AIRWAY PRESSURE CHANGES DURING "BAG SQUEEZING"*

I. HACK†, A. KATZ,† C. EALES, B.Sc. (Physiotherapy) (Witwatersrand)‡

SUMMARY

Pressure data during controlled ventilation on a ventilator, "bagging" and slow "bagging" are reviewed. The technique for effective "bagging" is suggested.

OPSOMMING

Data omtrent drukke gedurende gekontroleerde ventilasie terwyl pasiënte met 'n ventilator behandel word, "bagging" en stadige "bagging" word nagegaan. Die tegniek vir doeltreffende "bagging" word voorgestel.

INTRODUCTION

A study was done to clarify and understand the very widely used physiotherapeutic technique of "bag-squeezing". It was attempted to establish the relevance of the rate of pressure change which occurs during "bag-squeezing" compared with the tidal ventilation of a patient on a ventilator. From a physiological point of view, the following were also investigated: relative dangers, indications and contra-indications and the appropriate technique of using the self-inflating bag.

The Ambu-bag is a self-inflating, manually operated bag consisting of an inner lining of natural rubber and an outer covering of Neoprene. The outer lining allows for the automatic return of the bag to its original shape after compression. Attached to the bag is a one-way non-rebreathing valve. On compression of the bag, air is directed through the valve to the patient and during expiration and release of the bag the expired air is allowed out into the atmosphere with very little, if any, resistance thus preventing rebreathing into the bag. The volume delivered by most bags is up to 1,2 to 1,3 litres when compressed maximally. On normal compression, the bag yields about 600 - 800 ml. If required, a positive end expiratory pressure (PEEP) valve can be attached to the bag, which can maintain a PEEP of up to 10 cm water. Air, which may be enriched with oxygen, passes from the bag through the non-return valve via the connector tubing to the intubated patient (either endotracheal tube or tracheostomy).

"Bag-squeezing" is a manual technique for hyperinflation of the lungs which is used extensively in intensive care units by physiotherapists. It is used in conjunction with chest manipulations (vibrations, shaking, rib springing) and suctioning.

Indications for the use of an Ambu-bag

Resuscitation

In combination with a simple face mask for any form of respiratory failure until a definitive airway has been established. Once the endotracheal or tracheostomy tube is in situ, "bagging" may be continued — the bag now being attached directly to the intubation tube. For the inexperienced operator, mouth to mouth resuscitaion is probably a safer method.

Inability to cough

"Bag-squeezing" is used in conjunction with suctioning to stimulate a cough reflex. After "bagging" the expiratory phase of respiration is assisted with manual compression or vibration of the thorax in order to gain a more forceful expiration and to aid removal of secretions. For example, when a patient on elective pentothal loses his cough reflex, "bagging" and vibrations are used during treatment to simulate a cough and move the secretions.

Reinflation

Reinflation of microatelectatic areas after suctioning.

Cough production

Production of an efficient cough where the lung secretions are more difficult to remove because of intubation.

Loosening secretions

"Bag-squeezing" may move the warm saline which is injected into the endotracheal or tracheostomy tube into more distal airways and around the alveolar walls, thus loosening secretions.

Limited respiratory effort

"Bagging" ensures periodic hyperinflation of the lungs, as in spontaneous deep breathing.

Ventilator malfunction or when ventilators are being cleaned

The patient is artificially ventilated using the self-inflating bag.

Contraindications for the use of the Ambu-bag

Patients with poor circulation and low cardiac output

An undesirable depression of the cardiac output may result because of the positive pressure generated in the thorax.

Pneumothorax, intercostal drain or bronchopleural fistula

In the patient with an undrained pneumothorax, a clamped intercostal drain or in the case of a bronchopleural fistula, because the increased airway pressure could lead to a tension pneumothorax.

Low haemoglobin

In patients with a low haemoglobin level who do not have a sufficient oxygen-carrying capacity of the blood. Hyperinflation of the lungs in an attempt to improve blood oxygenation would serve no useful purpose.

Bronchospasm

In severe bronchospasm, the very high intrathoracic pressures created, could increase the bronchospasm.

RELATIVE CONTRAINDICATION FOR THE USE OF AN AMBU BAG

In patients with multiple rib fractures, where "bagging" could dislodge the bones at the fracture site with resultant piercing of a lung. In this case a suggested tidal volume of 600 - 800 ml should be used for "bagging".

Complications and Dangers

Pneumothorax

Generation of very high inspiratory pressures could result in the rupture of alveoli, even in relatively normal lungs. The probability of causing a pneumothorax is increased in emphysematous patients, following multiple rib fractures or after subclavian vein catheterisation (Lewis, 1978).

