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Review article

The clinical advantage of nasal high-flow in respiratory management during procedural sedation: A scoping review on the application of nasal high-flow during dental procedures with sedation

Shinji Kurata[a], Takuro Sanuki[b], Hitoshi Higuchi[c], Takuya Miyawaki[c], Seiji Watanabe[d], Shigeru Maeda[e], Shuntaro Sato[f], Max Pinkham[g], Stanislav Tatkov[g], Takao Ayuse[a,*]

[a] Division of Clinical Physiology, Department of Translational Medical Sciences, Nagasaki University Graduate School of Biomedical Sciences, Nagasaki, Japan
[b] Department of Dental Anesthesiology, Kanagawa Dental University, Kanagawa, Japan
[c] Department of Dental Anesthesiology, Okayama University, Okayama, Japan
[d] Division of Dental Anesthesiology, Department of Science of Physical Functions, Kyushu Dental University, Fukuoka, Japan
[e] Department of Dental Anesthesiology, Tokyo Medical and Dental University, Tokyo, Japan
[f] Clinical Research Center, Nagasaki University Hospital, Nagasaki, Japan
[g] Fisher & Paykel Healthcare Ltd, Auckland, New Zealand

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ABSTRACT

Structured summary: Rationale: Nasal high-flow (NHF), a new method for respiratory management during procedural sedation, has greater advantages than conventional nasal therapy with oxygen. However, its clinical relevance for patients undergoing oral maxillofacial surgery and/or dental treatment remains uncertain and controversial, due to a paucity of studies. This scoping review compared and evaluated NHF and conventional nasal therapy with oxygen in patients undergoing oral maxillofacial surgery and/or dental treatment.

Materials and methods: A literature search of two public electronic databases was conducted, and English writing randomized controlled trials (RCTs) of nasal high flow during dental procedure with sedation reviewed. The primary and secondary outcomes of interest were the incidence of hypoxemia and hypercapnia during sedation and the need for intervention to relieve upper airway obstruction, respectively.

Results: The search strategy yielded 7 studies, of which three RCTs met our eligibility criteria, with a total of 78 patients. Compared with conventional nasal therapy with oxygen, NHF significantly reduced the incidence of hypoxemia and hypercapnia during procedural sedation.

Conclusion: NHF can maintain oxygenation and possibly prevent hypercapnia in patients undergoing dental treatment. Additional RCTs are needed to clarify and confirm these findings.

Contents

* Corresponding author.
E-mail address: ayuse@nagasaki-u.ac.jp (T. Ayuse).

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1. Introduction

Procedural sedation is an effective method to reduce fear and anxiety in patients undergoing oral maxillofacial surgery and/or dental treatment. However, there is a risk for upper airway obstruction due to anesthesia and positional influences, such as mouth-opening and neck flexion [1–4]. Therefore, effective mechanical intervention and respiratory management are required to maintain oxygenation. Nasal high-flow (NHF), a new method for respiratory management during procedural sedation, is more effective than conventional nasal therapy with oxygen to maintain upper airway patency due to its effect of increasing pressure and washout of carbon dioxide (CO_2) in the airways [5–7]. However, its clinical relevance for patients undergoing oral maxillofacial surgery and/or dental treatment remains uncertain and controversial, due to limited studies.

NHF delivers inhalation gas at high-flow (8–70 L/min), with adjustable and relatively constant oxygen concentration (21 %–100 %), temperature (31–37 °C), and humidity [8,9]. Compared with conventional oxygenation methods using nasal cannula, NHF produces a continuous positive airway pressure that can cause mild lung recruitment [10,11]. Thus, it can reduce the dead space, thereby improving oxygenation and comfort in critically ill patients [12,13]. Recently, we reported that NHF improves ventilation during propofol sedation, which may reduce the risk of complications related to hypoventilation [14]. In addition, some effects of NHF, such as increased functional residual capacity and end-expiratory lung volume, can improve oxygen saturation in obese patients [15].

