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Peak expiratory flow rates produced with the Laerdal and Mapleson-C bagging circuits

This study compared the peak expiratory flow rates (PEFR) at different inspiratory pause pressures (IPP) produced by the Mapleson-C circuit and the Laerdal self-inflating resuscitator. The difference in PEFR produced by the two circuits was significantly different at the lowest and the highest IPP studied (13 and 38cm H_2O). The greatest differences in the mean expiratory flow rates produced was, however, only 0.07 litre sec $^{-7}$. The authors suggest that the choice of bagging circuit should depend on the experience and familiarity of the therapist with the circuit.

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Manual inflation of the lungs is a technique used for optimising arterial oxygen content and hyperinflation of the alveoli. It is suggested that this technique can increase arterial oxygen content, correct pulmonary atelectasis and increase movement of secretions towards the central airways (Clement and Hubsch 1968, Webber 1990). During respiratory physiotherapy of an intubated patient, the therapist often uses a bagging circuit to inflate the patient's lungs with a large tidal volume, then suddenly releases the bag to create a fast expiratory flow rate for effective secretion mobilisation (Webber 1990). This technique simulates a cough – or more correctly, a huff – as the glottis remains open. An earlier study using a test lung showed that at an inspiratory pause pressure (IPP) of 40cm H_2O, a Laerdal circuit (Laerdal Medical Ltd UK) could produce an expiratory flow rate of 3.75 litre sec^{-1}, and a Mapleson-C circuit could produce an expiratory flow rate of 2.9 litre sec^{-1} (Jones et al 1991). The ability of the bagging procedure to produce such high flow rates in vivo has not been reported.

The choice of the bagging systems employed in different intensive care units appears to be a subjective decision based upon individual ICU staff preference. A recently published survey (Jones et al 1992) revealed that the bags commonly used for manual inflation by physiotherapists in the United Kingdom, Australia and Hong Kong are: the Hope bag, the Ambu self-inflating bag, the Mapleson-C circuit and the Laerdal silicone resuscitator. The Mapleson-C circuit is a system made up of a two-litre anaesthetic inflating reservoir bag attached to an expiratory valve, with the fresh gas inlet in between (Atkinson et al 1987). The Laerdal silicone bag is designed in such a way that excess gas-inlet flow to the inflation bag is vented to atmosphere (or the reservoir bag). This minimises the risk of over-inflation of the lung with resultant barotrauma, and the incidence of a significant decrease in venous return is reduced. These risks are compensated for in the Mapleson-C circuit only if the expiratory pressure relief valve is carefully adjusted. A separate pressure limiting device is incorporated into the child and infant models in the Laerdal bag. This limits the maximum peak pressure generated in the patients' lungs. The Laerdal resuscitator is therefore inherently safer for use by staff of variable experience.

The aim of this study was to measure and compare the peak expiratory flow rates (PEFR) produced in sedated intubated patients with the Mapleson-C circuit and the Laerdal self-inflating resuscitator at different inspiratory pause pressures.

Method

Thirty patients aged between 11 and 79 years, who required mechanical ventilation through either a nasotracheal or an endotracheal tube (internal diameter 6.5 to 8.5mm), were studied. All patients were sedated with a morphine infusion of 2 to 4mg min^{-1}. Tracheal suctioning was performed on each patient before the investigation, to minimise airway resistance caused by secretions in the large airways. The

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patients were randomly divided into two groups, each receiving two sessions of the bagging procedure. Group I received bagging with the Mapleson-C circuit during the first session and with the Laerdal bag in the second session. The procedures were reversed in Group II.

In Group I, a Mapleson-C breathing system consisting of a Heidbrink MIE SuperLite 7003 expiratory valve and a 2 litre antistatic re-breathing bag (BS 3352, Warne Surgical Products Ltd UK) was attached to an autospirometer (AS-500, AutoSpiro, Minato Medical Science Co. Ltd Japan), a pressure manometer (Magnehelic, Dwyer Instruments Inc. USA), and the patient's endotracheal tube (Figure 1). The Magnehelic manometer displayed pressure as inches H_2O. All pressure variables were subsequently converted to cm H_2O. A constant oxygen flow rate at 12 litre min^{-1} (a rate commonly used by the authors in clinical practice during the bagging of an adult patient) was delivered to the breathing circuit. The expiratory valve (Figure 2) was adjusted to allow the gas to fill the bag at such a rate that 12 breaths could be delivered to the patient per minute. The bag was squeezed to generate an inspiratory pause pressure (IPP) of 13cm H_2O of pressure measured on the manometer and then suddenly released. The PEFR was measured by the autospirometer. The patient was then disconnected from the circuit and mechanical ventilation recommenced. This whole procedure was repeated five times. Five readings were considered sufficient as successive readings varied by less than 1 per cent from the initial recordings.

