



Hypoxemia during procedural sedation in adult patients: a retrospective observational study

L'hypoxémie pendant la sédation chez le patient adulte: une étude observationnelle rétrospective

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Abstract

Purpose Since 2010, new guidelines for procedural sedation and the Helsinki Declaration on Patient Safety have increased patient safety, comfort, and acceptance considerably. Nevertheless, the administration of sedatives and opioids during sedation procedures may put the patient at risk of hypoxemia. However, data on hypoxemia during procedural sedation are scarce. Here, we studied the incidence and severity of hypoxemia during procedural sedations in our hospital.

Methods A historical, single-centre cohort study was performed at the University Medical Centre Utrecht (UMCU), a tertiary centre in the Netherlands. Data from procedural sedation in our hospital between 1 January 2011 and 31 December 2018 (3,459 males and 2,534 females; total, 5,993) were extracted from our Anesthesia Information Management System. Hypoxemia was defined as peripheral oxygen saturation < 90% lasting at least two consecutive minutes. The severity of hypoxemia was calculated as area under the curve. The relationship between the severity of hypoxemia and body mass index

(BMI), American Society of Anesthesiologists (ASA) Physical Status classification, and duration of the procedure was investigated. The primary outcome was the incidence of hypoxemia.

Results Twenty-nine percent of moderately to deeply sedated patients developed hypoxemia. A high incidence of hypoxemia was found in patients undergoing procedures in the heart catheterization room (54%) and in patients undergoing bronchoscopy procedures (56%). Hypoxemia primarily occurred in longer lasting procedures (> 120 min) and especially in the latter phases of the procedures. There was no relationship between severity of hypoxemia and BMI or ASA Physical Status.

Conclusions This study showed that a considerable number of patients are at risk of hypoxemia during procedural sedation with a positive correlation shown with increasing duration of medical procedures. Additional prospective research is needed to investigate the clinical consequences of this cumulative hypoxemia.

Résumé

Objectif Depuis 2010, les nouvelles lignes directrices pour la sédation procédurale et la Déclaration d'Helsinki concernant la sécurité des patients ont considérablement augmenté la sécurité, le confort et l'acceptation des patients. L'administration de sédatifs et d'opioïdes pendant les interventions sous sédation peut toutefois mettre le patient à risque d'hypoxémie. Cependant, les données concernant l'hypoxémie pendant une sédation procédurale sont rares. Ici, nous avons étudié l'incidence et la sévérité de l'hypoxémie pendant la sédation procédurale dans notre hôpital.

Méthode Une étude de cohorte historique monocentrique a été réalisée au Centre médical universitaire d'Utrecht

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(UMCU), un centre tertiaire aux Pays-Bas. Les données des sédations procédurales réalisées dans notre hôpital entre le 1^{er} janvier 2011 et le 31 décembre 2018 (3459 hommes et 2534 femmes; au total, 5993 patients) ont été extraites de notre système de gestion de l'information en anesthésie. L'hypoxémie a été définie comme une saturation périphérique en oxygène < 90 % durant au moins deux minutes consécutives. La sévérité de l'hypoxémie a été calculée en tant que surface sous la courbe. Les relations entre la sévérité de l'hypoxémie et l'indice de masse corporelle (IMC), la classification du statut physique selon l'American Society of Anesthesiologists (ASA) et la durée de l'intervention ont été étudiées. Le critère d'évaluation principal était l'incidence d'hypoxémie.

Résultats Vingt-neuf pour cent des patients sous sédation modérée à profonde ont développé une hypoxémie. Une incidence élevée d'hypoxémie a été observée chez les patients subissant des interventions en salle d'hémodynamie (54 %) et chez les patients subissant des bronchoscopies (56 %). L'hypoxémie est principalement survenue lors d'interventions plus longues (> 120 min) et particulièrement dans les phases plus tardives des interventions. Aucune relation n'a été observée entre la sévérité de l'hypoxémie et l'IMC ou le statut physique ASA.

Conclusion Cette étude a démontré qu'un nombre considérable de patients sont à risque d'hypoxémie pendant la sédation procédurale, une corrélation positive ayant été démontrée avec une durée prolongée des interventions médicales. D'autres recherches prospectives sont nécessaires pour étudier les conséquences cliniques de cette hypoxémie cumulée.