Hypotension

The hypotensive patient already has a decreased cardiac output and the compensatory mechanism of peripheral venous constriction in an attempt to decrease the further drop in cardiac output during positive pressure breathing is ineffective. Severe hypotension may then

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† B.Sc. Physiotherapy IV 1980.

‡ Part-time lecturer, Sub-Department of Physiotherapy, University of the Witwatersrand.

TABLE 1. Numerical data calculated from graphs. Pressures in brackets represent PEEP values for those patients.

Patient	*Average number of divisions during controlled ventilation*	*Average number of divisions during "bagging"*	*Ventilator Pressure (cm H_2O)*	*Pressure Represented by one division*	*Calculated Pressure during "bagging" cm (H_2O)*	*Percentage of "bagging" greater than ventilation*
A.	11,0	19,125	32 (8)	2,18	41,69 (+8)	55,28
B.	17,67	26,5	20 (5)	0,85	22,5 (+5)	37,5
C.	18,67	27,125	28	1,5	40,69	45,32
D.	19,1	33	28 (4)	1,46	48,18 (+4)	62,79
E.	25,25	33,5	28 (10)	0,71	23,79 (+10)	20,68

occur.

Hypoxia

This can result in patients with severe respiratory failure if the oxygen flow is inadequate or if "bagging" is not carried out correctly and the patient is underventilated. As a precaution the cardiac monitor should be used to warn the operator of the possible bradycardia which may occur as a result of the hypoxia.

Depression of the respiratory drive

Over-ventilation of the patient can result in the blowing off of carbon dioxide and depression of the respiratory drive.

METHOD

Studies were conducted on five adult patients in the intensive care units of the Johannesburg General Hospital. Patients were ventilated on a Bennet respirator via a tracheostomy or an endotracheal tube. A pressure transducer was attached to the Portex connection of the patient's catheter mount and then to a recorder with an oscilloscope and tracer from which graphs of pressure changes were obtained. A comparison could then be made between the patient's respiration as controlled by the ventilator and that which was obtained from "bag-squeezing".

Pressure changes of controlled respiration were recorded. (Fig. 1).

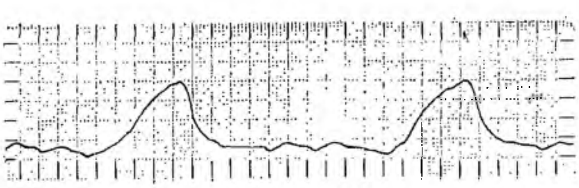

Fig. 1. Pressure changes during controlled ventilation.

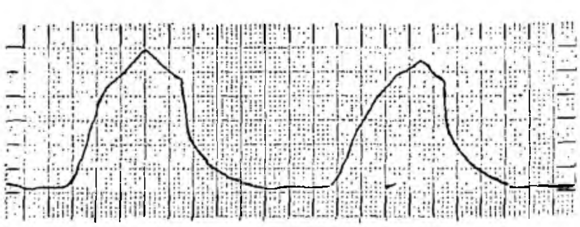

Fig. 2. Pressure changes during "bagging".

A self-inflating bag was then attached to the distal end of the catheter mount and a second tracing was recorded whilst the patient was being "bagged". (Fig. 2).

The appropriate PEEP value was applied by means of a PEEP valve attached to the bag, as required by the patient.

The techniques of squeezing the bag involved the operator compressing the bag with both hands, the ulnar borders resting on the bed for support to minimise movement at the tracheostomy site. The bag was compressed with both hands to give the operator some idea of the compliance of the lung. Each compression allowed for the delivery of a volume of air sufficient to hyperinflate the lungs. The patient was "bagged" five to six times with the patient in the supine position. Initially, a spirometer was attached to the bag in an attempt to measure the volume of gas delivered to the patient. This, however, proved inaccurate because when the bag was attached to the oxygen, the spirometer needle moved round continuously as a result of the oxygen flow. It was estimated that a volume of 1,2 to 1,3 litres of gas was delivered to the patients.

From the peak pressures during controlled respiration the mean peak pressure was calculated by averaging the number of divisions on the graph paper from the base line to the peak pressure point. The average number of divisions were then equated to the mean peak pressure (in cm H_2O). From this data it was possible to calculate how many centimetres of water one division represented. This value was then used to calculate the pressure measurements during "bagging". A comparison was then made between the pressures of controlled respiration and "bagging" in terms of "percentage greater than". (Table 1).

Finally, as a comparison, slow gentle "bagging" to deliver a tidal volume (600 - 800 ml) was included and pressure tracings were recorded (Fig. 3).

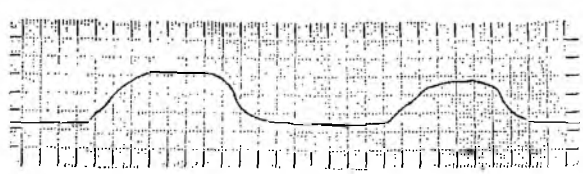

Fig. 3. Pressure changes during slow, gentle "bagging" (a much flatter graph with a much smaller peak pressure).

