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Respiration and the Airway

RESPIRATION AND THE AIRWAY

Optimizing oxygenation and intubation conditions during awake fibre-optic intubation using a high-flow nasal oxygen-delivery system

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Abstract

Background: Awake fibre-optic intubation is a widely practised technique for anticipated difficult airway management. Despite the administration of supplemental oxygen during the procedure, patients are still at risk of hypoxia because of the effects of sedation, local anaesthesia, procedural complications, and the presence of co-morbidities. Traditionally used oxygen-delivery devices are low flow, and most do not have a sufficient reservoir or allow adequate fresh gas flow to meet the patient's peak inspiratory flow rate, nor provide an adequate fractional inspired oxygen concentration to prevent desaturation should complications arise.

Methods: A prospective observational study was conducted using a high-flow humidified transnasal oxygen-delivery system during awake fibre-optic intubation in 50 patients with anticipated difficult airways.

Results: There were no episodes of desaturation or hypercapnia using the high-flow system, and in all patients the oxygen saturation improved above baseline values, despite one instance of apnoea resulting from over-sedation. All patients reported a comfortable experience using the device.

Conclusions: The high-flow nasal oxygen-delivery system improves oxygenation saturation, decreases the risk of desaturation during the procedure, and potentially, optimizes conditions for awake fibre-optic intubation. The soft nasal cannulae uniquely allow continuous oxygenation and simultaneous passage of the fibrescope and tracheal tube. The safety of the procedure may be increased, because any obstruction, hypoventilation, or periods of apnoea that may arise may be tolerated for longer, allowing more time to achieve ventilation in an optimally oxygenated patient.

Key words: anaesthetic techniques, fibre-optic; intubation, tracheal tube; oxygen, delivery systems

Awake fibre-optic intubation (AFOI) is performed in patients where it is anticipated that induction of anaesthesia with apnoea may lead to loss of the airway, inability to ventilate, and ultimately, hypoxaemia. The technique is not without risk, however, and desaturation remains an important and real possibility in these patients. The fourth national audit project of the Royal College of Anaesthetists (NAP4) highlighted how this technique can fail, with the review panel identifying airway obstruction, bleeding, and over-sedation among the common reasons for the seven reported failures; all complications which may rapidly lead to hypoxaemia.[1]

High-flow humidified nasal oxygen therapy (up to 70 litres min^{-1}) is a method of delivering oxygen that has been increasingly adopted in adult patients across many clinical areas. In critical care and the emergency department, in patients with acute respiratory failure, the use of high-flow nasal cannulae (HFNC) has been shown to increase oxygen saturation (Sp_{O_2}) and arterial oxygen partial pressure and to reduce the frequency of breathing.[2–3]

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Editor's key points

- During awake fibreoptic intubation, conventional methods of supplying low-flow oxygen may be insufficient to prevent desaturation.
- A high flow humidified transnasal oxygen delivery system, used during awake fibreoptic intubation in 50 patients with anticipated difficult airways, always increased the oxygen saturation above baseline values, despite one case of apnoea.
- The high flow nasal oxygen delivery system is potentially useful during attempts at awake fibreoptic intubation.

Proposed mechanisms are a washout of nasopharyngeal dead space by the high flow, a reduction in the work of breathing, and the provision of a degree of positive airway pressure.[4]

At our institution, a major head and neck regional oncology and maxillofacial centre, we regularly use an awake fibre-optic technique to manage complex airway conditions in high-risk patients (~180 patients per annum). To our knowledge, a high-flow oxygen-delivery system has not yet been reported for oxygenation during AFOI. In this observational study, our primary aim was to investigate the potential advantages of HFNC as an oxygen-delivery technique to optimize oxygenation and prevent desaturation and hypercarbia; and additionally, to observe any improvement in overall intubation conditions, and its feasibility for use in routine practice for AFOI.

