We have previously reported the effect of different circuit types in 
2002, Maxwell and Ellis 2003). In this paper we report the results for 
a subset of subjects in that study where we also examined the 
effect of maintaining bag compression during expiration with the 
Mapleson-C circuit on peak expiratory flow rate and I:E flow rate 
ratio.

Method

Subjects were recruited through flyers sent to principle referral 
and major metropolitan hospitals in New South Wales (NSW 
Health 1998) and posted on noticeboards at the School of 
Physiotherapy, University of Sydney. Subjects were eligible to 
participate in the study if they were experienced cardiothoracic 
physiotherapists or had used manual hyperinflation regularly in the 
past, but may have not been in clinical practice in the last 12 months, 
were eligible to participate. 
All subjects received an information sheet and signed a consent 
form. Ethics approval was obtained from the Human Ethics 
Committee, University of Sydney.

As part of the larger study all subjects performed manual 
hyperinflation with rapid release using three different circuits 
(Air Viva 2\(^\text{TM}\), Mapleson-C with the CIG valve\(^{\text{®}}\) and Mapleson-
F) and delivering two different target volumes (1.4 litres for all 
three circuits and empty-the-bag for the Mapleson circuits) in 
random order. A two litre antistatic rebreathing bag\(^{\text{®}}\) was used for 
the Mapleson circuits. The Air Viva 2 was used as a self-
inflating circuit and the gas flow to the Mapleson circuits was 12 
l/min. Inspiration was performed over three seconds timed to a 
metronome. No instruction as to how to perform expiration was 
given except that subjects were asked to perform valve/bag 
release as they would to enhance secretion clearance. Each trial 
lasted two minutes.

It was noted that the first nine subjects of the primary study all 

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**Introduction**

Manual hyperinflation is used by physiotherapists to assist 
secretion clearance in intubated patients. While the use of ‘rapid 
release’ for the expiratory phase has been advocated as the 
optimal technique there are a number of different circuits used in 
Australia and overseas (Hodgson et al 1999, Jones et al 1992b), 
and what constitutes rapid release could vary depending on the 
circuit type. Circuits designed primarily for resuscitation, such as 
the Air Viva 2, Laerdal, and Puritan MRB2, have inbuilt, one-way 
valves that prevent rebreathing, and are not meant to be 
manipulated. Thus rapid release with these circuits involves 
release of the bag. In contrast, Mapleson-B and C circuits (which 
can also be used for manual hyperinflation) are derived from 
aesthesia circuits which have valves that can be manipulated 
and, during expiration, the operator may or may not maintain bag 
compression. In this situation rapid release could refer to release 
of the valve only or release of both the valve and the bag. Both 
techniques have been observed in Australia by the authors and, 
although there a number of papers published where the 
Mapleson-B or C circuits have been used for manual 
hyperinflation (Barker and Adams 2002, Clapham et al 1995, 
Clarke et al 1999, Clement and Hübisch 1968, Hila et al 2002, 
Jellema et al 2000, Mccarren and Chow 1996, Ntoumenopoulos 
Singer et al 1994, Windsor et al 1972), few papers describe 
whether bag compression was maintained (Berney and Denelhy 
2002, Jones et al 1992a, Jones et al 1991, Maxwell and Ellis 

We have previously reported the effect of different circuit types 
and rapid release on flow profiles during manual hyperinflation 
(Maxwell and Ellis 2003). In this paper we report the results for 
a subset of subjects in that study where we also examined the 

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**Key words:** Intensive Care; Pulmonary Ventilation; Physiotherapy; Respiration, Artificial
chose to release the bag and the valve of the Mapleson-C circuit during expiration with rapid release. This was different from the first author's experience with this circuit and therefore the last six subjects were asked to also perform rapid release with and without bag compression at the two target volumes. Subjects were given time to familiarise themselves with the equipment, to practise with the circuits (including release technique for the Mapleson-C), delivering the two target volumes, and allowed to rest for as long as they wished between each trial.

The bagging circuit was connected in series to a pneumotachometer and a test lung. The compliance of the ‘lung’ was set at 0.05 l/cmH2O, and the resistance of the ‘trachea’ and ‘main bronchi’ was 2.33 ± 5% cmH2O at a flow rate of 1.0 l/sec. A custom-designed data acquisition and analysis system, used to sample the signal from the pneumotachometer, calculated volume delivered and recorded peak inspiratory and expiratory flow rates (Maxwell et al. 2001). The peak inspiratory to expiratory flow ratio was then calculated manually. Data were analysed with repeated measures ANOVA and are reported as mean (SEM).