Keywords procedural sedation · hypoxemia · respiratory complications · safety

Because of exponential growth in diagnostic and therapeutic minimally invasive interventions, the demand for procedural sedation has increased considerably. Traditionally, procedural sedation was considered to be of secondary importance in relation to the intervention itself and was performed by a nurse or physician who was also involved in performing or assisting the intervention. The hazards and risks of procedural sedation were accepted as calculated risk. One of the first alarming reports was by Quine *et al.* in 1995 on the morbidity and mortality in gastrointestinal endoscopy under sedation.¹ In their 14,149 patients, 64 cases of cardiorespiratory complications with four associated mortalities were identified. Nevertheless, at that time, monitoring of patients was uncommon and specific competences for the sedation practitioner were not

defined. The first international guidelines on sedation were published at the beginning of this millennium, and the Helsinki Declaration on Patient Safety in Anesthesiology by the European Board of Anaesthesia (EBA) and European Society of Anaesthesiology (ESA) was established in 2010.² The EBA, ESA, and Canadian Anesthesiologist's Society proposed updated guidelines in 2018 and 2021 to improve patient safety during procedural sedation.^{3–5} These recommendations contain guidelines regarding careful patient selection, training of staff, drugs, monitoring, recovery, and a scale to assess the level of sedation to improve safety.

During procedural sedation, potent sedatives and analgesics are administered with the associated risk of potential deleterious hemodynamic and respiratory complications. Studies by Schilling *et al.*, Metzner *et al.*, and Vaessen *et al.* identified the cardiopulmonary risks associated with procedural sedation and also showed a positive relationship between the comorbidity of patients and the duration of procedural sedation to cardiopulmonary complications.^{6–8} This associated risk of potential respiratory complications is illustrated by the increase of claims regarding mortality in and outside the operating room: during anesthetic care outside the operation room, claims because of severe respiratory adverse events were two times more common than similar claims related to in-operation room procedures (44% vs 20%).⁷

Although the professional approach towards procedural sedation and its safety has been increased, data on hypoxemia during procedural sedation are limited. Saunders *et al.* performed a meta-analysis on patient safety during procedural sedation with a focus on capnography in 2017.⁹ The analyzed articles displayed hypoxemia below 90% and 95% for over 15 sec, and most studies showed hypoxemia < 85%. Nevertheless, they did not analyze specific patient subgroups. Data providing constructive evaluation of the severity of hypoxemia are lacking.

We therefore investigated data available from our own anesthesia database and focused on hypoxemia during procedural sedation.

Methods

Type of study

We performed a single-centre historical cohort study at the University Medical Centre Utrecht (UMCU), a tertiary centre in the Netherlands. The local ethics committees waived the need to obtain historical informed consent (UMCU Medical Research Ethics Committee, protocol number 19-815/C, approved 17 December 2019).

The article adheres to the *Strengthening the Reporting of Observational Studies in Epidemiology* (STROBE) recommendations.¹⁰

Patients

Data of all procedures under moderate-to-deep level of sedation in adults (age >18 yr) between 1 January 1 2011 and 31 December 2018 were collected. All data were anonymized before analysis.

The preprocedural condition of all patients was investigated and documented according to standard pre-anesthesia evaluation under final responsibility of the Anesthesia Department.^{5,11} Patients were screened for a difficult airway, obstructive sleep apnea, obesity, pulmonary hypertension, and other high-risk cardiac and pulmonary diseases. All patients were continuously observed and monitored with non-invasive blood pressure, peripheral oxygen saturation (SpO₂), a continuous three lead electrocardiogram, respiratory rate, and waveform capnography. Oxygen was supplemented at a rate of 2–5 L·min⁻¹ using a nasal cannula. Sedation was mostly performed using propofol together with alfentanil or remifentanyl. A limited number of procedures were performed using ketamine or any combination of these drugs. By local protocol, all sedation procedures were aimed at moderate to deep sedation, using an Observer Assessment of Alertness/Sedation Score (OAA/S score)¹² of 3 to 2, regardless of their ASA Physical Status.⁶ Procedures with minimal to no sedation were not included in the data, as these procedures were not supported by the anesthesiology department. All patients were asked to fast six hours in advance and abstain from liquids two hours in advance.¹³

All moderate to deep sedations were performed by our institutional team, which consists of sedation practitioners and (attending) anesthesiologists. Sedation practitioners performed all procedural sedation under either indirect supervision of an anesthesiologist who was available immediately if required or direct supervision in case of high-risk patients, such as morbid obese patients with ASA IV. All sedation practitioners were anesthetic nurses with additional training and certification in the management of patients under moderate to deep sedation including initiating and dosing sedatives, monitoring patients, airway management skills, and treating cardiopulmonary complications until the arrival of the supervising anesthesiologist.⁶ If necessary, endotracheal intubation was performed under direct supervision or by the attending anesthesiologist.