1.1. Objective

Since the oxygenation strategy during procedural sedation for patients undergoing oral maxillofacial surgery and/or dental treatment remains controversial, in this study, we compared the effects of NHF and conventional oxygen therapy on oxygen saturation in patients undergoing dental treatment. To our knowledge, this is the first scoping review on this topic.

2. Materials and methods

This scoping review was performed in accordance with the PRISMA-ScR guidelines [16]. The principal investigator performed a systematic literature search for articles published in English before December 10, 2021, using the PubMed and Cochrane databases and the following search criteria: (high-flow nasal cannula OR HFNC OR high-flow nasal cannula therapy OR high-flow oxygen therapy through nasal cannula OR NHF dental treatment OR dentistry OR oral surgery OR oral maxillofacial surgery sedation OR procedural sedation OR intravenous sedation OR intravenous anesthesia). This search strategy yielded a total of 7 articles. After screening the titles, abstracts, and keywords and excluding animal studies, study protocol, reviews, guidelines or conference abstracts, case reports, articles with unclear inclusion criteria, and duplicate articles, three randomized controlled trials (RCTs) satisfied the following inclusion criteria: clinical studies, comparison between NHF and conventional oxygen therapy (nasal cannula and/or face mask), and dental treatment or oral maxillofacial surgery, and were included in this scoping review. The data extracted from each RCT include the authors, study year, country, and design, number and type of patients, target procedure and outcomes (Table 1). The primary and secondary outcomes of interest were the incidence of hypoxemia and hypercapnia during procedural sedation and the need for intervention to alleviate upper airway obstruction, respectively.

3. Results

The literature search of the PubMed and Cochrane databases identified 7 articles of the following types: review, meta-analysis, case report, animal experiments, letter, laboratory studies, guidelines and conference abstract. Three of these articles were related to English NHF RCTs during dental procedure with sedation. Further screening of the full texts identified three RCTs that met our inclusion criteria [15,17,18]. The data extracted from these RCTs are detailed in Table 1. All three studies were conducted in Japan. A total of 78 patients (obese, pediatric, and adult) underwent either a dental procedure or treatment. Midazolam and/or propofol were used as sedatives. Patients were randomized to either the nasal cannula control group (5 L/min) or NHF (30, 40 or 50 L/min) treatment group. In obese patients (BMI > 25), the partial pressure of arterial carbon dioxide ($PaCO_2$) was 50.1 ± 6.0 mmHg (95 % CI 47.2–53.1) in the control group and 47.6 ± 4.8 mmHg (95 % CI 45.2–50.0) in the NHF (40 % O_2, 40 L/min) group ($P = 0.018$) [15]. In pediatric dental patients, the lowest peripheral capillary oxygen saturation values during treatment were higher in the NHF group (2 kg/L/min up to a maximum of 30 L/min) compared to the control group ($P < 0.05$) [17]. In addition, 10 patients in the control group compared to 3 patients in the NHF group required jaw lifting to relieve upper airway obstruction and facilitate spontaneous breathing ($P < 0.05$). In adult dental patients in which sedation was induced by bolus administration of midazolam (0.05 mg/kg) followed by continuous administration of propofol (target blood concentration: 1.2–2 μg/mL), there was a significant difference between the partial pressure of carbon dioxide ($PaCO_2$) and oxygen (PO_2) between the Nasal Cannula groups (5 L/minute through a conventional nasal cannula) and NHF (50 L/min) groups ($P < 0.05$) indicating that NHF therapy prevented hypoxia compared to control treatment [18].

4. Discussion

This review is the first scoping review to summarize the efficacy of Nasal high-flow to prevent hypoxia and hypercapnia during dental treatment with sedation. Alterations in the $PaCO_2$ are rarely measured during surgical procedures. However, at least one study found that the $PaCO_2$ was lower in patients that received NHF therapy compared to controls [15]. In that study, the $PaCO_2$ was measured once, at the 10 min time point after the beginning of the dental procedure in obese patients with intellectual disabilities. The findings from two RCTs [17,18] suggested that NHF therapy can prevent upper airway obstruction and improve the respiratory condition of pediatric dental patients under sedation. The use of NHF in pediatric dental patients significantly improved the lowest peripheral capillary oxygen saturation values during treatment, reduced the need for intervention to relieve upper airway obstruction, and facilitated spontaneous breathing. Furthermore, NHF therapy prevented hypoxia in adult dental patients. In a letter to the editor concerning the article by Higuchi et al. [15], several key points were made regarding the clinical implications of the criteria for defining hypoxemia, interpretation of interventions such as chin lift, explanation for head position, and the occurrence rate of hypoxia during procedural sedation for dental treatment [19]. In another letter to the editor [20]

