitation both as first and second line providers. We do not consider that lack of visual

feedback from chest wall movement (which may not be easily seen) affected the ability of our participants to use the devices. In using laboratory conditions, without asking participants to provide a seal between mask and face and clear verbal instructions, we probably optimised the performance of both candidates and instructors. We may, therefore, have overestimated the likelihood of delivering optimal inflation breaths.

The measurement device we used provided a fairly crude output, sampling only every 200 ms. We anticipate that more frequent sampling of the inflations would have shown more, rather than less, variation from the desired breathing characteristics. However, the clinical relevance of this is unknown.

Our definition of target pressure range was fairly broad. Further analysis (data not shown) considering a target pressure range of 30 ± 3 cm H₂O produced results, which were not markedly different from those presented.

The study takes no account of the dynamic compliance of the newborn infant's lung and the variable compliance of our test lung could not reflect the in vivo situation accurately. Additionally, we used a sealed system and in vivo leaks may occur that will protect the newborn lung from higher pressures, particularly when a mask is in use. However, resuscitation devices should deliver inflation breaths in as consistent and predictable a way as possible.

This study was performed with self-inflating bags with 40 cm H₂O blow-off valves. It is now possible to purchase bags with 35 cm H₂O valves. However, even where bags have more appropriate blow-off valves, inappropriate use can override these as our data shows. All practitioners must be aware that such blow-off valves are flow sensitive, and therefore to a degree operator dependent. Furthermore, as well as providing at times excessive pressures, our subjects were not able to provide sustained pressures in or near the target range.

Longer low pressure rather than short high pressure inspiratory times are widely accepted as being appropriate for resuscitation, at least in term infants [2]. It may be argued that while 240-ml bags delivered statistically significantly shorter breaths, the clinical difference was not relevant and that shorter inspiratory times are as effective. Even if we disregard the technical limitations and laboratory conditions of this study and accept this argument, the findings that self-inflating bags of either size were frequently associated with inconsistent and at times very high inflation pressures remain pertinent.

Finer's group studied anaesthesia bags, 500-ml self-inflating bags and the “Neopuff” device [7]. They asked subjects to attempt a 5 s inflation of a manikin via a face mask, which is rather longer than usually recommended [4,8]. Our work focussed on instructors and candidates' ability to deliver inflations using three devices including a 240-ml bag, which is still in use in many units [5]. As well as showing the relative imprecision of the 240-ml bag, our results are consistent with those shown in the figures in the paper by the Finer group.

Our results are entirely consistent with those of Field et al. [9]. They found significantly better tidal volumes with the 500-ml Laerdal bag than with the 240-ml Laerdal bag in 10 real resuscitations, but did not consider a T piece device such as the “Tom Thumb”, nor the ability of inexperienced operators. The authors aimed to achieve sustained inflations, but although the smaller bag appears to have delivered shorter breaths in clinical practice the paper gives little information as to the statistical significance of this finding.

In a recent publication, Hussey et al. showed similarly heterogeneous maximum peak inspiratory pressure delivery using self-inflating bags to those shown in our study [10]. It is especially concerning that in both our study and that of Hussey, experienced resuscitators seemed to generate excessive pressures with the self-inflating bag as often as less experienced operators.

Current recommendations suggest that long inspiratory times are optimal for initial inflation breaths. Detailed review of this subject is beyond the scope of this paper, but the work of Vyas et al. suggests that a prolonged inflation will result in greater functional residual capacity after initial inflation breaths have been given [2].

5. Conclusions

Our work does not support the use of the infant (240-ml) Laerdal bag for newborn resuscitation and suggests that even the paediatric (500-ml) Laerdal bag should be used with caution. We believe this work supports wider use in term infants of a variable pressure blow-off system such as the “Tom Thumb” or the “Neopuff”, which also provides for variable positive end expiratory pressure. Such devices can only however be relied on when a secure gas supply can be provided, which may not be the case in developing health care systems or out of hospital situations. We did not set out to test the ability of providers to deliver lower pressures with any of the devices. However, the lack of precision in

delivering inflation breaths that we have detected provides little reassurance that recommendations for lower inflation pressures in very preterm infants can be delivered using self-inflating bags in clinical practice.

Conflict of interest

Sam Oddie and Jonathan Wyllie both have longstanding voluntary involvement in Newborn Life Support Course training.

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