

the test slides was measured on a 3.7-m screen. We then calculated the maximum distance:width ratio at which a given point size would remain legible for persons with a visual acuity of 20/20, 20/30, or 20/40.

The distance:width ratio averaged 9:1 (range 7:1–11:1) for refresher course lecture and panel discussion rooms. Most of these rooms used a 3.7-m (12-foot) screen, whereas the scientific sessions were generally held in smaller rooms that could accommodate only smaller screens. The distance:width ratio for the scientific sessions averaged 7:1 (range 5:1–15:1).

An individual with 20/30 visual acuity would find 30-point lowercase letters legible at a distance:width ratio of 10:1 (table 1). This approaches the worst viewing conditions at the 1990 Annual Meeting. Although 30-point text is legible, most people find it easier to read letters larger than the minimum they can discern. Using 36-point type on a 26 × 17-cm template would provide legible text in 75% of the meeting rooms for an individual with 20/40 visual acuity sitting in the last row and would provide comfortable reading in all rooms for individuals whose visual acuity was at least 20/30. The type used on alternative template sizes should be scaled directly from these recommendations. For example, halving the template size from 26 × 17 cm to 13 × 8 cm (5 × 3.5 inches) halves the size of the type that should be used from 36 point to 18 point.

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Pneumothorax Reexacerbated by a Self-inflating Bag-valve Device

To the Editor:—A self-inflating bag-valve device is commonly used to ventilate the lungs of patients in an emergency setting. Although pneumothorax during resuscitation has been reported as a result of malfunctioning valves,¹⁻³ little attention has been given to the oxygen (O₂) supply hose tail as a potential source of mechanical malfunctioning. We report a case of pneumothorax that occurred because of a problem with the O₂ tail and supply hose of a self-inflating bag-valve device (Intertech/Inspiron®, Lincolnshire, IL; model 008003).

A 33-yr-old man with a known history of intravenous drug abuse presented to the emergency room after sustaining gun-shot wounds to the neck, left chest, and abdomen. The patient was awake, alert, and oriented and breathing spontaneously with O₂ supplemented via nasal insufflation. Physical examination revealed a blood pressure of 120/56 mmHg, a heart rate of 107 beats/min, and a respiratory rate of 20 beats/min but decreased breath sounds over the left chest. The pulse oximeter read 100% O₂ saturation. A left-sided chest tube, placed by the surgeons, drained serosanguinous material. After consultation with the trauma surgeons, elective intubation was performed, and the patient's lungs were ventilated with a self-inflating bag-valve device receiving supplemental O₂ from an unregulated wall outlet. The patient's vital signs after intubation were essentially unchanged.

The patient was placed in a sitting position to facilitate performance of a chest x-ray. The patient was then placed supine, at which time it became increasingly difficult to ventilate the lungs. The surgeons were advised of the problem. Shortly thereafter, total body subcutaneous emphysema developed with rapid desaturation noted on the pulse oximeter. Concomitant hypotension and tachycardia ensued. Suspecting a problem with the recently placed left-sided chest tube, the chest tube was removed. The left-sided chest tube was replaced by the surgeons, but ventilation remained impossible. A second bag-valve device was substituted, with which the lungs were ventilated with ease. The patient was transferred to the operating room, where he underwent exploratory laparotomy uneventfully.

When the original self-inflating bag-valve device was inspected, it

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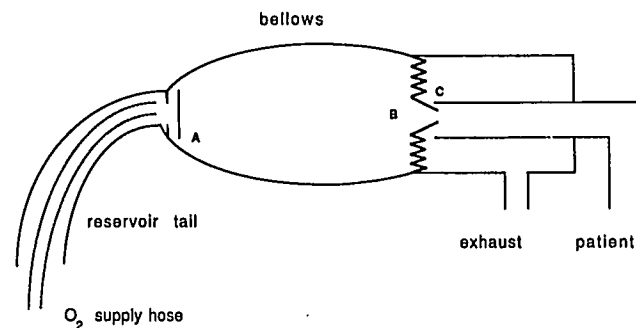


FIG. 1. Self-inflating bag-valve device. During inspiration, when the bag/bellows is compressed, flap valve A closes, and positive pressure is generated. This pressure both opens fish-mouth valve B, allowing gas flow to the patient, and pushes floppy rubber valve C outward, preventing gas from passing out the exhaust port. During exhalation, when the bag/bellows is released, the pressure becomes subatmospheric. Then valve A opens, drawing fresh gas into the bag/bellows from both the O₂ supply hose and the reservoir tail; valve B closes, preventing exhaled gas from entering the bag/bellows; and valve C opens, permitting the patient to exhale through the exhaust port.

is pushed outward to prevent gas from passing out the exhaust port. When the bag is released, pressure in the self-inflating reservoir bag becomes subatmospheric; valve A opens, drawing fresh gas into the reservoir bag from both the O₂ supply hose and the tail; valve B closes in order to prevent exhaled gas from entering the reservoir bag; and valve C opens, permitting the patient to exhale through the exhaust port.

