Case Reports/Case Series

Noninvasive bilevel positive airway pressure for preoxygenation of the critically ill morbidly obese patient

[La ventilation en pression positive non invasive à bi-niveau pour la préoxygénation des obèses morbides sévèrement malades]

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Purpose: We describe the use of noninvasive bilevel positive airway pressure (BiPAP) in a critically ill, hypoxemic and morbidly obese patient for preoxygenation prior to rapid sequence induction of anesthesia.

Clinical features: A critically ill morbidly obese patient (body mass index: 49 $kg \cdot m^{-2}$) was scheduled for urgent laparoscopic cholecystectomy. Preoxygenation with 5 $L \cdot min^{-1}$ oxygen flow resulted in a moderate increase in oxygen saturation (S_pO_2) from 79% to 90%. Prior to rapid sequence induction of anesthesia, a trial of noninvasive BiPAP with oxygen delivery at 5 $L \cdot min^{-1}$ increased his S_pO_2 to 95% initially, with full saturation of 99% achieved when oxygen flow was increased to 10 $L \cdot min^{-1}$. Bilevel positive airway pressure with an inspiratory and expiratory pressures of 17 cm H_2O and 7 cm H_2O, respectively, was applied using a full face mask to achieve a tidal volume of 8 $mL \cdot kg^{-1}$. Rapid sequence induction proceeded uneventfully.

Conclusions: Prior to rapid sequence induction of anesthesia in patients with respiratory compromise secondary to factors which reduce FRC, noninvasive BiPAP in combination with supplemental oxygen may be indicated whenever traditional preoxygenation does not provide adequate oxyhemoglobin saturation. Improved oxygenation is most likely attributable to improved ventilation and alveolar recruitment.

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Objectif *: Nous décrivons l'utilisation de la ventilation en pression positive non invasive à bi-niveau (BiPAP) chez un patient sévèrement malade, hypoxémique et obèse morbide, pour la préoxygénation précédant l'induction de l'anesthésie en séquence rapide.*

Éléments cliniques *: Un patient sévèrement malade et obèse morbide (indice de masse corporelle : 49 $kg \cdot m^{-2}$) s'est présenté pour une cholécystectomie laparoscopique urgente. La préoxygénation avec un débit d'oxygène de 5 $L \cdot min^{-1}$ a eu pour résultat une augmentation modérée de la saturation d'oxygène (S_pO_2) de 79 % à 90 %. Avant l'induction de l'anesthésie à séquence rapide, un essai de BiPAP non invasive avec un débit d'oxygène à 5 $L \cdot min^{-1}$ a accru sa S_pO_2 à 95 % initialement, avec une saturation complète achevée à 99 % lorsque le débit d'oxygène a été accru à 10 $L \cdot min^{-1}$. La ventilation en pression positive bi-niveau avec des pressions inspiratoire et expiratoire de 17 cm H_2O et 7 cm H_2O respectivement a été appliquée à l'aide d'un masque facial total afin d'obtenir un volume courant de 8 $mL \cdot kg^{-1}$. L'induction à séquence rapide s'est déroulée sans incident.*

Conclusion *: Avant l'induction de l'anesthésie à séquence rapide chez les patients présentant des difficultés respiratoires secondaires à des facteurs réduisant la capacité fonctionnelle résiduelle, la BiPAP non invasive combinée à de l'oxygène supplémentaire pourrait être indiquée lorsque la préoxygénation traditionnelle ne fournit pas une saturation de l'oxyhémoglobine appropriée. Une meilleure oxygénation est sans doute attribuable à une meilleure ventilation et à un meilleur recrutement alvéolaire.*

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MAXIMAL preoxygenation before emergency endotracheal intubation is essential in critically ill morbidly obese patients as a result of reduced functional residual capacity (FRC), increased intrapulmonary shunting, and increased total body oxygen consumption.[1] Baillard *et al.*[2] showed in critically ill patients that noninvasive ventilation (provided in the form of pressure support ventilation) in the intensive care unit setting ensured improved oxygen saturation (S_pO_2) before, during, and after endotracheal intubation as compared with the standard preoxygenation technique.