**Results**

The subjects included one graduate research student, one academic, and four clinicians/clinical educators. Four subjects were female. Time since graduation ranged from 3 to 22 years. All subjects had experience with the Air Viva 2, two with the Mapleson-C, and four with the Mapleson-F. All subjects chose to release both the bag and the valve when first asked to perform rapid release with the Mapleson-C circuit, therefore the trials maintaining bag compression always followed these trials. The order of the volume delivered reflected the randomised order of the larger trial. As randomisation of the order of maintaining or releasing the bag could not be achieved within the design of the larger study, a regression analysis was performed for the larger study (n = 15) to examine if there was an effect on PEFR due to familiarity with the circuit, or an order effect for which of the two target volumes was delivered first. Familiarity with the circuit had no significant effect at either the 1.4 litre (0.09 l/sec, 95% CI -0.26 to 0.46, p = 0.56) or empty-the-bag targets (0.06 l/sec, 95% CI -0.35 to 0.47, p = 0.75). The effect of the order of volume delivered was -0.30 l/sec (95% CI -0.65 to 0.04, p = 0.08) and 0.17 l/sec (95% CI -0.22 to 0.57, p = 0.36) for the 1.4 litre and empty-the-bag targets respectively.

There was no significant difference between maintaining compression or releasing the bag at the 1.4 litre and empty-the-bag targets for volume delivered (1.49 (0.02) vs 1.44 (0.03) l, p = 0.31) and 2.05 (0.17) vs 1.93 (0.09) l, p = 0.57 respectively) and PIFR (1.00 (0.08) vs 1.00 (0.05) l/sec, p = 1.00 and 1.25 (0.03) vs 1.34 (0.05) l/sec, p = 0.30 respectively; see Figure 1). PEFR was reduced by maintaining bag compression during expiration (1.54 (0.08) vs 2.00 (0.07) l/sec and 2.02 (0.14) vs 2.29 (0.08) l/sec for the 1.4 litre and empty-the-bag targets respectively), but this was only statistically significant at the 1.4 litre target (p = 0.008).

All trials produced I:E flow rate ratios of less than 0.9. However, maintaining bag compression increased the ratio. The effect was significant at the 1.4 litre target but not for the larger volume (0.65 (0.04) vs 0.50 (0.02), p = 0.02 and 0.63 (0.04) vs 0.59 (0.04), p = 0.49 respectively).

**Discussion**

Maintaining bag compression during expiration significantly reduced PEFR and increased the I:E flow rate ratio at the 1.4 litre but not for the empty-the-bag target for the Mapleson-C circuit with the CIG DF655 valve in this test lung model. Although only a small number of subjects participated in this arm of the larger study, the subjects were representative of those in the larger study.
group with respect to current employment, previous familiarity with the circuits, and PEFR generated when performing rapid release with the Mapleson-C circuit without bag compression. Based on this, the findings from the regression analysis, and the fact that the difference made by maintaining bag compression at the 1.4 litre target was clearly significant, we believe that maintaining bag compression does reduce PEFR and increase the I:E flow rate ratio at this volume. Although difference in PEFR was not statistically significant for the empty-the-bag target, there was some reduction with maintaining bag compression. This study highlights the importance of clearly documenting operator performance during manual hyperinflation so that studies are reproducible.

One clinical implication of not maintaining bag compression during expiration with a Mapleson-B or C circuit is rebreathing of carbon dioxide, as some of the patient’s exhaled breath will return to the anaesthesia bag and connecting tubing. The amount of rebreathing that may occur is dependent on the fresh gas flow rate to the circuit, with a flow of at least twice minute ventilation recommended (Barash et al 1992). The only study to report the effect of manual hyperinflation on carbon dioxide level found no significant change (Clarke et al 1999). A Mapleson-C circuit was used in the study but unfortunately the authors did not report if compression of the bag was maintained, nor the gas flow rate to the circuit. Physiotherapists who perform manual hyperinflation without bag compression during expiration need to consider the potential effect of gas flow rate to the circuit and required minute ventilation.

Conclusion

Maintaining bag compression during expiration can influence PEFR when using the Mapleson-C circuit and CIG DF655 valve in a test lung model. This was statistically significant at a 1.4 litre but not at an empty-the-bag target. Both release techniques produce an I:E flow rate ratio that meets theoretical requirements to assist secretion movement.

Physiotherapists need to be aware that differences in the performance of manual hyperinflation may affect the PEFR generated but this needs to be confirmed in the clinical setting. The effect of variation in performance on other outcomes such as carbon dioxide levels also requires further investigation.

Footnotes

(a) CIG Medishield (b) CIG Medishield, CIGDF655 (c) Ohmeda, Ref 372762 (d) Hans Rudolph Inc., Kansas City, model 3813 (e) Vent Aid’ TTL Test Training Lung’, Michigan Instruments Inc.

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