Data collection

The following information was collected from the Anesthesia Information Management System (AIMS) (Anstat, Carepoint B.V., the Netherlands) and patient electronic medical records: age, body mass index (BMI), sex, ASA Physical Status classification, type of procedure and medical specialty, duration of procedure, oxygen saturation values, and respiratory in-procedure complications and interventions: hypotension, intubation, use of supraglottic airway, use of face mask ventilation, insertion of oral airway, or performing chin lift or jaw thrust. Data on complications and interventions were obtained from the AIMS and patient records. Each complication was regarded as a separate event. Our AIMS records the oxygen saturation every minute. To reduce the risk of artifacts possibly resulting from the sampling rate of one value per minute by the AIMS, hypoxemia was defined as oxygen saturation < 90% lasting for two or more consecutive minutes. We calculated the area under the curve (AUC) as previously shown,¹⁴ with a small adaption in time period. For each hypoxemic event, time in minutes, magnitude of oxygen desaturation, and AUC (by multiplying duration in minutes and the drop in saturation under 90%) were determined. For example, a desaturation of five minutes of 88% provided an AUC of 10 (five minutes × 2%). For further analysis, patients were divided into subgroups by medical specialty (gastroenterology, cardiology, and pulmonology). All other disciplines were combined to one “other” group because of small group sizes. Missing values were retrieved through medical record screening. To address potential bias, possible uncertainties in data collection were discussed among several researchers. Other physiologic data such as heart rate and blood pressure were not collected since these were not the focus of the current investigation.

Primary and secondary outcomes

The primary outcome was the incidence of hypoxemic events. The individual AUC values were accumulated per patient. Thereafter, the accumulated AUC per patient were summed for each subgroup (medical specialty). The AUC was used as a surrogate outcome for risk assessment of procedural sedation. Secondary outcome measures were the duration of the procedure per subgroup, lowest mean saturation per subgroup, and intraprocedural respiratory complications and interventions.

Statistical analysis

Statistical analysis was performed using SPSS version 23 (IBM, Chicago, IL, USA). Analysis was performed on the following groups: ASA Physical Status, BMI, specialty of physician performing the procedure, and duration of procedure. Duration of the procedure was grouped into categories of 30 min. BMI was stratified into two groups (< 25 or ≥ 25 kg·m⁻²). Distribution of data were identified using skewness and kurtosis, and the Kolmogorov–Smirnov test. Differences among subgroups were analyzed using Student's *t* test (BMI) or one-way analysis of variance (ANOVA) with Bonferroni post-hoc analysis (procedure duration) if data were normally distributed. Non-normally-distributed data were analyzed using the Mann–Whitney U test (medical specialty), Friedman's ANOVA (normalized AUC), or mixed models in SPSS (ASA Physical Status). Data were considered statistically significant if $P \leq 0.05$. A normalized AUC was calculated for the cardiology group because the range of procedure durations was wide. Therefore, the procedures were divided into groups with a duration lasting from 60 up to > 210 min, containing a time window of 30 min each. To calculate the normalized AUC, the AUC was divided by the number of patients in each group. All tables were constructed according to the statistical reporting and table construction guideline by the *Canadian Journal of Anesthesia*.¹⁵

Results

Primary outcome

There was no sedation-related mortality in the 5,993 patients included. Data were missing for BMI in 23 patients.

Table 1a displays patient characteristics. Table 1b displays the number of procedures, the incidence of hypoxemia, and the duration of the procedures for the four groups. Almost 30% of the sedated patients developed a desaturation $< 90\%$ for at least two consecutive minutes. The most respiratory desaturations occurred during procedures performed by cardiologists and pulmonologists (54% and 56%, respectively, desaturated at least two minutes consecutively). The median duration of the procedures was significantly higher in the cardiology group (median, 178 min; 95% confidence interval [CI], 175 to 183) than in the pulmonology group (median, 54 min; 95% CI, 115 to 136; $P < 0.001$), gastroenterology group (median, 40 min; 95% CI, 125 to 136; $P < 0.001$) and “other” group (median, 78 min; 95% CI, 86 to 121; $P < 0.001$).