The O₂ supply hose does not feed directly to the interior of the bag but rather to a partially enclosed space adjacent to the inlet port of valve A. Corrugated tubing attached to this space effectively enlarges this space and provides a reservoir of O₂ for the resuscitator. The open end of the corrugated tubing functions as a valveless positive pressure relief, preventing the O₂ line pressure from reaching the patient. In the case reported here, the tail became obstructed, allowing positive pressure to develop within the reservoir. The pressure rose very rapidly because the O₂ from the wall outlet used a needle-valve fitting that allowed a flow in excess of 80 l·min⁻¹ at 50 psi, driving pressure to enter the reservoir bag. The pressure kept valves A and B open but held valve C closed. Consequently, the patient was insufflated with O₂ and unable to exhale.

Pulmonary barotrauma results when excessive intrathoracic pressure causes alveoli to overdistend and rupture. Small gas bubbles then may travel through the adventitia of the pulmonary vessels to the mediastinum. Gas bubbles breaking through the fascial planes of the neck results in subcutaneous emphysema. When the gas is forced through the mediastinal pleura, a pneumothorax results. If it is forced through the diaphragm, pneumoretroperitoneum and pneumoperitoneum result.

Hillman and Albin reported four patients with pulmonary barotrauma during cardiopulmonary resuscitation.¹ In two patients, excessive airway pressures were generated during bag-mask or bag-endotracheal tube ventilation using high flows (*i.e.*, rapid bag compression); in another patient, the one-way valve on a ventilating circuit (Air-Viva Mark 1) stuck in the inspiratory position. Klick *et al.* described similar malfunctioning of the inspiratory one-way valve of a hand resuscitator (Hope Resuscitator, Ohio Medical Products, Madison, WI).² Mechanisms that generate excessive airway pressures during anesthesia

were described by Newton and Adams and included obstruction to outflow of gases from the patient with failure to open the pop-off valve, kinking of the outlet tubing of the Ayres T-piece, and sticking of the one-way inspiratory valve.³

The current case reveals several precautions that should be taken when a self-inflating resuscitator is used. First, bag-valve devices using pressure relief or overpressure relief valves intrinsic to their design protect the patient from exposure to high airway pressures. Second, the incoming O₂ flow to the reservoir of a bag-valve device should be regulated to avoid exposing the patient to high pressures. Finally, care must be taken to avoid pinching the O₂ supply tail.

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In Reply:—Intertech Resources does not agree that the patient injury referenced in the case report was caused by a problem or malfunction of the model 008003 Manual Resuscitation Device.

This device has been designed and manufactured in compliance with ASTM F920, Standard Specification for Minimum Performance and Safety requirements for Resuscitators Intended for Use with Humans. This standard states "valve malfunction or 'lock-up' at high supplementary gas flows may lead to the transmission of excessive pressures to the lungs. These pressures have been reported to cause injury and even death. Resuscitators are commonly used at oxygen input flows of 15 l/min, and often the flowmeter is adjusted to 'flood' or 'flush' setting either by accident or intent. Although it may not be possible to design a valve that can safely withstand maximum 'flood' flows of 80-100 l/min, all resuscitators should be capable of withstanding flows of 30 l/min while maintaining normal function. The adjustment between 15 l/min and the 30-l/min portion or the 'flood' setting on most flowmeters is small. This requirement will provide at least some margin of safety. With information supplied by the resuscitator manufacturer about maximum safe flow, the user may select a safe flow-regulating device." The instructions for use that accompany the device suggest regulating the flow at 15 l/min.

Intertech's device functions normally with or without the oxygen reservoir (tail) obstructed or kinked at 30-l/min flow rates. The device functions normally at the 80-l/min flow rate referenced in the letter by Tucker *et al.* It is only the use of an unregulated oxygen source that produces the potential for patient injury.

Although this case involved an Intertech product, corrugated tubing is used as an oxygen reservoir on manual resuscitators from all major competitors. In addition, Intertech offers products with reservoir bags and an expandable reservoir tube that would make occlusion of the reservoir, and the potential for this incident, highly unlikely.

We fully agree with the precautions recommended by the authors but not the indication that this incident is due to any failure or lack of a robust design of the device.

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