SHORT REPORT

Free-flow oxygen delivery to newly born infants

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Resuscitation guidelines recommend administration of free-flow oxygen to newly born infants who breathe but remain cyanosed. Self-inflating resuscitation bags are described as unreliable for this purpose. We measured oxygen concentrations $\geq 80\%$ delivered through a 240 mL Laerdal self-inflating resuscitation bag and from 5 mm tubing inside a cupped hand.

Resuscitation guidelines advise, “free-flow oxygen should be administered to babies who are breathing but have central cyanosis.”¹ The Neonatal Resuscitation Program (NRP) recommends the following devices: a flow-inflating bag and mask, an “oxygen mask” held close to the infant’s face, oxygen tubing from a cupped hand close to the face and a T-piece resuscitator.² The NRP says that “free-flow oxygen cannot be given reliably by a mask attached to a self-inflating bag”.² Our observations, and those of others,³ indicates self-inflating bags can provide free-flow oxygen.

There is little evidence to help clinicians choose how to provide free-flow oxygen. In an international survey the Laerdal infant resuscitator was the most commonly used resuscitation device.⁴

The study aims were to determine the oxygen concentration (FiO₂) delivered:

1. From an unsqueezed Laerdal 240 mL self-inflating resuscitation bag and mask when; (a) the mask is leak free; (b) the mask is held at varying distances above the face
2. From 5 mm oxygen tubing held inside a cupped hand placed at varying distances above the face.

METHODS

FiO₂ was measured using a Hudson oxygen analyser (Hudson RCI, Durham, USA) calibrated before each study. We used a Laerdal Silicone Resuscitator (240 mL) with a 600 mL reservoir bag (Laerdal, Stavanger, Norway) and 100% oxygen. The bag was not squeezed.

FREE-FLOW OXYGEN INTO A LEAK-FREE FACEMASK (STUDY 1)

This study aimed to simulate delivering oxygen with the mask (Fisher & Paykel, New Zealand) applied firmly to the face without a leak. To produce a leak-free system we sealed the face end. For each study, the resuscitation bag was connected to 100% oxygen at different flow rates and the time started when the oxygen analyser was inserted into the mask, to mimic placing the mask on the face. FiO₂ was measured at 15, 30 and 60 seconds with 100% oxygen flowing into the resuscitation bag at 1, 2, 3, 4, 5, 6, 8 or 10 l/min. Each study was performed with five Laerdal bags.

FREE-FLOW OXYGEN INTO A FACEMASK HELD JUST ABOVE AN INFANT’S FACE (STUDY 2)

We simulated delivering free-flowing oxygen using a 240 mL Laerdal self-inflating resuscitation bag and 600 mL reservoir with the mask held above the face, using 100% oxygen at 5 l/min, the minimum flow recommended for self-inflating bags.² The mask was held 1, 2, 3, 4, or 5 cm above the face of a Laerdal neonatal mannequin (Laerdal, Stavanger, Norway). The resuscitation bag had a spirit level to ensure the mask was level. The oxygen analyser was fitted inside the mannequin’s mouth with the sensor level with the lips (fig 1). With oxygen flowing the time started immediately the mask was placed over the sensor. FiO₂ at 30 seconds was recorded. Measurements were performed with five bags.

FREE-FLOW OXYGEN DELIVERED FROM 5 MM OXYGEN TUBING HELD IN A CUPPED HAND (STUDY 3)

Twelve participants held 5 mm diameter oxygen tubing in a cupped hand over the mannequin’s mouth and nose as if they were giving oxygen to a neonate. FiO₂ was measured with the oxygen tubing at 1, 2, 3, 4 and 5 cm above the mouth of the mannequin (oxygen sensor) and recorded at 30 seconds. The test started when 100% oxygen, at 5 l/min, was turned on.

RESULTS

In study 1 the mean (range) of FiO₂ delivered to a leak free facemask at different times after the oxygen was turned on, and at different flow rates, of 100% oxygen are shown in table 1.

In study 2 the mean (range) FiO₂ measured after 30 seconds when the face mask was held at 1, 2, 3, 4 or 5 cm above the mouth (oxygen analyser) was 86% (78–89), 42% (42–43), 40% (39–42), 43% (43–44) and 39% (38–40) respectively.

In study 3 the mean (range) FiO₂ measured after 30 seconds when the oxygen was delivered at 5 l/min from oxygen tubing held inside a cupped hand at 1, 2, 3, 4 or 5 cm above the mouth, was 96% (90–100), 85% (68–100), 79% (51–99), 69% (50–100) and 64% (36–98) respectively.

DISCUSSION

Our study shows that a high FiO₂ is delivered using a self-inflating bag and reservoir if the mask is held 1 cm above a mannequin’s face. In contrast, if there is no mask leak, the FiO₂ is less than 50%. Free-flow oxygen is also delivered in high concentrations from 5.0 mm oxygen tubing held inside a cupped hand directly above and close to the mouth and nose. The large variation in the FiO₂ delivered with this method, is probably due to the different techniques used by participants to form a cupped hand.