Rapid growth of sedation procedures and BMI

The number of procedures grew rapidly between 2011 and 2018: from 116 procedural sedation procedures in 2011 to 1,859 procedures in 2018. Additionally, the distribution of ASA Physical Status scores shifted towards ASA III, as in 2011 31% of procedures were scored ASA III compared with 51% in 2018. Regardless of this increase, ASA score and hypoxemia were not significantly related. Although we found an increase in the total number of patients with a BMI > 25 kg·m⁻² (26% of all patients in 2011 vs 49% of all patients in 2018), a higher BMI and the incidence of hypoxemia were not significantly related.

Severity of oxygen desaturation

The Figure 1 displays the incidence of hypoxemic events in the four groups. It shows that cardiology procedures frequently took > 120 min, whereas in other groups the procedures were shorter. As the Figure suggests a relationship between the length of duration of procedure and an increased incidence of hypoxemia in the cardiology group, we further explored this relationship. The median desaturation time was 86, 91, 142, 141, and 262 min for procedures taking 90–120, 120–150, 150–180, 180–210, and > 210 min, respectively. To investigate the effect of procedure duration on the risk of hypoxemia, we further investigated the data from the cardiology group since this group contained the longest procedures and the highest mean AUC (see Table 1). When normalized for group size, the AUC in the cardiology group seemed to increase as the number of desaturations increased: the median normalized AUC for all first desaturation events was 0.06 (95% CI, 0.11 to 0.24) compared with 2.22 (95% CI, -25 to 30) for all 18 desaturation events. This finding was statistically significant ($P < 0.001$).

We did not find any significant difference in lowest measured saturation between different medical specializations or different procedure durations.

Interventions during complications

Data collected from our complication database are displayed in Table 2. In the registration database, 402 complications and interventions were recorded. The most frequently registered intervention was the use of face mask ventilation. Only a few patients were registered to have undergone endotracheal intubation or insertion of a supraglottic airway.

