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CASE REPORT

IVOX in ARDS: respiratory effects and serious complications

Y. Gasche, J.A. Romand, R. Prêtre, P.M. Suter

IVOX in ARDS: respiratory effects and serious complications. Y. Gasche, J.A. Romand, R. Prêtre, P.M. Suter. ©ERS Journals Ltd 1994.

ABSTRACT: We describe the beneficial effects of an intravenous oxygenator (IVOX) on ventilatory pressure requirement, and also several severe complications related to its use in a young trauma victim developing severe acute respiratory distress syndrome (ARDS).

In this patient, adequate systemic oxygenation could not be maintained despite the use of fractional inspired oxygen of 1.0, high level positive end-expiratory pressure (PEEP), and nitric oxide inhalation (30 ppm). The introduction of an intravenous oxygenator improved arterial oxygenation and CO_2 elimination, allowing a decrease in minute ventilation and airway pressure. However, hepatic cytolysis, acute renal dysfunction and iliac vein thrombosis developed concomitantly, in spite of full anticoagulation with heparin. These complications resolved rapidly after removal of the IVOX device and the patient made a good recovery.

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Division of Surgical Intensive Care and Clinic of Cardiovascular Surgery, Depts of Anesthesiology and Surgery, Hôpital Cantonal Universitaire, Geneva, Switzerland.

Correspondence: P.M. Suter
Division of Surgical Intensive Care
Dept of Anesthesiology
Hôpital Cantonal Universitaire
1211 Geneva 14
Switzerland

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In severe adult acute respiratory distress syndrome (ARDS), it is often necessary to apply elevated airway pressure and high fraction of inspired oxygen (F_{IO_2}), in order to achieve adequate systemic oxygenation. Since the volume of nonconsolidated alveolar tissue available for gas exchange and compliance are greatly diminished in ARDS, a normal tidal volume may cause serious alveolar hyperventilation and overdistension, damaging the alveoli and capillaries. To avoid these detrimental effects on the lung, new strategies have been developed to decrease tidal volume and intrapulmonary pressure in ARDS, thus favouring the recovery of the lung parenchyma. Examples are hypoventilation with permissive hypercapnia [1], extracorporeal membrane oxygenator (ECMO) and extracorporeal carbon dioxide removal ($ECCO_2R$), all of which make it possible to decrease positive pressure ventilation and F_{IO_2} in this situation [2, 3].

More recently, an intravenous oxygenation system (IVOX) has been developed (Cardiopulmonics Inc., Salt Lake City, Utah, USA) and is currently being tested [4]. The following case report describes potential respiratory benefits and clinically important side-effects of this new device.

Case report

A 26 year old man was admitted to our hospital with multiple trauma. He developed severe ARDS within a few days. Conventional treatment methods, such as controlled mechanical ventilation with positive end-expiratory pressure (PEEP), high F_{IO_2} and negative fluid balance, were rapidly insufficient to maintain adequate systemic oxygenation: F_{IO_2} had to be kept between 0.85 and 1.0 in order to obtain an arterial oxygen saturation above 85%, peak inflation pressure (PIP) was greater than 4 kPa (40 cmH_2O), and the patient developed a right pneumothorax requiring drainage. Conventional mechanical ventilation combined with high frequency jet ventilation (HFJV) was instituted to lower intrapulmonary pressure [5], and nitric oxide, by continuous inhalation of 30 parts per million (ppm), was administered to increase systemic oxygenation. Unfortunately, no improvement could be obtained. At this point, it was proposed to insert an intravenous oxygenator (IVOX) in the vena cava. The device was inserted *via* the right femoral vein without difficulty (fig. 1). Full anticoagulation by heparin infusion was initiated. During the hours following the start of intravenous oxygenation, arterial blood gases improved allowing the reduction of both tidal volume (510 to 420 ml) and PEEP (from 1.2 to 0.7 kPa) leading to a subsequent fall in PIP from 4.2 to <3 kPa (fig. 2). However, the patient developed an acute renal dysfunction and biochemical signs of hepatic cytolysis, shortly after the insertion of the IVOX.

Both organ functions continued to deteriorate until the third day, when it was decided to remove the IVOX device. This resulted in rapid improvement in both hepatic and renal function tests (fig. 3).

Following removal of the IVOX, the respiratory situation gradually deteriorated again; consequently, F_{IO_2} and tidal volume had to be increased and the PIP rose to >4