Using the same technique, PEFR measurements were repeated at each IPP of 20, 25, 31 and 38cm H_2O. All the above measurements were then duplicated in the same patient with the Laerdal resuscitator bag.

It was noted that at lower inspiratory pause pressures, the expiratory valve of the Mapleson-C circuit was in a more open position to avoid generation of a higher pressure than desired. When generation of a higher IPP was required, this valve was in a more closed position. To allow a fast PEFR, the valve was opened quickly at the same time as bag release during expiration. This was performed with each different IPP.

In Group II, patients received bagging with the Laerdal circuit first and then the whole procedure was repeated with the Mapleson-C circuit.

Data were analysed with the SPSS PC+ statistics program, using students paired *t*-tests and significance level was $p < 0.05$. Data are presented as means (±Standard Deviation) unless otherwise stated.

Table 1.
Mean peak expiratory flow produced by the two circuits at different pressure gradients. Values are in litres per second (+SD).

	Mapleson-C circuit	Laerdal circuit	*p* value
13cm H_2O	0.66 (±0.20)	0.70 (±0.17)	0.034*
20cm H_2O	1.04 (±0.25)	1.07 (±0.17)	0.260
25cm H_2O	1.22 (±0.27)	1.23 (±0.19)	0.909
31cm H_2O	1.44 (±0.30)	1.42 (±0.23)	0.579
38cm H_2O	1.67 (±0.38)	1.60 (±0.30)	0.038*

* $p < 0.05$

Results

The results demonstrated an increase in PEFR with an increasing IPP for both circuits (Figure 3). At an IPP of 13cm H_2O, the mean PEFR produced by the Laerdal circuit was significantly higher than that produced by the Mapleson-C circuit ($p < 0.05$). However, at 38cm H_2O IPP, the Mapleson-C system produced a significantly higher flow rate than the Laerdal circuit ($p < 0.05$). The difference in the mean PEFR between the two circuits was not significant at 20, 25, and 31cm H_2O.

The standard deviations of the PEFR produced by the Mapleson-C circuit were consistently higher than those of the PEFR produced by the Laerdal bag (Table 1).

Discussion

Manual hyperinflation (also known as bagging or bag squeezing) is often used with chest vibration to assist with the removal of secretions in intubated patients (Webber 1990). During the bagging procedure, the physiotherapist inflates the patient's lungs with a large tidal volume establishing a large alveolus-to-mouth pressure gradient. The normal physiological expiratory flow rate is determined by the alveolus-to-mouth pressure gradient and the airway resistance (Nunn 1987). If the bag is released quickly by the therapist, the sudden drop in the pressure gradient will create a fast expiratory flow rate in the airway. According to Selsby and Jones (1990), detaching the mucus from the mucociliary lining requires a mist flow, and mist flow occurs at flow velocities of greater than 2500cm sec^{-1}. A high expiratory flow rate is therefore believed to assist in generating mist flow and in shifting the secretion towards the central airways (Webber 1990). During the end inspiratory phase of the bagging procedure, the positive pressure can be momentarily held by maintaining the bag in the squeezed position. This pressure measured by a manometer attached to the bagging circuit is the inspiratory pause pressure (IPP) of the respiratory cycle. In accord with the in vitro study (Jones et al 1991), the result of the present study showed an increased PEFR with an increased IPP.