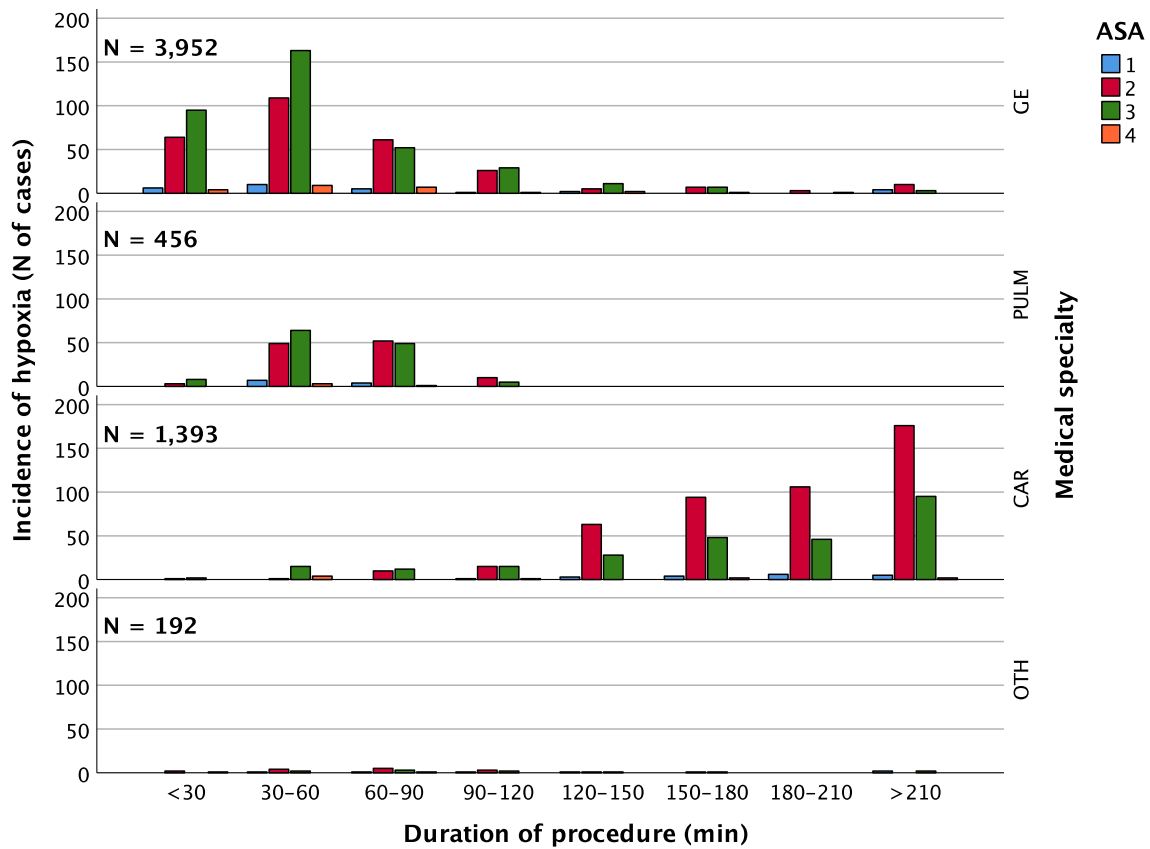


Figure 1 Incidence of respiratory desaturation subdivided by duration and ASA classification. ASA = American Society of Anesthesiologists Physical Status classification score; CAR = cardiology; GE = gastroenterology; PULM = pulmonology; OTH = other.

Discussion

Respiratory depression and/or upper airway obstruction causing hypoxemic events are well established risks and complications of moderate to deep sedation procedures. This historical cohort study confirms this risk of hypoxemia, as we found that 29% of the patients undergoing procedural sedation developed significant hypoxemia. It is important to notice that these events occurred in a setting which fully complies with international sedation guidelines.^{3,5,16} In addition, patient health conditions were assessed preoperatively and sedation was performed by well-trained and experienced sedation practitioners using adequate monitoring and postprocedural care.

We decided to use both incidence and AUC to better reflect the potential harm of hypoxemia. Niklewski *et al.* introduced the use of the AUC of desaturations to integrate the number, depth, and duration of oxygen desaturations.¹⁴ By integrating these factors into one outcome measure, one might better understand the magnitude of desaturation and therefore the potential risk of the associated hypoxemia. Since the clinical importance of hypoxemia is uncertain, we displayed the dimensions of hypoxemia in our

population by AUC. By normalizing the AUC by the number of patients in the specialization subgroups, we were able to draw better conclusions from our findings. In the cardiology group, the normalized AUC significantly increased as the number of hypoxemic events increased. Nevertheless, this finding is up for discussion, since patient numbers decreased as procedure duration increased.

Our reported incidence of hypoxemia is slightly higher than reported in most other papers, reporting hypoxemia incidences between 12 and 33%.¹⁷⁻²⁰ Differences could be explained by discrepancies in populations, with more patients scoring ASA III and IV in the present cohort. Also, conducted procedures in this study cohort often lasted longer than those reported in the literature.¹⁷⁻²⁰ Differences in the incidence of hypoxemia can also be elucidated by definition of hypoxemia, which is only more stringent in one other study that exceeds our incidence: > ten seconds of < 90% saturation (33% desaturations).¹⁹ Although our two-minute cut-off is arbitrary, we believe this cut-off point reduces the number of artifacts regarding desaturations compared with lower cut-off times. Within two minutes, a nonrelevant desaturation will certainly be adequately responded to and a relevant desaturation is likely to persist. A desaturation of less than two minutes

TABLE 1 Patient characteristics

(a) Patient characteristics					
Total patients n					5,993
Male n (%)					3,459 (59%)
Age (yr)					
Mean (SD)					59 (15)
BMI (kg·m ⁻²)					
Mean (SD)					26 (5)
Range					13–60
ASA Physical Status n (%)					
I					281 (5)
II					2,894 (48)
III					2,638 (44)
IV					179 (3)
Subgroup	GE*	Cardio [†]	Pulm [‡]	Other	Total
(b) Respiratory data					
Total patients	3,952	1,393	456	192	5,993
N					
Total patients with hypoxemic events n (%)	698 (18)	755 (54)	255 (56)	35 (18)	1,743 (29)
Duration of the procedure in minutes					
Mean (SD)	52 (41)	178 (73)	56 (20)	84 (55)	83 (73)
Median [IQR]	40 [36]	178 [80]	54 [27]	79 [63]	54 [79]
Range	507	561	141	334	562