Bilevel positive airway pressure (BiPAP) is a form of noninvasive ventilatory support that combines aspects of pressure support and continuous positive airway pressure (CPAP). BiPAP uses two pressure levels: inspiratory positive airway pressure (IPAP) and expiratory positive airway pressure (EPAP) which can be adjusted independently. We report the use of BiPAP provided by a stand-alone BiPAP machine in the operating room for preoxygenating a critically ill, hypoxemic and morbidly obese patient undergoing urgent surgery prior to rapid sequence induction of anesthesia, as compared to the traditional preoxygenation in the same patient. Consent for publication was obtained according to guidelines of the American University of Beirut Medical Center.

Case summary

A 70-yr-old morbidly obese male patient (body mass index = 49 $kg \cdot m^{-2}$), with a history of coronary artery disease, congestive heart failure, and obstructive sleep apnea presented to our emergency department with signs of respiratory compromise; arterial P_aO_2 and P_aCO_2 on room air were 51 mmHg and 66 mmHg respectively (Table). His chest *x-ray* showed mild cardiomegaly and evidence of moderate bilateral pulmonary congestion. The patient was scheduled to undergo urgent laparoscopic cholecystectomy under general anesthesia for a gangrenous gall bladder. It was deemed that the patient's general medical condition was related to chronic illness, and that delay of surgery would be unlikely to result in further optimization of his preoperative status.

Prior to rapid-sequence induction of anesthesia, and following application of routine monitors and an indwelling radial arterial line, the patient was preoxygenated for three minutes using a circle system and a tightly fitting face mask under tidal volume breathing at an oxygen flow rate of 5 $L \cdot min^{-1}$. From a baseline S_pO_2 of 79%, this preoxygenation sequence failed to increase his SpO_2 above 90%, as assessed by pulse oximetry (CO_2SMO, Novametrix Medical Systems Inc., Wallingford, CT, USA). Corresponding arterial blood gas analysis at this time documented an increase of P_aO_2 from 51 mmHg up to 60 mmHg, with no change in P_aCO_2. In view of the low S_pO_2 and P_aO_2 values and the high P_aCO_2, the patient was disconnected from the anesthesia circuit and was started on noninvasive ventilatory support using a noninvasive BiPAP device as an independent and stand-alone BiPAP system (Respironics Inc.; Murrysville, PA, USA). Initial settings included an IPAP of 17 cm H_2O and an EPAP of 7 cm H_2O using a full face mask to achieve a tidal volume of 8 $mL \cdot kg^{-1}$; oxygen flow of 5 $L \cdot min^{-1}$ was delivered via the BiPAP mask. The patient's S_pO_2 and P_aO_2 values increased to 95% and 81 mmHg, respectively, within three minutes of BiPAP application. Concurrently, the P_aCO_2 decreased from 64 mmHg to 46 mmHg, associated with an increase in pH from 7.30 to 7.41. Augmenting the oxygen flow to 10 $L \cdot min^{-1}$ resulted in a further increase in the S_pO_2 and P_aO_2 up to 99% and 95 mmHg respectively over the next two minutes with no further changes in P_aCO_2 and pH (Table).

Following BiPAP preoxygenation, rapid sequence induction of anesthesia was achieved with ketamine 2 $mg \cdot kg^{-1}$ *iv* and succinylcholine 1.5 $mg \cdot kg^{-1}$ *iv* and cricoid pressure was applied. The BiPAP and oxygen flow were then discontinued while awaiting onset of paralysis, and within 45 sec, the S_pO_2 decreased from 99% to 85%. Direct laryngoscopy revealed a grade 1 laryngeal view and orotracheal intubation was

TABLE Arterial blood gas analyses

	Room air	*O_2 at 5 $L \cdot min^{-1}$*	*BiPAP (17/7 cm H_2O) O_2 at 5 $L \cdot min^{-1}$*	*BiPAP (17/7 cm H_2O) O_2 at 10 $L \cdot min^{-1}$*
P_aO_2 (mmHg)	51	60	81	95
P_aCO_2 (mmHg)	66	64	46	47
pH	7.29	7.3	7.41	7.41
Saturation (%)	79	90	95	99
BE	+3	+3	+4	+4

BiPAP = bilevel positive airway pressure; BE = base excess.

achieved on the first attempt. After verifying the correct tube position by capnography and the presence of bilateral breath sounds, the patient was immediately ventilated with 100% oxygen, which restored his S_pO_2 to 99% within two minutes.