Methods

Between November 2013 and March 2015, AFOI was performed in 50 adult patients, with supplemental oxygen delivered using an HFNC. Optiflow™ (Fisher & Paykel Healthcare, Auckland, New Zealand), a commercially available high-flow humidified transnasal oxygen-delivery system, was used (Fig. 1). The decision to perform an AFOI was judged clinically, based on the presence of abnormal pharyngeal or laryngeal pathology, anatomical factors predictive of difficult airway management, and information gained from previous anaesthetics.

Fig 1 Optiflow™ high-flow humidified oxygen-delivery system.

In all instances, the procedure was performed facing the patient, with the patient sitting in an upright position. Optiflow™ 50–70 litres min^{-1} was applied after the standard monitoring was established (three-lead ECG, non-invasive blood pressure, and pulse oximetry). No patient received premedication.

In those requiring a nasal route of intubation, Moffats' solution containing 100 mg cocaine was applied to the nasal passages, using a nasal mucosal atomization device. The oropharynx was anaesthetized in all using 4% lidocaine 5 ml via a laryngotracheal mucosal atomization device. All patients received sedation via i.v. target-controlled infusion adjusted to an appropriate level of conscious sedation. Patients received plasma target concentrations of propofol between 0.5 and 1 μg ml^{-1} and remifentanil 2–3 ng ml^{-1}. Optiflow™ remained on continuously throughout the procedure and was discontinued only once successful tracheal intubation was confirmed and the tracheal tube connected to the anaesthetic breathing circuit and ventilator. General anaesthesia was then induced.

The patients' age, sex, BMI, co-morbidities, baseline and immediate postintubation Sp_{O_2}, and end-tidal carbon dioxide ($ETCO_2$) were recorded. Preoxygenation time referred to the time from HFNC application to the start of sedation, and total transnasal oxygenation time from the application of HFNC to the time at which the tracheal tube was connected to the anaesthetic breathing circuit. The study was approved and registered with our institute's research and development department.

Results

Forty-six patients were to undergo elective surgical procedures, two urgent (for postsurgical thoracic duct leak and neck haematoma), and two immediate interventions (for acute stridor post-extubation and after radiotherapy). Of the elective procedures, 45 were for head and neck procedures and the remainder for ophthalmic, orthopaedic, renal, and breast procedures. Thirty-nine patients received a nasal and 11 an oral intubation.

There were 37 male and 13 female patients. The mean (SD) BMI was 27 (9.7) kg m^{-2}, with 10 patients being classified as obese (BMI >30 kg m^{-2}), and the mean (SD) age was 57.9 (13.4) yr. Twenty-four

Table 1 Features contributing to the decision to perform an awake fibre-optic intubation

	All patients (n=50)
Active suspected or confirmed pharyngolaryngeal cancer	25
Previous head and neck radiotherapy	12
Previous neck dissection with free-flap reconstruction	5
Supra- or subgottic stenosis	3
Large goitre with retrosternal extension and tracheal compression	3
Acute stridor	2
Large neck haematoma	1
Chronic systemic disease associated with neck and jaw restriction (Goldenhar syndrome and epidermolysis bullosa)	2
Obesity	
Severely obese (BMI 35–39 kg m^{-2})	3
Morbidly obese (BMI 40–49 kg m^{-2})	3
Super morbidly obese (BMI 50+ kg m^{-2})	1

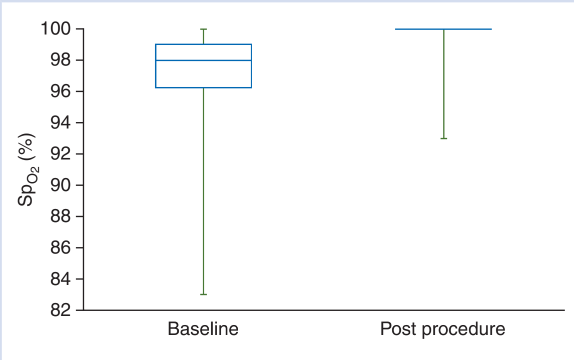

Fig 2 Baseline and immediate postprocedure oxygen saturation (Sp_{O_2}) for all patients. Box plot shows median and first and third quartiles. Vertical extensions indicate minimum and maximum observed measurements.