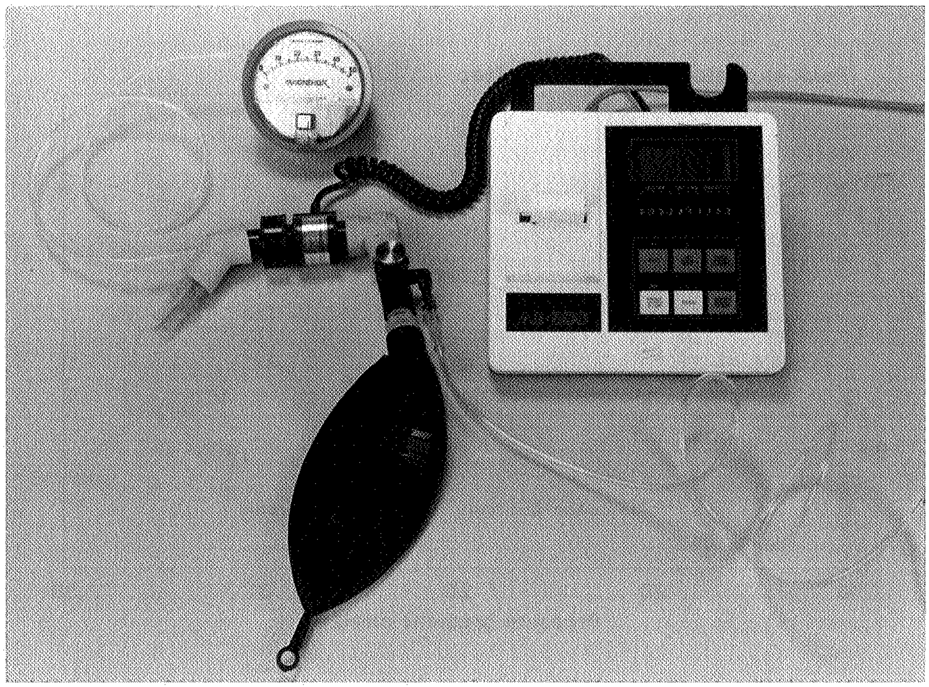

Figure 1.
Mapleson-C circuit attached to the autospirometer (to the right of the reservoir bag) and manometer.

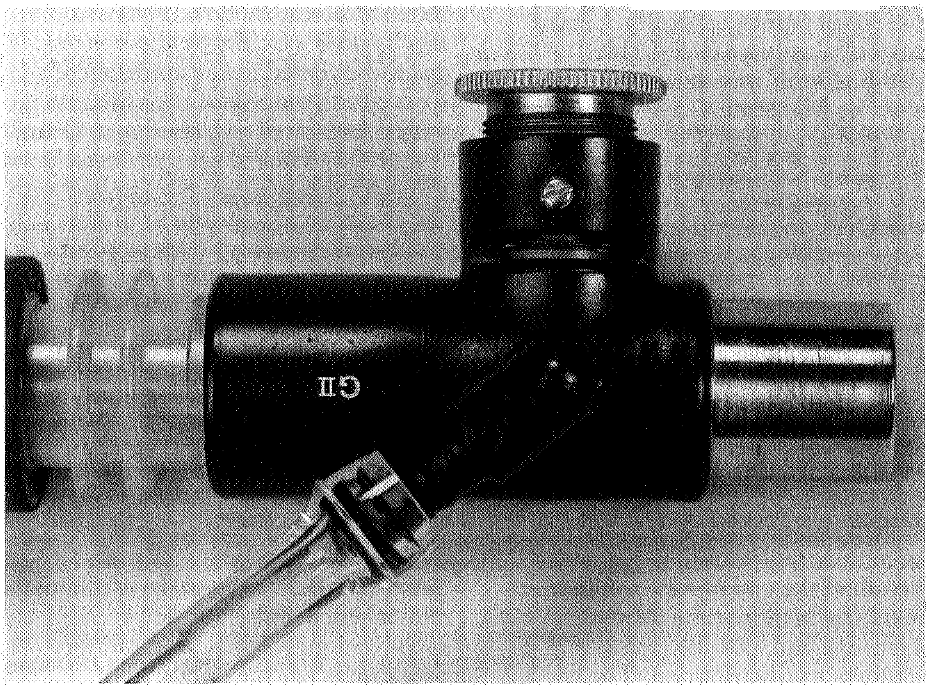

Figure 2.
Heidbrink expiratory valve in the Mapleson-C circuit.

However, the difference in the PEFR produced by the two circuits showed statistical significance only at the two extremes of the inspiratory pause pressures 13cm H_2O and 38cm H_2O. The difference was considered to be clinically insignificant throughout.

Expiratory flow rate can be affected by the fresh gas flow, the rate at which the bag is released, the resistance in the expiratory valve, the chest wall and lung recoil and the airway resistance of the patient. The dynamic relationship between expiratory flow rate, airway anatomy and the visco-elastic properties of mucus are complex. It is impossible to standardise or control the lung mechanics in different patients during two different bagging sessions. To minimise interpatient variation, the present study used the same patient as the control for each bagging circuit. Suctioning was performed five minutes before each bagging procedure to minimise the effect of secretions and suction on airway resistance.