Intraoperatively, anesthesia was maintained with sevoflurane in 50% oxygen:air, supplemented by continuous infusion of cisatracurium and remifentanil. Oxygen saturations were well maintained (95%) using volume-controlled ventilation with a tidal volume of 900 mL and a respiratory rate of 16 breaths·min^{-1}. Laparoscopic cholecystectomy was accomplished uneventfully within 60 min. At the end of surgery, anesthesia was discontinued and the patient was transferred to the intensive care unit while remaining intubated and ventilated. Two hours postoperatively, the trachea was extubated and the patient was managed by intermittent noninvasive BiPAP ventilation for 48 hr.

Discussion

In a critically ill morbidly obese patient scheduled for urgent surgery, noninvasive BiPAP promptly improved oxygenation prior to rapid sequence induction of anesthesia. It is likely that a more profound decrease in S_pO_2 might have resulted had laryngoscopy and tracheal intubation been attempted following the traditional technique of preoxygenation, which was unable to restore S_pO_2 above 90%. Baillard *et al.*[2] showed that a significant linear correlation exists between S_pO_2 at the end of preoxygenation and the minimal S_pO_2 during endotracheal intubation. Also, Baraka *et al.*[3,4] have demonstrated with different preoxygenation techniques, that rapid oxyhemoglobin desaturation can occur whenever S_pO_2 decreases below 99%.

Critical illness and/or morbid obesity associated with respiratory failure can decrease oxygen stores in the FRC and increase the alveolar-arterial oxygen pressure gradient. Applying CPAP during preoxygenation has been suggested to optimize preoxygenation in critically ill patients, on the assumption that CPAP will increase the FRC of the lung.[5] However, Cressey *et al.*[6] demonstrated no prolongation in the time to desaturate to 90% following preoxygenation with 7.5 cm H_2O CPAP with 100% oxygen when compared with standard preoxygenation in apneic morbidly obese women. Further, Cressey *et al.*[6] postulated that the effectiveness of CPAP in their study could have been enhanced by higher CPAP levels since increased CPAP may further expand the FRC. Recently, the use of noninvasive ventilation and CPAP/positive end-expiratory pressure (PEEP)[2] has been shown to improve oxygenation in critically ill patients, attributed to increased FRC, improving alveolar recruitment and preventing derecruitment, decreasing ventilation/perfusion mismatch and decreasing the alveolar-arterial oxygen gradient.[7,8] In our report, the use of noninvasive BiPAP with IPAP = 17 cm H_2O and EPAP = 7 cm H_2O achieved a notable improvement of oxyhemoglobin saturation, associated with less hypercarbia as compared with the traditional technique of preoxygenation in the same patient.

Noninvasive ventilatory support in the form of BiPAP provides high-flow positive airway pressure that cycles between IPAP and EPAP in response to the patient's own breathing effort.[9] The EPAP works as a form of PEEP and the gradient between the IPAP and EPAP works as a driving pressure responsible for inflation of the lung with a tidal volume.[9,10] In our patient, EPAP was set at 7 cm H_2O to facilitate alveolar recruitment, increase FRC and decrease the alveolar-arterial oxygen gradient. Inspiratory positive airway pressure was set at 17 cm H_2O and, as such, a driving pressure gradient of 10 cm H_2O was achieved that generated a tidal volume of approximately 7–8 mL·kg^{-1}. Potential adverse effects of noninvasive BiPAP include gastric insufflation, distention and aspiration.[11,12] However, there are no reported cases of barotrauma or serious hemodynamic changes associated with noninvasive BiPAP.

In conclusion, traditional preoxygenation at an oxygen flow rate of 5 L·min^{-1} in a critically ill, hypoxemic, and morbidly obese patient scheduled for urgent surgery, could not restore adequate S_pO_2. Application of noninvasive BiPAP (17/7 cm H_2O) and an oxygen flow of 10 L·min^{-1} increased S_pO_2 to 99%. Whenever traditional oxygenation fails to achieve an adequate level of oxygenation ($S_pO_2 \geq 99\%$) as a result of factors known to decrease FRC, noninvasive BiPAP is a practical and effective technique to improve oxyhemoglobin saturation.

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