Table 1
Study characteristics of clinical study included in the scoping analysi

Source	Country	Design	Primary outcome	Other outcome (s)	Randomization groups	No. of patients randomized	Journal	Procedure	Sedation	Patients	Significant
Higuchi et al. [15]	Japan	A randomized crossover trial	Minimum SpO2	Incidence of hypoxemia	Treatment group, NHF 40 L/min 40 % Oxygen vs nasal cannula 5 L/min	18	J Oral Maxillofac Surg	Dental procedure	Sedation was induced using propofol and maintained at a bispectral index of 50–70	Intellectual disability patients	p = 0.0052 primary outcome
Sago et al. [17]	Japan	A randomized controlled trial	Need for intervention	lowest peripheral capillary oxygen saturation	Treatment group, NHF 30 L/min vs nasal cannula 5 L/min	30	J Oral Maxillofac Surg	Dental procedure	Bolus of 1 mg/kg of propofol intravenously, followed by continuous infusion at 5–12 mg/kg/hour.	Pediatric patients	p < 0.05 promary, secondary outcome
Sago et al. [18]	Japan	A randomized controlled trial	Minimum SpO2	Need for intervention	Treatment group, oxygen at 5 L/minute nasal cannula, 30 L/minute NHF, 50 L/minute through the NHF	30	J Oral Maxillofac Surg	Dental treatment	Midazolam (0.05 mg/kg) followed by continuous administration of propofol (target blood concentration, 1.2–2 mg/mL)	Adults patients	p < 0.05 promary, secondary outcome

concerning the article by Sago et. al. [18] suggestions were also made regarding the interpretation of hypercapnia occurrence, the influence of mouth opening, and the need for better insight into hemodynamic data during sedation.

The clinical usefulness of NHF in dental treatment during sedation was also recently demonstrated in a case report of a 5-year-old female who was diagnosed with caries and pulpitis [21]. She received dental treatment under intravenous sedation with midazolam and target control infusion (TCI) with propofol, with an effect-site concentration (Ce) of 1.6–2.0 mg/mL, sedation level of four, and a NHF cannula with a fraction of inspired oxygen (FiO_2) of 1.0 and a flow rate of 10 L/min. No obvious airway obstruction or desaturation was reported during her treatment.

Nasal high flow is advantageous for respiratory management during dental treatment under sedation for several reasons. During sedation, the upper airway anatomy may be the dominant factor governing upper airway collapsibility, due to significant impairment of neural mechanisms that control compensatory neuromuscular responses [1]. As a result, a 3–6 cmH_2O increase in the pharyngeal critical pressure (P_{CRIT}) – a measure of upper airway collapsibility – can occur during sedation [2]. NHF therapy may be beneficial for maintaining upper airway patency during dental procedural sedation, since it can produce positive pressures equivalent to the pressure required to open the airways, depending on the flow rate [6]. Positional changes, such as neck flexion and bite (mouth) opening which can cause upper airway obstruction, occur frequently during procedural sedation for dental treatment and oral maxillofacial surgery. Neck flexion decreases pharyngeal size and increases passive P_{CRIT} in anesthetized patients [4,22]. Neck flexion with a 10-degree deviation from the neutral position, reportedly increases the passive P_{CRIT} by 4.9 ± 3 cmH_20 [4]. It is essential to keep the mouth open during oral maxillofacial surgical procedures and dental treatment; however, this may cause obstruction [2,23]. Mouth opening impacts mandibular movement similar to neck flexion, and thus decreases the space enclosed by the maxilla, mandible, and cervical vertebrae and increases the soft tissue volume inside the bony box, similar to neck flexion [2,22]. NHF therapy may have the advantage of producing positive pressure to open the upper airway equivalent to the degree of closure caused by mouth opening and neck flexion.