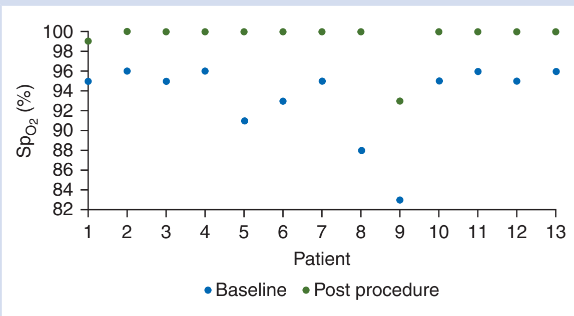

Fig 3 Improvement in Sp_{O_2} with high-flow nasal cannulae in the 13 patients who had baseline Sp_{O_2} less than 97%.

were smokers, seven diagnosed with chronic obstructive airways disease, and five with obstructive sleep apnoea. Thirteen had documented cardiovascular disease. The range of features present that led to the decision to perform an awake fibre-optic technique are shown in Table 1.

The mean (SD) preoxygenation time was 2.2 (1.6) min and mean (SD) transnasal oxygenation time 17.9 (4.3) min. Median [IQR (range)] baseline Sp_{O_2} was 98 [96–98 (83–100)]%. Figure 2 shows the overall improvement in Sp_{O_2} from baseline. Of note, 13 patients had baseline Sp_{O_2} less than 97%, and Fig. 3 shows their increase in Sp_{O_2} with the HFNC. There was one instance of apnoea attributable to over-sedation during fibrescope passage, where spontaneous respiration was regained ~1 min after discontinuing sedation. The immediate median [IQR (range)] postprocedure Sp_{O_2} was 100 (100–100 [93–100])% and $ETCO_2$ was 4.8 [4.3–5.2 (3.5–6.7)] kPa. There were no instances of desaturation below the baseline value during any procedure. There were no instances of airway trauma or other complications. During the routine postoperative visit, all patients reported a comfortable experience in terms of receiving oxygen therapy with Optiflow™.

Discussion

We found HFNC to be well tolerated in these patients with complex airway anatomy and pathology, many of whom also had BMIs or underlying cardiorespiratory disease that placed them at a higher risk of rapid oxygen desaturation should hypoventilation or apnoea occur. There were no instances of desaturation below baseline, despite an average procedure time of almost 18 min. In addition, the $ETCO_2$ after the procedure was also in the normal range in all patients, despite the use of sedation, notably also in the one patient in whom apnoea occurred, where the Sp_{O_2} remained 100% and $ETCO_2$ after the procedure was 4.6 kPa.

We observed various other favourable features specific to this procedure, in addition to supplemental oxygenation. The soft nasal prongs allowed simultaneous nasal passage of the fibrescope and tracheal tube, uniquely allowing for uninterrupted oxygenation, with no instances of nasal trauma. We speculated that the high flow rate aided the atomization and delivery of the local anaesthetic through the upper airway to the trachea and could also help prevent collapse of the nasal passage for better visualization and instrumentation. The humidified airflow may potentially also help to protect friable postradiotherapy mucosa and therefore help to reduce the risk of bleeding.

The conventional forms of oxygen delivery used for AFOI are low-flow variable performance devices; nasal cannulae, facemasks, nasal sponges, suction catheters placed in the nostril, or via the working channel of the fibrescope. The patient's peak inspiratory flow rate exceeds the oxygen flow and ambient air entrained to dilute the fractional inspired oxygen (F_{IO_2}). Nasal cannulae can comfortably supply up to an F_{IO_2} of only 0.36. A study of healthy unsedated volunteers undergoing AFOI, who received oxygen via standard low-flow nasal cannulae, found the incidence of desaturation below 80% to be 1.5%.[5] The use of sedative agents leads to the constant possibility of hypoventilation and inducing apnoea. In addition, in those patients with pathology-related chronically obstructed upper airways who become apnoeic, the rate of desaturation will be greater because they may have a lower initial alveolar O_2 tension, plus a higher work of breathing. Additionally, the application of lidocaine to the upper airway has been shown to reduce dynamic inspiratory airflow,[6] and there have been several case reports linking total airways obstruction with local anaesthetic topicalization alone.[7–9]

