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Waste gas scavenging during inhalational pediatric anesthesia in Belgium: results of a nationwide questionnaire survey

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Abstract : *Background:* Volatile anesthetic agents remain a cornerstone in pediatric anesthesia. Studies have shown that staff exposure to waste anesthetic gases is highest during inhalational induction in this subgroup.

Aim: This survey was undertaken to assess the current practice in pediatric anesthesia, waste anesthetic gas scavenging and the related air quality measurements in Belgian anesthesiology departments.

Method: The 17-question electronic survey using Questback™ was sent to the chairmen of all 94 Belgian departments of anesthesiology. This survey assessed the department's characteristics and the departmental practices regarding induction and maintenance of anesthesia in pediatric patients. Special attention was given to which type of breathing system was used in pediatric anesthesia and the presence of gas scavenging systems both in and out of the operating room. Further areas of interest were the type and frequency of waste anesthetic gas concentration measurements performed in the hospital.

Results: Seventy-one departments (75,5%) responded. Gas scavenging during mask induction in pediatric anesthesia is rather infrequently applied in Belgian hospitals and the open breathing system remains the circuit of choice. During maintenance of pediatric anesthesia, gas scavenging application is twice higher compared to the induction phase. N_2O remains a popular agent during induction in pediatric anesthesia. Waste anesthetic gases concentration measurements were conducted in only 25% of all Belgian hospitals and we found a strong relationship between use of gas scavenging during mask induction and implementation of waste anesthetic gases concentration measurements in the operating room.

Conclusion: Despite associated occupational health outcomes, the open system without gas scavenging and use of N_2O remain popular in pediatric anesthesia, especially during induction. Therefore, we advocate the implementation of standardized European exposure limits, maximal use of waste anesthetic gases scavenging in and outside the operating room and frequent waste anesthetic gases concentration measurements in the operating room to reduce occupational exposure.

Keywords : survey ; occupational exposure ; anesthetics ; inhalation ; nitrous oxide ; scavenger system, breathing systems.

Introduction

Volatile anesthetic agents are a cornerstone in pediatric anesthesia. Their rapid and reliable pharmacological characteristics produce hypnosis without the need for an intravenous line prior to induction. This is especially advantageous in younger children who may become traumatized by unnecessary needle manipulations. Traditionally, in many countries an open breathing system without gas scavenging is used for induction with volatile agents in pediatric patients (1). This increases occupational exposure to waste anesthetic gases dramatically

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during pediatric anesthesia. Consequently, studies have shown that staff exposure is highest during inhalational induction, in the Post Anesthesia Care Unit and in non-operating theatre situations due to improper room ventilation (2, 3).

Parallel to the increased use of volatile anesthetics, there remain concerns about the effects of acute and chronic waste anesthetic gas exposure to perioperative staff members.

A broad spectrum of adverse health outcomes, ranging from Parkinson's disease and allergic dermatitis to teratogenicity and congenital anomalies (4-6), may be linked to occupational exposure to waste anesthetic gases.

To date, worldwide uniform threshold-limit concentrations for volatile anesthetics have not been defined (7). In the United States, the National Institute for Occupational Health and Safety recommends a strict exposure limit of 25 parts per million measured as time-weighted average for nitrous oxide (N_2O), and 2 parts per million for halogenated anesthetics (without concomitant N_2O exposure) (7). In the European Union however, the determined upper limits of exposition are less strict and vary considerable between countries (8).

Nevertheless, occupational chronic waste anesthetic gases exposure should be as low as possible. Therefore, waste anesthetic gases scavenging to limit exposure to health care providers has gained importance.

Waste anesthetic gases scavenging by air-suction devices removes the air/gas mixture emitted through the overflow valves of the breathing circuit´s expiratory limb, thereby preventing the mixture to get into the surgical air space (8). Furthermore, it is important to take measurements of waste anesthetic gases concentration in the operating room.

Therefore, the primary aim of this survey was to investigate the application of air-suction devices in pediatric anesthesia, both in and out of the operating room, and the practice of waste anesthetic gases concentration measurements in Belgian anesthesiology departments. Secondary outcome measures included which type of anesthesia drugs and techniques are mainly used during induction and maintenance of pediatric anesthesia in Belgian hospitals.