4.1. Limitation

In this scoping review, our literature search was focused specifically on dentistry. As a result, we found a very limited number of RCTs that assessed the effect of NHF during dental procedures that required sedation. Furthermore, compared to other RCTs that require procedural sedation [24–27], there are several mechanical factors including positional changes that influence upper airway patency during dental procedures.

5. Conclusions

In dental treatment and oral maxillofacial surgery under procedural sedation, the treatment site shares a portion of the upper airway. Therefore, in addition to the risk of upper airway obstruction due to the influence of anesthesia on neuromuscular function, other mechanical factors, such as mouth opening and neck flexion may increase the risk of upper airway obstruction. NHF induces several cmH_2O of positive pressure that can eliminate upper airway obstruction due to positional change and can, therefore, be used as a supplementary respiratory management tool. Furthermore, CO_2 wash-out during NHF reduces the risk of various hypercapnia-induced secondary complications.

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Declaration of Competing Interest

There are no conflicts of interest to declare for all authors.

References

[1] Ayuse T. Understanding mechanism of upper airway obstruction. Masui 2010;59(Suppl:):S81–101.
[2] Ayuse T, Inazawa T, Kurata S, Okayasu I, Sakamoto E, Oi K, et al. Mouth-opening increases upper-airway collapsibility without changing resistance during midazolam sedation. J Dent Res 2004;83(9):718–22.
[3] Inazawa T, Ayuse T, Kurata S, Okayasu I, Sakamoto E, Oi K, et al. Effect of mandibular position on upper airway collapsibility and resistance. J Dent Res 2005;84(6):554–8.
[4] Walsh JH, Maddison KJ, Platt PR, Hillman DR, Eastwood PR. Influence of head extension, flexion, and rotation on collapsibility of the passive upper airway. Sleep 2008;31(10):1440–7.
[5] Pinkham M, Burgess R, Mundel T, Tatkov S. Nasal high flow reduces minute ventilation during sleep through a decrease of carbon dioxide rebreathing. J Appl Physiol 1985;126(4):863–9. 2019.
[6] Pinkham M, Tatkov S. Effect of flow and cannula size on generated pressure during nasal high flow. Crit Care 2020;24(1):248.
[7] Mazmanyan P, Darakchyan M, Pinkham MI, Tatkov S. Mechanisms of nasal high flow therapy in newborns. J Appl Physiol 1985;128(4):822–9. 2020.
[8] Roca O, Hernandez G, Diaz-Lobato S, Carratala JM, Gutierrez RM, Masclans JR, et al. Current evidence for the effectiveness of heated and humidified high flow nasal cannula supportive therapy in adult patients with respiratory failure. Crit Care 2016;20(1):109.
[9] Renda T, Corrado A, Iskandar G, Pelaia G, Abdalla K, Navalesi P. High-flow nasal oxygen therapy in intensive care and anaesthesia. Br J Anaesth 2018;120(1):18–27.
[10] Rajan S, Joseph N, Tosh P, Kadapamannil D, Paul J, Kumar L. Effectiveness of transnasal humidified rapid-insufflation ventilatory exchange versus traditional preoxygenation followed by apnoeic oxygenation in delaying desaturation during apnoea: a preliminary study. Indian J Anaesth 2018;62(3):202–7.
[11] Berlin D, Singh I, Barjaktarevic I, Friedman O. A technique for bronchoscopic intubation during high-flow nasal cannula oxygen therapy. J Intensive Care Med 2016;31(3):213–5.
[12] Maggiore SM, Idone FA, Vaschetto R, Festa R, Cataldo A, Antonicelli F, et al. Nasal high-flow versus Venturi mask oxygen therapy after extubation. Effects on oxygenation, comfort, and clinical outcome. Am J Respir Crit Care Med 2014;190(3):282–8.