Published AFOI studies and case series in real patient populations report desaturations rates <90% of between 3 and 14.3%, when oxygen is administered via standard nasal cannula at 2–4 litres min^{-1}.[10 11]

High-flow nasal cannulae provide an increased F_{IO_2} because the higher flow rates are capable of matching or exceeding the patient's peak inspiratory flow, preventing room air entrainment. Naso- and oropharyngeal dead space is washed out with oxygen-rich gas and acts as a reservoir. Flows of 35 litres min^{-1} with mouth closure have been shown to create positive expiratory nasopharynx pressures of up to 5.3 cm H_2O.[12] At flow rates of 70 litres min^{-1}, this is the only available technique to deliver 100% F_{IO_2} continuously throughout an oral or nasal awake fibreoptic intubation. The humidification of the gases counteracting the drying effect of high flow has been shown to lead to greater patient comfort and higher tolerance compared with conventional methods, and to help with mucociliary clearance.[3 13]

These features suggest that HFNC may be particularly beneficial in delivering oxygen during respiratory or anaesthetic procedures. During bronchoscopy, and in sedated patients undergoing dental procedures, the use of humidified transnasal oxygenation has yielded higher Sp_{O_2} and oxygenation characteristics compared with conventionally used nasal cannulae or venturi masks.[14 15]

Transnasal humidified rapid-insufflation ventilatory exchange (THRIVE) is a technique recently described, using a high-flow nasal oxygen cannula to increase the apnoeic window in patients with difficult airways undergoing general anaesthesia.[16] In patients undergoing hypopharyngeal or laryngotracheal surgery, with humidified high-flow transnasal cannulae used for preoxygenation and continued under general anaesthesia until a definitive airway was secured (up to 17 min), there were no desaturations below 90%. The rate of increase of $ETCO_2$ was found to be lower than previously described (0.15 kPa min^{-1}) during this apnoeic period. This principle of continuous insufflation to facilitate both oxygenation and carbon dioxide clearance through gas mixing and flow-dependent dead space flushing is one that becomes particularly relevant during an AFOI when a patient determined to have a difficult airway becomes inadvertently apnoeic. The window for attempts to regain spontaneous respiration or intubate the trachea is extended, reducing the risk of occurrence of hypoxaemia or carbon dioxide retention.

The human factors benefits of creating a calm environment during what is regarded by many as a stressful procedure in high-risk patients is easily appreciated. Effective and continuous oxygenation leads to more stable vital signs and will allow for a higher level of attention to be paid to achieving the task itself. These stable, favourable conditions could also allow for better teaching and training opportunities, with a wider margin of safety, for a procedure that may be performed infrequently.

In conclusion, we recommend that the question of how best to deliver oxygen during AFOI is one which should be given greater consideration and become the focus of future comparative studies. Our observational series has found that HFNC is well tolerated in spontaneously breathing patients undergoing AFOI, improves oxygenation, and may potentially prevent desaturation arising as a result of apnoea or hypoventilation. It is currently the only method available to provide the patient continuously with 100% F_{IO_2} during awake nasal or oral fibre-optic intubation. We would advocate its use in high-risk patients undergoing AFOI to minimize the potential for hypoxaemia to occur and make AFOI an inherently safer procedure.

Authors' contributions

Study design, performing procedures, data collection and analysis, and writing manuscript: S.B.

Performing procedures, data collection, reviewing and editing manuscript: M.J. and R.A.F.

Study concept and design, performing procedures, data collection, reviewing, editing, and approving manuscript: I.A.

Declaration of interests

None declared.

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