Methods

A list of all Belgian general and university hospitals (N = 94) was obtained from the Belgian Association of Hospitals website (www.hospitals.be/hospitals-list). The chairmen of all 94 departments of anesthesiology in Belgium were invited by email to participate in the present survey. They all received a survey link, through Questback (https://www.questback.com), an online survey tool. The survey consisted of a covering letter and a questionnaire including 17 questions assessing the department's characteristics and the departmental practices regarding induction and maintenance of anesthesia in pediatric patients (addendum). Special attention was given to which type of breathing system was used and if air-suction devices were applied during pediatric anesthesia. The survey also consisted of questions on the hospital´s policy regarding non-operating room anesthesia and type and frequency of waste anesthetic gases concentration measurements performed at locations of non-operating room anesthesia. The questions were developed by dr. Ory and subsequently reviewed and approved by all investigators. The first email was sent on May 29, 2015. Reminders were sent to non-responders weekly (4 times). The remaining non-responders received an identical written questionnaire by post. Responses were collected between May 29, 2015 and October 15, 2015. Descriptive statistics were used to summarize numeric responses. A chi-square test for independence was performed to test for possible relationship between use of gas scavenging (yes vs no) during induction of children aged 1-4 y, and implementation of waste anesthetic gases concentration measurement (yes vs. no) in the operating room. A chi-square test was also performed to test for possible relationship between use of N_2O and type of hospital (general vs. academic). A $P < 0.05$ was considered significant.

Results

During the period May 2015-October 2015, responses were received from 71 departments (response rate 75.5%). The characteristics of participating hospitals are listed in Table 1.

Breathing systems, the use of gas scavenging and waste anesthetic gases concentration measurements

Characteristics of breathing systems and use of gas scavenging for induction and maintenance of general anesthesia within each age group are presented in respectively figure 1a and 1b. Anesthesia in children less than 1 year old was performed in 68 out of 71 responding hospitals and above 1 year old in all responding hospitals. Gas scavenging during mask induction in children aged < 1 y was applied in only 50% of the departments (Fig. 1A). During induction in children aged 1-4

Table 1

Characteristics of participating centers

	All hospitals	University hospitals	General hospitals
	N (%)	**N (%)**	**N (%)**
Number of hospitals	71	7	64
Response rate	71/94 (76)	7/11 (64)	64/83 (77)
Number of pediatric cases/week			
<10	5	0	5
10 - 20	26	0	26
21 - 50	28	2	26
> 50	12	5	7
Uniform technique of induction		7/7	51/63
No uniform technique of induction ➔ Difference in:		0/7	12/63
open vs. closed system		-	8/12
induction of anesthesia		-	6/12
maintenance of anesthesia		-	3/12

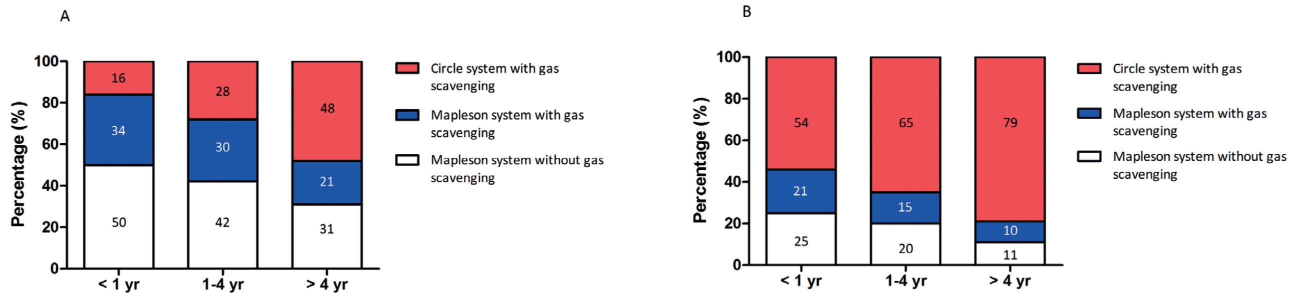

Fig. 1. — Type of breathing system used for induction and maintenance within each age group. Breathing systems and the use of gas scavenging in the different age categories during induction (A) and during maintenance (B). Data are presented as percentages.

y and >4 y, respectively 58% and 69% of the 71 responding departments applied gas scavenging (Fig. 1A). During maintenance of anesthesia (Fig. 1B), gas scavenging was more frequently applied (i.e. 75%, 80% and 89% for respectively children aged <1 y, between 1 and 4 y and > 4 y). The past 5 years, waste anesthetic gases concentration measurements were performed in 18 departments (25.5%). In 46 departments (64.5%) no measurements were taken and in 7 departments (10%) data were missing. Waste anesthetic gases concentration measurements were performed by 3 out of 7 university hospitals (43%) and 15 out of 63 general hospitals (24%). After exclusion of departments with missing data, significantly more departments where gas scavenging was used during mask induction implemented waste anesthetic gas concentrations measurements (for children aged 1 - 4 y : $X^2 = 4.716$; $P = 0.0298$).