It should not be possible for fresh gas to mix with expired gas with the Laerdal circuit, and therefore the fresh gas flow should have little effect on the expired gas flow rate. In the Mapleson-C circuit attached to a re-breathing bag, however, the fresh gas flow rate can significantly influence expired flow. This was most apparent when the IPP was low, as only a small volume of air was required to be delivered to the patient at low IPP. The re-breathing bag was therefore partially filled with some gas before the start of expiration. This may decrease the mouth-to-bag pressure gradient, thus retarding the expiratory flow in the circuit. This may explain why, at 13cm H_2O, the PEFR produced by the Laerdal bag was significantly higher than that produced by the Mapleson-C system.

The rate at which the bag is released may have the effect of retarding the expiratory flow in the circuit. Although the study was performed by the same physiotherapist, who is experienced with the bagging procedure, it was not possible to avoid some variation in the rate at which the bag was released.

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This was particularly pertinent when the Heidbrink expiratory valve of the Mapleson-C circuit had to be adjusted for different inspiratory pause pressures to avoid over filling of the bag. This factor, however, did not affect the Laerdal bag. The silicone material in the Laerdal bag allowed the bag to self-inflate at a constant rate after each compression and, as expected, the flow variation in terms of standard deviation values produced by the Laerdal bag were much lower than that of the Mapleson-C circuit.

The difference in the resistance of the expiratory valves in the two circuits may also explain the differences in the expiratory flows produced. The fishmouth expiratory valve in the Laerdal bag allows the expired gas to escape to the atmosphere with minimal resistance ranging from 0.16 to 1.31cm H_2O (Dorsch and Dorsch 1975). In contrast, the Heidbrink expiratory valve in the Mapleson-C system offers a much higher resistance which ranges from 1 to 40cm H_2O (Russell 1983) and allows the expired gas to flow back into the bag, thus retarding expiratory flow (Jones et al 1991).

The properties of the two circuits used are different. It was difficult to maintain a high and stable inspiratory pause pressure in the Mapleson-C circuit and to control the speed of expiratory valve release in the self-inflating Laerdal bag was almost impossible. These made standardisation of the bagging technique of the two circuits difficult. However, this study aimed at investigating and comparing the clinical performance of the two different circuits in regard to the PEFR produced.

The study demonstrated a significant difference in the expiratory flow rates in the two circuits at IPP of 13cm H_2O and 38cm H_2O. Standard deviations of the mean PEFR produced by the Mapleson-C circuit were consistently greater at all pressure gradients when compared with those of the Laerdal circuit. The standard deviations for both circuits were, however, highest at IPP of 38cm H_2O, making interpretation of the results at this IPP more difficult.

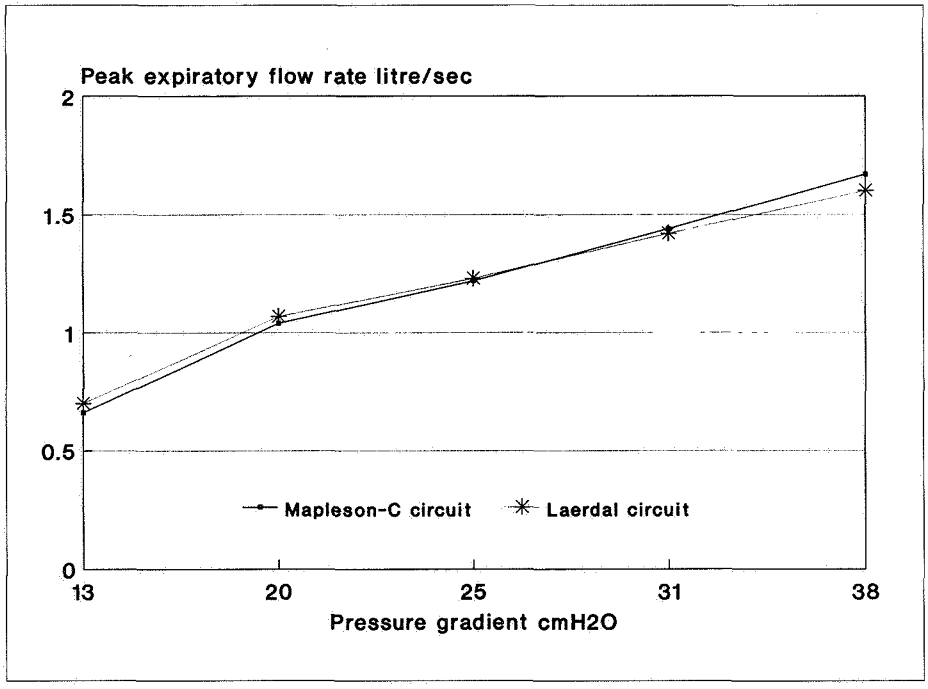

Figure 3.
PEFR produced by the two circuits at different pressure gradient.