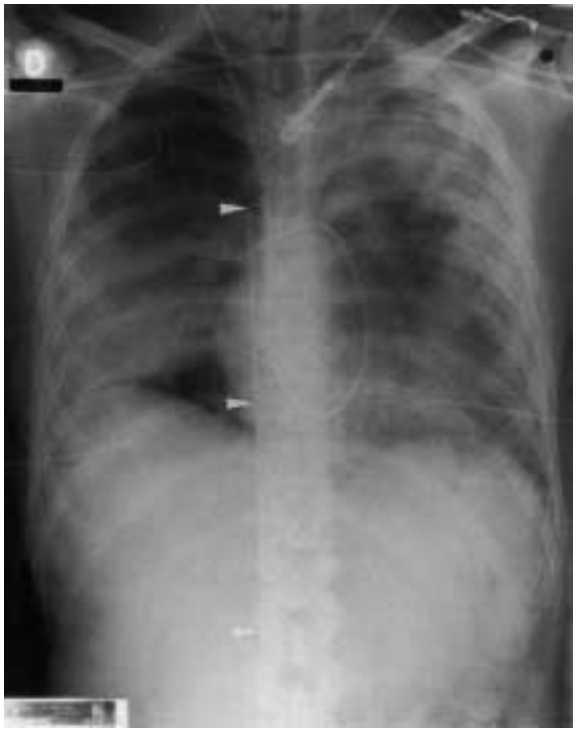

Fig. 1. – Chest X-ray after insertion of an intravenous oxygenation system (IVOX) in the vena cava (arrowheads). Note bilateral chest tubes placed for drainage of pneumothoraces, a Swan-Ganz pulmonary artery catheter and a central venous line introduced *via* the left jugular vein.

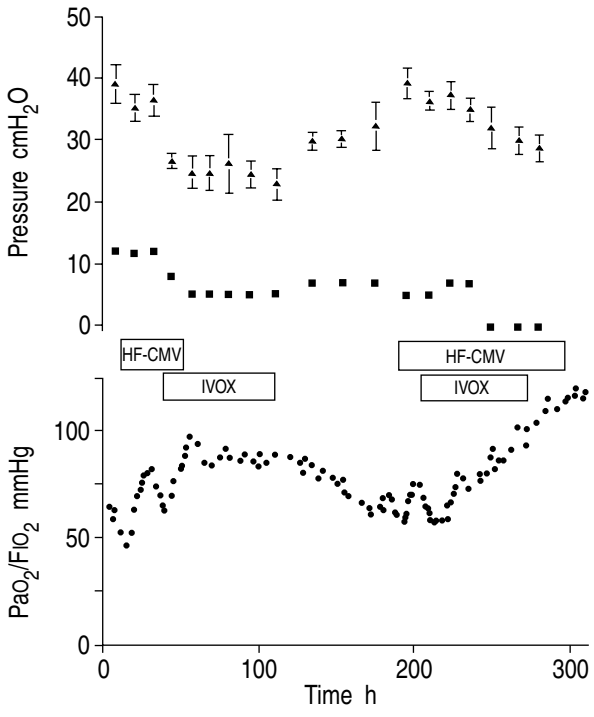

Fig. 2. – Time course of positive end-expiratory pressure (PEEP) required, peak inflation pressure (PIP) and arterial oxygen tension/fraction of inspired oxygen (Pa_{O_2}/F_{IO_2}) ratio before, during and after the use of combined high frequency with conventional mechanical ventilation (HF-CMV) and an intravenous oxygenation system (IVOX). ▲: PIP; ■: PEEP.

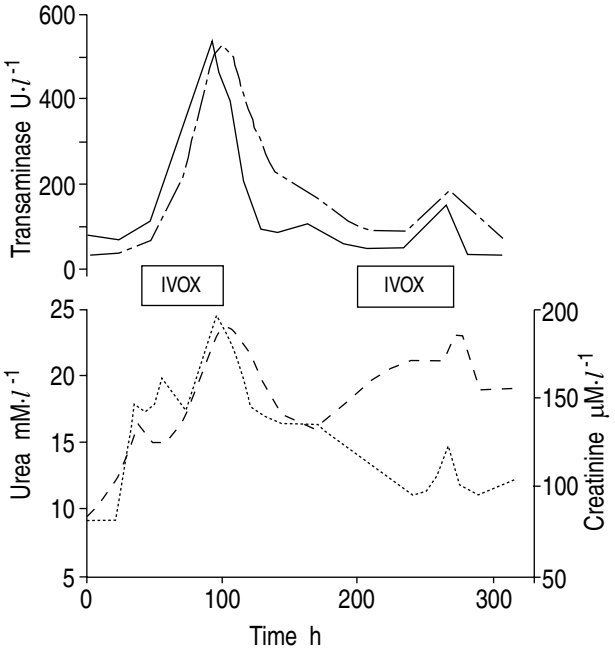

Fig. 3. – Serum levels of transaminases, urea and creatinine before, during and after the insertion of the intravenous oxygenation system (IVOX) device. ——: L-aspartate aminotransferase (ASAT); ····· : L-alanine aminotransferase (ALAT); ——: urea; ·····: creatinine.

kPa, with a PEEP of 0.5 kPa. Combined high frequency ventilation was reintroduced with little success, and it was decided to use the IVOX for a second time. Arterial blood gases improved progressively during the second trial with the device, permitting a decrease in F_{IO_2}, PEEP and tidal volume (fig. 2), but acute disturbance of the liver and renal function recurred (fig. 3), although less markedly than on the first occasion. In addition, after 36 h, a right iliac vein thrombosis developed despite adequate anticoagulation with intravenous heparin; the IVOX had, therefore, to be removed again 72 h after insertion.

