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 O$_2$ 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 O$_2$ supply hose does not feed directly into 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 O$_2$ for the resuscitator. The open end of the corrugated tubing functions as a valveless positive pressure relief, preventing the O$_2$ 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 O$_2$ 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 O$_2$ 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 facial 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, pneumomediastinum and pneumoperitoneum result.

Hillman and Albin reported four patients with pulmonary barotrauma during cardiopulmonary resuscitation. 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 I) 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). 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.

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 O$_2$ 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 O$_2$ supply tail.

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REFERENCES


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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 50-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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