Abbreviation: NRP, Neonatal Resuscitation Program

Figure 1 Oxygen concentration measured at the mannequin's mouth when 100% oxygen was delivered and the facemask was held at different distances from the mouth, measured with callipers and 100% oxygen flowing into the inlet at 5 l/min.

Carter *et al*⁵ measured the oxygen flow from oxygen-filled self-inflating resuscitators and found that the outlet flow was lower than that at the inlet. However, they did not measure FiO_2 . Bakr and El Attar³ investigated the FiO_2 flowing passively from the front of an Ambu bag, and an unspecified valve-bag-mask device. With the Ambu bag, no oxygen came out of the patient end. With the valve-bag-mask the FiO_2 leaving the bag varied from 100% to 49%.

Davies *et al*⁶ investigated the FiO_2 at the exit of three devices, including standard oxygen tubing and a Laerdal infant resuscitation bag. Like us, they found a higher FiO_2 close to the device, which fell with small increases in distance from the device.

Martell and Soder⁷ investigated the Laerdal infant resuscitator. They found that outflow was 18–24% of inflow. This is because there is a valve between the resuscitation bag and reservoir bag which opens when pressures in the reservoir bag above exceed 1 cm H_2O . They also used a lung simulator to measure the FiO_2 leaving a self-inflating bag compared with oxygen tubing. The exits of both devices were placed about 12 mm from, and pointing at the lung simulator inlet. They did not have a mask attached to the bag or a cupped hand round the oxygen tubing to direct the oxygen into the simulator. The FiO_2 ranged from 23% to 68% using 5 l/min of 100% oxygen.

The results of our study of free-flow oxygen from a resuscitation bag only apply to the 240 ml Laerdal infant resuscitator. Clinicians attending newly born infants should be aware of the characteristics of their own equipment.

What is already known on this topic

- Free-flow oxygen is recommended for newly born infants who are breathing but have central cyanosis.
- There are a variety of devices which are available to provide free-flow oxygen. These include: a flow-inflating bag and mask, face mask, funnel, T-piece resuscitator and oxygen tubing held in a cupped hand close to the infant's face.
- The Laerdal self-inflating resuscitation bag is the most commonly used inflating device in the delivery room but it has been reported as unreliable for providing free flow oxygen.

What this study adds

- A 240 mL Laerdal silicone self-inflating bag, with a reservoir attached, unsqueezed with 100% oxygen flowing into the bag at 5 l/min can be used to provide high concentrations of free-flow oxygen to spontaneously breathing newly born infants who remain cyanosed.
- Free-flowing oxygen can be delivered in high concentrations from 5 mm oxygen tubing held inside a cupped hand.

CONCLUSION

Leclerc⁸ wrote, "Self-inflating resuscitation bags must not be used to deliver oxygen in spontaneously breathing patients". This study shows that the Laerdal self-inflating resuscitation bags deliver free-flow oxygen when placed close but not tightly applied to an infant's face and the flow into the bag is at least 5 l/min. Oxygen can also be delivered from 5 mm oxygen tubing held inside a cupped hand over an infant's mouth and nose.

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Table 1 Mean (range) FiO_2 measured in a leak free facemask, at different times after starting the oxygen flow using a self-inflating Laerdal Silicone Resuscitator (240 ml) with a 600 ml oxygen reservoir bag and 100% oxygen flowing into the inlet at different flow rates (Study 1)

	10 l/min	8 l/min	6 l/min	5 l/min	4 l/min	3 l/min	2 l/min	1 l/min
15 sec	75% (57–89)	66% (62–73)	39% (26–62)	39% (30–75)	32% (22–42)	35% (23–49)	22% (21–22)	21% (21)
30 sec	76% (58–90)	67% (63–76)	41% (30–63)	51% (31–75)	32% (22–44)	37% (24–51)	22% (21–25)	21% (21)
60 sec	78% (61–92)	70% (64–81)	44% (34–64)	56% (36–75)	34% (22–47)	41% (25–60)	23% (21–26)	21% (21–22)

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IMAGES IN NEONATAL MEDICINE.....

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Incidental finding of endocarditis in a preterm neonate

Intracardiac vegetations in neonates are relatively rare and are usually diagnosed on discovery of related symptoms such as persistent thrombocytopenia, a new onset murmur or persistent sepsis.^{1,2} We present the case of a female twin 25+2 week preterm neonate with a birth weight of 840 g, and bilateral grade IV intraventricular haemorrhages. An intracardiac vegetation was diagnosed incidentally on day 17 of life after routine monitoring of a patent ductus arteriosus unresponsive to medical treatment. Echocardiography revealed a vegetative mass extending to both atria with its centre attached to the atrial septum at the level of the foramen ovale. This vegetation carries a high risk of embolisation to the brain because of its unique position. On the previous day a peripherally inserted central catheter was placed and noted to touch the interatrial septum. Blood cultures grew *Staphylococcus warneri* which was sensitive to vancomycin and she began a 6-week course, with good response.

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Figure 1 Subcostal 4-chamber view: atrial vegetations denoted by arrows extending to both atria. RA: right atrium; LA: left atrium; RV: right ventricle; LV: left ventricle; IAS: interatrial septum.