An IPP of 38cm H_2O is often used by physiotherapists, especially when a high tidal volume is desirable. Although this investigation showed that the Mapleson-C system produced a significantly higher PEFR statistically, the greatest difference in PEFR was only 0.07 litre sec^{-1} and is therefore unlikely to have any clinically relevant effect on secretion mobilisation.

The thin rubber used in the antistatic re-breathing bag allows experienced users a more accurate assessment of the patient's thoraco-abdominal compliance, which varies not only between patients, but also between treatments in the same patient. This system also enables the physiotherapist to momentarily hold the patient's breath at the end of lung inflation, resulting in more time for gas exchange and, possibly, a more uniform gas distribution. The re-breathing bag used in the Mapleson-C circuit is also larger, which is sometimes necessary to ensure adequate alveolar expansion in patients with large lung volumes. The Laerdal bag nonetheless permits a more reliable expiratory flow. Furthermore, this bag has a facility to allow excess gas to be vented to the atmosphere (preventing the risk of overinflation with the inspired gas, see figure 4) and is therefore safer to use, particularly for therapists who are not familiar with the control and adjustment of the Heidbrink valve in the Mapleson-C circuit.

Conclusion

The Laerdal bag produced a significantly higher peak expiratory flow than the Mapleson-C circuit at an IPP of 13cm H_2O. The reverse was true at 38cm H_2O IPP. The greatest difference in the PEFR produced by these circuits was only 0.07 litre sec^{-1}, and therefore is likely to have minimal clinical effect on secretion mobilisation. A fast peak expiratory flow rate is not the only goal of bagging or determinant of secretion mobilisation and there are various

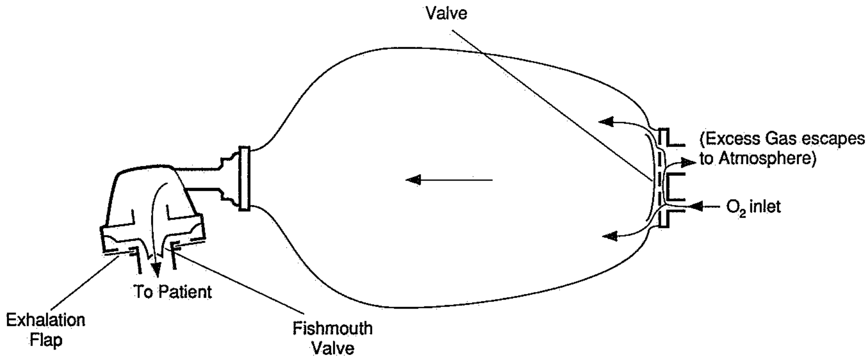

Figure 4.
A schematic diagram showing the safety device of the Laerdal bag.

reasons supporting the use of either of the two breathing circuits. The choice is mainly determined by the familiarity of the therapist with a particular circuit. As the Laerdal bag is easier and safer to use, and produces a more reliable expiratory flow, the authors recommend this bag to therapists who are less experienced with the bagging procedure.

Secretion mobilisation is one of the important aims in respiratory physiotherapy and further investigation of the factors facilitating secretion mobilisation are required.

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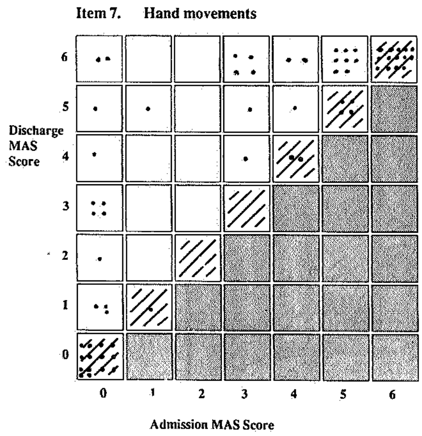
Correction



One of the figures included in the original article by Catherine Dean and Fiona Mackey, Motor assessment scale scores as a measure of rehabilitation outcome following stroke, which was published in the *Australian Journal of Physiotherapy*, Volume 38, Number 1, contained an error.

The correct version of item 7, Figure 2, produced here, has two dots at the grid position 4,4. These dots were missing from the version printed on page 33. The mistake was made at final page make-up stage.