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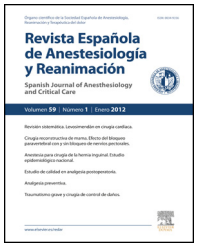

ORIGINAL ARTICLE

Minimum oxygen flow needed for vital support during simulated post-cardiorespiratory arrest resuscitation☆

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Cardiopulmonary resuscitation;
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Abstract According to the ERC and the AHA guidelines, FiO_2 should be titrated to achieve an $O_2Sat \geq 94\%$. The aim of this study was to determine the minimum oxygen flow and time needed to reach an FiO_2 of 0.32 and 0.80 during post-cardiac arrest care. An experimental analysis was performed that consisted of a simulated post-cardiac arrest situation. Different resuscitators were tested and connected to an artificial lung: Mark IV, SPUR II, Revivator Res-Q, O-TWO. The oxygen flow levels tested were 2, 5, 10 and 15 lpm. Bonferroni and Mann–Whitney *U* tests were used. An FiO_2 of 0.32 or more was obtained using any of the oxygen flow and resuscitators. Only the Mark IV achieved an FiO_2 of 0.80 after a minimum of 75 s ventilating with 2 or 5 lpm. Clinical and statistical differences ($p < .05$) were found: at 15 lpm it took 35 s to reach an FiO_2 of 0.80 or more for Mark IV (85.6 [0.3]) and Revivator (84.3 [1.5]) compared to 50 s for SPUR II (87.1 [6.4]); at 2 lpm, all of the devices reached an FiO_2 of ≥ 0.32 at 30 s (Mark IV (34.8 [1.3]), Revivator (35.7 [1.5]) and SPUR II (34.4 [2.1]), except for O-TWO, which took 35 s (36.3 [4.3]). Patients could be ventilated with any of the resuscitators using 2 lpm to obtain an FiO_2 of 0.32, although possibly O-TWO would be the last option during the first 60 s. In order to reach an FiO_2 of 0.80, ventilating with 10 lpm should be sufficient, and preferably using Mark IV or Revivator Res-Q. In conclusion, on observing the results of our study, in any possible scenario, it would be advisable to use Revivator Res-Q or Mark IV rather than O-TWO or SPUR II.

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PALABRAS CLAVE
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Fracción inspirada de oxígeno;
Resucitador

Mínimo flujo de oxígeno necesario para soporte vital durante la simulación de reanimación post parada cardiorrespiratoria

Resumen De acuerdo con las guías de la AHA y la ERC, la FiO_2 a administrarse debería ser aquella con la que se obtuviera una $SatO_2 \geq 94\%$. El objetivo de este estudio es determinar el mínimo flujo de oxígeno y tiempo necesarios para alcanzar una FiO_2 de 0,32 y de 0,80 durante el manejo posparada cardiaca. Se emplearon diferentes reanimadores, que fueron conectados a un pulmón artificial: Mark IV, SPUR II, Revivator Res-Q, O-TWO. Los flujos de oxígeno probados fueron 2, 5, 10 y 15 lpm. Los test estadísticos aplicados fueron Bonferroni y U de Mann-Whitney. Se obtuvo una $FiO_2 \geq 0,32$ con cualquiera de los flujos de oxígeno y reanimadores. Tras un mínimo de 75 s ventilando con 2 o 5 lpm, solo se consiguió una FiO_2 de 0,80 con Mark IV. Se hallaron diferencias clínica y estadísticamente significativas ($p < 0,05$): con 15 lpm se necesitaron 35 s para alcanzar una $FiO_2 \geq 0,80$ con Mark IV (85,6 [0,3]) y Revivator (84,3 [1,5]) comparado con los 50 s que precisó SPUR II (87,1 [6,4]); con 2 lpm, todos los resucitadores alcanzaron una $FiO_2 \geq 0,32$ en 30 s(Mark IV (34,8 [1,3]), Revivator (35,7 [1,5]) y SPUR II (34,4 [2,1]), excepto O-TWO, que necesitó 35 s (36,3 [4,3]). Para alcanzar una FiO_2 de 0,32 se podría emplear cualquiera de los resucitadores usando 2 lpm, aunque quizá el menos recomendable sería O-TWO. Si el objetivo fuera una FiO_2 de 0,80, debería bastar con 10 lpm, usando preferiblemente Mark IV o Revivator Res-Q. En conclusión, atendiendo a los resultados de nuestro estudio, ante cualquier situación potencial, sería preferible emplear Revivator Res-Q o Mark IV que O-TWO o SPUR II.

Introduction

The majority of patients experience cardiac arrest die at the time of the event. Even after return of spontaneous circulation (ROSC) and survival to intensive care unit admission, approximately 60% of these patients will not survive.[1–3] This is attributed to the post cardiac arrest syndrome (PCAS),[4] which involves global ischaemia–reperfusion injury, myocardial stunning, and anoxic brain injury, the latter being particularly strongly associated with mortality. This clinical entity (PCAS) occurs as a consequence of ROSC following cardiopulmonary reanimation manoeuvres in cardiac arrest. Reperfusion causes the formation of reactive oxygen species that produce oxidative stress leading to increased cellular death by diminishing mitochondrial oxidative metabolism, disrupting normal enzymatic activities, and damaging membrane lipids through peroxidation.[1]

There is increasing recognition that systematic post-cardiac arrest care after ROSC can improve the likelihood of patient survival with good quality of life.[5,6]

According to European Resuscitation Council (ERC) and American Heart Association (AHA) guidelines, inspired oxygen should be titrated to the lowest level required to achieve an arterial oxygen saturation of ≥94%, so as to avoid potential oxygen toxicity.[6,7] Hyperoxia contributes to reperfusion organ injury, because the excess of tissue oxygen generates free oxygen radicals, which are toxic.[1,5,8] In this respect, oxidant stress can be perpetuated in a persistently hyperoxic environment. As a result, these events may worsen brain injury via cellular inflammatory reactions in the neurons or their microenvironment (for example, activation of microglia and astrocytes).[1] In addition, parenchymal arterioles in the brain increase vasoconstriction after ischaemia and reperfusion, which could increase perfusion deficit; this seems to be due to calcium sensitization of smooth muscle and could contribute to infarct expansion.[9] Experimental studies have shown that 100% oxygen ventilation in early stages after ROSC is associated with worse prognosis.[10,11]

Ventilation can start at 10–12 breaths per minute, titrated to achieve a $PETCO_2$ of 35–40 mmHg or a $PaCO_2$ of 40–45 mmHg.[5,7] Hyperventilation could increase intrathoracic pressure and thus lower cardiac output[5,11]; whereas hypercapnia could increase intracranial pressure and cause acidosis.[5,12]

Rescuers might have to resort to Bag Valve Mask Devices (BVMD) to ventilate the patient, and might only have access to built-in oxygen cylinders with limited oxygen supply.[13] In this context, it would be of interest to determine the minimum oxygen flow (OF) rate needed to ventilate the patient and achieve the aforementioned objectives.

Different models of BVMD might show differences in fractional inspired oxygen (FiO_2) delivered, as this is influenced by characteristics such as the shape and the type of material used in the compressible unit, the tidal volume delivered, and the OF rate employed.[14–16] The objective of this study was to determine the minimum OF rate and time needed to reach an FiO_2 of 0.32 and 0.80 during post cardiac arrest care using different models of BVMD and different oxygen flows.

Materials and methods

Experimental analysis was carried out during a simulated post-cardiac arrest situation to evaluate the FiO_2 achieved and the time required to achieve it.