The respiratory data are subdivided in the three main specializations and one “other” group. A hypoxemic event is defined as a peripheral saturation (SpO₂) < 90% lasting for at least two minutes

IQR = width of interquartile range; SD = standard deviation

*Gastroenterology; [†]Cardiology; [‡]Pulmonology

TABLE 2 Registered respiratory interventions and complications

Event	Number of patients	Percentage of total sedations
Total interventions/complications	402	
Face mask ventilation	319	5%
Requirement for intubation	6	0.1%
Supraglottic airway	8	0.1%
Insertion of an oral airway or performing chin lift	8	0.1%
Other	61	1%

The data show the number of registered interventions and complications during procedural sedation. The “others” group includes application of non-breathing masks or venturi masks, increasing O₂ flow through nasal cannula, and hypotension

would likely have a higher incidence; however, it is doubtful that such short hypoxemia is of additional clinical relevance. Additionally, in our institution, procedures will not start before all patient monitoring measurements are accurate and reliable. Therefore, we believe that a cut-off point of two minutes is a suitable measure for relevant hypoxemia. Saunders *et al.* created two cut-off points for mild and severe desaturations.⁹ Since the AUC gives an

estimate of the harm of the hypoxemia, we targeted one cut-off point (< 90%) as sufficient.

Our study did not show a relationship between hypoxemia and BMI. This surprising finding replicates the findings of a study by Khan *et al.*,²¹ in which there was no increase in respiratory complications in patients with a BMI > 30 kg·m⁻². Even though our database lacked information on the BMI of 23 patients, we are convinced

that these missing data have a limited influence on our findings because our total study population is extensive. The absent effect of BMI on the risk of developing hypoxemia might be explained by careful selection of patients allowed to undergo procedural sedation. Patients at high risk for hypoxemia were occasionally rejected for procedural sedation. These patients were instead treated under general anesthesia with secured airways to minimize the risk of hypoxemia. This screening strategy is in line with the international guidelines for procedural sedation.^{3,5}

One of the reasons for the considerable number of hypoxemic events is not only the growing number of sedation procedures in the last eight years, but probably also the relative increase of patients with comorbidity in the last five years, expressed by higher ASA scores. In 2019, Behrens *et al.*¹⁹ showed that patients with an ASA score of greater than II had an increased risk for overall complications during procedural sedation. Sub-analysis for hypoxemia in individuals with ASA > II was unfortunately not included. We did not find any correlation between ASA Physical Status classification and hypoxemia, which concurs with earlier data published by Vaessen *et al.*⁶

We also observed an increase in the duration of sedation procedures over time. This may be because minimally invasive examinations and treatments have been developed in several medical specialties. Although we found no relationship between lowest measured oxygen saturation values and the length of the procedure, the incidence of hypoxemia in procedures > 90 min was more likely in the second half of the procedure. This is illustrated by the fact that the median desaturation time lies in the second half of the procedure in each category. This could be associated with accumulation of sedative medication in combination with reduction of the functional residual capacity due to development of atelectasis as a result of more superficial breathing for a longer period of time. Since any given local anesthetic might wear off in the second half of the procedure, the sedation practitioner might have to give extra pain medication, contributing to such accumulation. Another contributing factor might be the risk of airway obstruction, which is common in lengthy procedures under general anesthesia in spontaneously breathing patients. It is therefore of great importance that monitoring is reliable and precise. The use of capnography has been advocated to prevent severe oxygen desaturation.^{4,9}

In our institute, procedural sedation is mainly performed using propofol in combination with alfentanil or remifentanil. The use of medication in our institution did not change between 2011 and 2018. It has been previously shown that propofol is safe to use in endoscopy.^{22,23} Nevertheless, accumulated doses of opioids may have a negative effect on respiratory saturation due to bradypnea.²⁴ This could have affected our incidence of

hypoxemia, especially in the long-lasting procedures. The relationship between medication and the severity of hypoxemia was not investigated in this study since all sedation in our institute is performed to gain the same OAA/S scores and the dosage of opioids is therefore deemed adequate.