During the days which followed, a rapid recovery of both liver and renal function was noted. The respiratory function continued to improve and the patient was extubated 10 days later. He was discharged from the intensive care unit, in good clinical condition, 51 days after admission and left the hospital on the 65th day.

Discussion

The idea of "resting" the lung in severe ARDS to allow time for healing has long been attractive. However, the results obtained with extracorporeal oxygenation systems of the ECMO or $ECCO_2R$ type are difficult to interpret because of nonstandardized inclusion criteria, multiple diagnoses and the frequent absence of control groups [2, 3]. Other techniques, of which IVOX is an example [4], have therefore been developed. The IVOX device consists of a catheter made up of several hundred hollow microfibres which carry the oxygen. The catheter is deployed inside the inferior and superior vena cava, and the transfer of oxygen and carbon dioxide occurs through

the membrane as a result of differences in partial pressure [6]. The safety and reliability of the system have been demonstrated in animal experiments [6].

The theoretical gas transfer capacity is 325 ml·min^{-1} for oxygen and 490 ml·min^{-1} for carbon dioxide. However, animal studies have shown this to be a gross overestimation, and only 81 ml·min^{-1} of O_2 transfer and 67 ml·min^{-1} of CO_2 could be achieved [6].

In humans, the maximal gas transfer reported is 84 ml·min^{-1} for O_2 and 82 ml·min^{-1} for CO_2 with an extreme variability between individuals [7]. In addition, any amelioration due to the IVOX rarely allows ventilatory parameters to be reduced [8].

The case presented here illustrates a clear improvement of arterial blood gases, following the use of IVOX, with the consequent possibility of decreasing tidal volume, minute ventilation and airway pressure, as recently reported by CONRAD *et al*. [9] and KALLIS *et al*. [10]. However, we also observed important side-effects and complications produced by the device, which must be considered. The thrombotic complications could be due to the fact that the configuration of the catheter is designed to present a large surface area for gas exchange, thus predisposing to local coagulation. The occurrence of pulmonary embolisms in the context of an ARDS is a serious danger. Furthermore, the volume of the oxygenator is not insignificant, and once deployed in the vena cava may cause a certain degree of circulatory obstruction. In patients who are haemodynamically unstable with borderline perfusion of organs, such as liver, kidney and pancreas, there is a risk of dysfunction or failure of these organs, most probably related to venous congestion and decreased perfusion pressure.

In conclusion, we report that the use of IVOX in ARDS can improve systemic oxygenation and CO_2 elimination, allowing a decrease in mechanical ventilatory support and peak inflation pressure, and thereby reducing the risk of barotrauma. These advantages, however, can be accompanied by serious complications, which have to be considered and which require close monitoring of coagulation variables and vital organ functions.

References

1. Hickling KG, Henderson SJ, Jackson R. Low mortality associated with low volume pressure limited ventilation with permissive hypercapnia in severe adult respiratory distress syndrome. *Intensive Care Med* 1990; 16: 372–377.
2. Hill JD, O'Brien TG, Murray JJ. Prolonged extracorporeal oxygenation for acute post-traumatic respiratory failure (shock-lung syndrome). *N Engl J Med* 1972; 286: 629–634.
3. Gattinoni L, Pesenti A, Mascheroni D, *et al*. Low-frequency positive-pressure ventilation with extracorporeal CO_2 removal in severe acute respiratory failure. *J Am Med Assoc* 1986; 256: 881–886.
4. Mortensen JD, Berry G. Conceptual and design features of a practical, clinically effective intravenous mechanical blood oxygen/carbon dioxide exchange device (IVOX). *Intern J Artific Org* 1989; 12: 384–389.
5. Berner ME, Rouge JC, Suter PM. Combined high-frequency ventilation in children with severe adult respiratory distress syndrome. *Intensive Care Med* 1991; 17: 209–214.
6. Bagley B, Bagley A, Henrie J, *et al*. Quantitative gas transfer into and out of circulating venous blood by means of an intravenacaval oxygenator. *Trans Am Soc Artif Intern Org* 1991; 37: 413–415.
7. High KM, Snider MT, Russell R, *et al*. Clinical trials of an oxygenator in patients with adult respiratory distress syndrome. *Anesthesiology* 1992; 77: 856–863.
8. Jurmann MJ, Demertzis S, Schaefers H, Wahlers T, Haverich A. Intravascular oxygenation for advanced respiratory failure. *Trans Am Soc Artif Intern Org* 1992; 38: 120–124.
9. Conrad SA, Eggerstedt JM, Romero MD. Prolonged intracorporeal support of gas exchange with an intravenacaval oxygenator. *Chest* 1993; 102: 158–161.
10. Kallis P, Al-Saady N.M, Bennet D, Treasure T. Clinical use of intravascular oxygenation. *Lancet* 1991; 337: 549.