[13] Sztrymf B, Messika J, Mayot T, Lenglet H, Dreyfuss D, Ricard JD. Impact of high-flow nasal cannula oxygen therapy on intensive care unit patients with acute respiratory failure: a prospective observational study. J Crit Care 2012;27(3). 324 e9-13.
[14] Mishima G, Sanuki T, Revie J, Pinkham M, Watanabe T, Kurata S, et al. Nasal high flow improves ventilation during propofol sedation: A randomized cross-over study in healthy volunteers. Respir Physiol Neurobiol 2020;277:103429.
[15] Higuchi H, Takaya-Ishida K, Miyake S, Fujimoto M, Nishioka Y, Maeda S, et al. Comparison of oxygen saturation between nasal high-flow oxygen and conventional nasal cannula in obese patients undergoing dental procedures with deep sedation: a randomized crossover trial. J Oral Maxillofac Surg 2021;79(9):1842–50.
[16] Tricco AC, Lillie E, Zarin W, O'Brien KK, Colquhoun H, Levac D, et al. PRISMA extension for scoping reviews (PRISMA-ScR): checklist and explanation. Ann Intern Med 2018;169(7):467–73.
[17] Sago T, Watanabe K, Kawabata K, Shiiba S, Maki K, Watanabe S. A nasal high-flow system prevents upper airway obstruction and hypoxia in pediatric dental patients under intravenous sedation. J Oral Maxillofac Surg 2021;79(3):539–45.
[18] Sago T, Harano N, Chogyoji Y, Nunomaki M, Shiiba S, Watanabe S. A nasal high-flow system prevents hypoxia in dental patients under intravenous sedation. J Oral Maxillofac Surg 2015;73(6):1058–64.
[19] Cheng Y, Shao LJ, Tian T, Xue FS. Comparing performance of nasal high-flow oxygen and conventional nasal cannula in obese patients undergoing dental procedures with deep sedation. J Oral Maxillofac Surg 2021;79(11):2180–1.
[20] Albores J, Barjaktarevic I, Berlin D, Esquinas AM. Predictability of prevention of hypoxia by nasal high-flow system in dental procedures. J Oral Maxillofac Surg 2016;74(2):225.
[21] Feng YP, Hsueh CT, Yang TS, Wong CS. Sedation for out-patient dental procedures in a child with recent upper respiratory inflammatory problems: Usefulness of high-flow nasal cannula. J Dent Sci 2018;13(3):283–4.
[22] Isono S, Tanaka A, Tagaito Y, Ishikawa T, Nishino T. Influences of head positions and bite opening on collapsibility of the passive pharynx. J Appl Physiol 2004.
[23] Meurice JC, Marc I, Carrier G, Series F. Effects of mouth opening on upper airway collapsibility in normal sleeping subjects. Am J Respir Crit Care Med 1996;153(1):255–9.
[24] Douglas N, Ng I, Nazeem F, Lee K, Mezzavia P, Krieser R, et al. A randomised controlled trial comparing high-flow nasal oxygen with standard management for conscious sedation during bronchoscopy. Anaesthesia 2018;73(2):169–76.
[25] Conway A, Collins P, Chang K, Kamboj N, Filici AL, Lam P, et al. High flow nasal oxygen during procedural sedation for cardiac implantable electronic device procedures: a randomised controlled trial. Eur J Anaesthesiol 2021;38(8):839–49.
[26] Thiruvenkatarajan V, Dharmalingam A, Arenas G, Wahba M, Liu WM, Zaw Y, et al. Effect of high-flow vs. low-flow nasal plus mouthguard oxygen therapy on hypoxaemia during sedation: a multicentre randomised controlled trial. Anaesthesia 2021.
[27] Nay MA, Fromont L, Eugene A, Marcueyz JL, Mfam WS, Baert O, et al. High-flow nasal oxygenation or standard oxygenation for gastrointestinal endoscopy with sedation in patients at risk of hypoxaemia: a multicentre randomised controlled trial (ODEPHI trial). Br J Anaesth 2021;127(1):133–42.