Our complication database showed interventions such as face mask ventilation, supraglottic airway placement, or intubation. Since our institution works with sedation practitioners under indirect supervision of an anesthesiologist, the sedation practitioners start treating hypoxemia by increasing oxygen supply, performing manual maneuvers such as jaw thrust, and reducing the level of sedation. Such interventions are possibly underreported in our database and could have influenced the incidence of desaturations and interventions. As soon as the anesthesiologist has arrived, he or she decides whether the patient needs intubation or a supraglottic airway. Therefore, such interventions will probably not occur within our two-minute cut-off point for relevant hypoxemia. In other recent studies regarding adverse events in moderate procedural sedation, face mask ventilation was the second most used intervention in treating adverse events.²⁵ We did not investigate the use of reversal agents, but we can only advocate adequate skill of providing sufficient face mask ventilation to whomever performs procedural sedation.

The incidence of hypoxemia was higher than anticipated. Previous studies showed that respiratory events are the most frequent complication during procedural sedation.^{1,7} In the Dutch system, sedation practitioners normally work under indirect supervision of an anesthesiologist. A study by Koers *et al.* showed that only 0.04% of patients who received sedation by trained sedation practitioners experienced an unfavourable outcome.²⁶ There are no studies that compare clinical outcome of procedural sedation performed by anesthesia providers with that performed by non-anesthesia providers. Nevertheless, in most institutions, sedation is not provided by anesthesia providers. Hypothetically, the incidence of hypoxemia during sedation might be higher in such institutions. In addition, although our AIMS registers which anesthesiologist is responsible, it does not register the presence of an anesthesiologist in the room, so we cannot compare outcome of procedures with or without direct supervision. Therefore, we can only strongly advise that all sedation providers work with adequate monitoring equipment and maintain airway management skills.

The clinical importance of severe hypoxemia is debatable. Theoretically, severe hypoxemia leads to anaerobic metabolism and circulatory changes, contributing to ischemia. Many clinicians believe that hypoxemia alone does not damage other organs.

Nevertheless, patients with coexisting disease are more at risk for hypoxemic cardiac or cerebral damage.²⁷ Also, a prospective study by Aguirre *et al.* showed a greater negative impact on neurobehavioral tests 24 hr after surgery in patients that had desaturations on cerebral level.²⁸ Currently, the clinical effects, if any, of relatively short duration hypoxemia are unknown.

This study has certain limitations. First, this is a historical study using data from our AIMS. Therefore, we are dependent on the accuracy of automatic and manual registry. This might result in an underestimation of respiratory risk for patients undergoing procedural sedation. Overestimation of the respiratory risk is unlikely. The risk of artifacts is small because monitor alarms trigger rapid action by the sedation practitioner. In addition, the sedation practitioner will only start procedural sedation when a reliable SpO₂ signal is present. Secondly, the sedation practitioner manually enters all intraprocedural interventions in the AIMS. This might lead to an additional underreporting and bias of such interventions. Third, we did not include information regarding patient follow-up, since this was not the focus of this study. Therefore, no conclusions can be drawn from this data about the clinical outcome of patients in the long-term. Also, we did not include data on blood pressure or heart rate. Therefore, we cannot conclude if hypoxemic events were preceded by circulatory changes. Additionally, our study consists of combined data of clinically admitted patients and day treatment procedural sedations during an almost ten-year window. This makes it impossible to assess all clinical histories. A fourth limitation is that the AUC does not differentiate between short but severe hypoxemia or long but mild hypoxemia. This makes the clinical interpretation of the AUC variable. The fifth limitation is possible population bias. In the Netherlands, trained sedation practitioners are allowed to conduct procedural sedation in ASA I–II patients if the risks for complications are deemed low. Since we are a tertiary centre, it is possible that the ASA I–II patients in our study might have had a relatively higher risk for hypoxemia than those in other centres, as there seems to be a need for anesthesia guidance.

Nevertheless, we are convinced that our data are relevant for increasing awareness, knowledge, and acknowledgement of hypoxemia related to procedural sedation. Our findings might be of value in the improvement of respiratory care during procedural sedation, and education or guidance of sedation practitioners in procedural sedation.

Conclusion

Approximately one third of patients undergoing procedural sedation developed hypoxemia. Patients requiring sedation for a longer time had an increased risk of developing hypoxemia. Nevertheless, mortality and complications or respiratory interventions during procedures appear to be relatively rare. Since the risk of hypoxemia was considerable during moderate to deep sedation, adequate monitoring by waveform capnography, deliberate patient selection and trained staff with face mask ventilation skills are mandatory to ensure patient safety, especially in longer lasting procedures. Additional prospective research with adequate follow-up is required to investigate the clinical consequences, such as 30-day complication rate, of these significant hypoxemic events.

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