RESULTS

Although each patient's pattern of ventilation differed depending on the machine setting and the patient's condition, the graph traced out during "bagging" was found to be relatively uniform for all patients tested and varied slightly depending on the degree and rate of compression of the bag.

From Table 1, it can be seen that in each case there was an increased percentage pressure when "bagging" was instituted.

The rate of increase in pressure, determined by the gradient of the graph (that is, change in Y-axis or pressure, divided by change in X-axis or time), was higher during "bagging", reaching a higher peak pressure. (Table 2). Once the peak pressure was reached, there was an initial gradual linear decline in pressure, followed by a very steep, almost vertical decline in pressure to the resting level.

Table 2. Gradients of graphs of patients during ventilation and "bagging".

Patient	*Gradient of Ventilation*	*Gradient of "Bagging"*
A.	0,34	1,55
B.	0,87	2,15
C.	0,83	1,64
D.	0,68	1,61
E.	0,92	1,03

DISCUSSION

The high rate of increase in pressure results from a greater volume of gas being delivered to the patient at a faster rate during "bagging" as opposed to that of tidal ventilation. This rapid increase in pressure results in an increased flow in the central airways which is transmitted to the more distal airways. With this increasing flow, turbulence in approximately the first 6 or 7 generations of the bronchial tree results, causing movement of any secretions present in these airways. Because a larger volume of gas is delivered at a higher pressure, gas is also forced beyond the secretions so that a high expiratory flow rate, assisted by vibrations, will move secretions more centrally. In addition, better ventilation of unobstructed alveoli could result in collateral airflow to alveoli which are filled with secretions or to collapsed alveoli whose terminal bronchi are obstructed.

The initial slow decline in pressure, once the peak pressure has been reached (Fig. 2), could possibly be attributed to leakage of expired air back through the valve into the bag. Bearing this in mind, slow gentle "bagging" which has a longer plateau (Fig. 3), will result in greater rebreathing. Therefore, it can be concluded that the slower the bag is released the greater the amount of rebreathing (Loehning et al., 1964).

A large inspiratory volume with a high pressure change followed by a high expiratory flow rate is comparable to the requirements for an effective cough. An effective cough depends on the velocity of the gas in the airways, where velocity (v) is equal to flow rate (V) divided by cross-sectional area (A): $v = V/A$. A small cross-sectional area and a high flow rate will produce an effective cough (Macklem, 1974). "Bagging" is an attempt to simulate this by producing a high expiratory flow rate in the tracheobronchial tree.

In the case of Patient E, there is not as marked a change in peak pressure and in gradient in "bagging" as compared to controlled ventilation. This can be attributed to the fact that this patient had severe bronchospasm and therefore high airway resistance. A relatively high peak pressure and gradient were obtained even during controlled ventilation.

Suggested Technique for Ambu-bagging

From the results, the authors suggest that the following technique of "bagging" be used to cause hyperinflation of alveoli, collateral airflow and movement of secretions.

In order to deliver a maximum volume of gas to the patient, the bag should be held in both hands, with the ulnar borders resting on a firm surface, e.g. the bed, and then compressed smoothly and maximally with both hands. This technique enables the operator to judge compliance, compress the bag accordingly and thereby minimise the possibility of causing a pneumothorax. A firm surface is suggested to support the hands, to minimise the movement of the bag during compression and thus preventing pulling at the tracheostomy site and discomfort for the patient. Gentle "bag-squeezing" with one hand will only result in delivery of a tidal volume and so the desired effects will not be achieved. If gentle "bag-squeezing" is used, the bag should be compressed and released quickly to minimise rebreathing.

"Bagging" should be used in conjunction with suctioning. Prior to suctioning the patient should be flushed with 100% oxygen in order to prevent the hypoxia which may result during the procedure. The patient is "bagged" five or six times in between the suctioning procedures. The "bagging" is combined with vibrations which are commenced as soon as the operator has completed squeezing the bag. The vibrations are continued throughout the expiratory phase in order to reinforce the high expiratory flow rate in moving secretions from the periphery to the central airways. If the patient is conscious, he is encouraged to cough while the suction catheter is being withdrawn. After suctioning, the patient is "bagged" again about three times to reinflate any atelectatic areas which may have occurred.

CONCLUSION

"Bag-squeezing" performed as suggested is the most effective means of simulating a cough. A large inspiratory volume is delivered at a high pressure forcing air beyond secretions. This is followed by a high expiratory flow rate propelling secretions to the proximal airways where they may be suctioned or coughed up and expectorated.

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