Choice of Mapleson systems

The type of Mapleson breathing system used in the responding hospitals is presented in Figure 2. Mapleson C and D systems are the most popular breathing systems with respectively 19 (27%) and 20 (28%) hospitals. Mapleson B and F systems are used in respectively 12 (17%) and 7 (10%) hospitals and Mapleson A and E systems are used in only a few hospitals. Four (6%) hospitals never use a Mapleson breathing circuit and 4 (6%) hospitals were not able to give information on this topic. A gas scavenging system connected to the Mapleson breathing system during induction of pediatric anesthesia is used in only 29 of 63 (46%) hospitals. More specifically, 15 out of the 31 hospitals using a Mapleson B or C circuit do not scavenge waste anesthetic gases during induction of pediatric anesthesia.

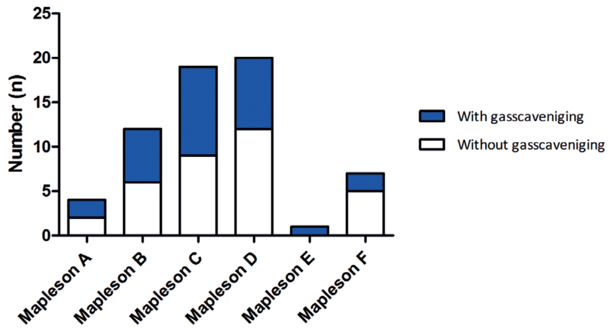

Fig. 2. — Mapleson systems. The type of Mapleson breathing system with or without gas scavenging used in the responding hospitals. Data are presented as absolute values.

Anesthetic agents during induction and maintenance of anesthesia

Characteristics of anesthetic agents used for induction and maintenance of general anesthesia classified by age group are presented in respectively Figure 3A and Figure 3B. Data of 1 hospital were missing (1%). Intravenous induction of anesthesia was the standard in 2% of children < 4 y and in 16% of children > 4 y (Figure 3A). For maintenance of anesthesia, 99% of the hospitals used sevoflurane for children < 4 y. Maintenance of anesthesia for children > 4 y was accomplished with sevoflurane in 97% of the hospitals and with intravenous anesthesia (propofol) in 2% of the hospitals (Fig. 3B). Use of N_2O was highest during induction (50%, 55% and 46% of the hospitals for respectively children aged < 1 y, between 1 and 4 y and > 4 y) (Fig. 3A) and dropped during maintenance of anesthesia (respectively 39%, 45% and 45% of the hospitals (Fig. 3B). N_2O was used in only 2 of 7 responding academic hospitals (28%) and in 37 of 64 general hospitals (57%). However, there was no statistically significant difference between the use of N_2O and the type of hospital ($X^2 = 2.476$; N = 71, p = 0.115).

Non-operating room anesthesia

Procedures under general anesthesia in pediatric patients outside of the operating room are performed in 43 responding hospitals (60.5%). Volatile anesthetics (sevoflurane and/or N_2O) were used outside of the operating room in 33 responding hospitals (46.5%). Gas scavenging systems connected to the breathing system outside of the operating room were only available in 6 of these hospitals (18%).

N_2O/oxygen sedation is administered by non-anesthesiologists in 46 hospitals (65%). In only 5 hospitals (11%), these gas mixtures are definitely administered with a gas scavenging system connected to the breathing system. In 8 hospitals (17.5%), data are missing and in 33 hospitals (71.5%), these gas mixtures are not administered with a gas scavenging system.

Discussion

This survey, collected from the chairmen of the departments of anesthesiology from all over Belgium, provides an insight into the application of gas scavenging in Belgian hospitals where pediatric anesthesia is performed. Moreover, it represents the practice of waste anesthetic gases concentration measurement in Belgian hospitals and the current state of Belgian pediatric anesthetic practice.

Gas scavenging during mask induction in pediatric anesthesia is rather infrequently applied in Belgian hospitals and is in relationship with the patient's age (lowest in children aged <1 y). During maintenance of pediatric anesthesia, gas scavenging application is twice higher compared to the induction phase. Our findings are in line with those of a previous pediatric anesthesia survey published by Marsh et al. in 2009. They showed that formal scavenging was employed by only 60%

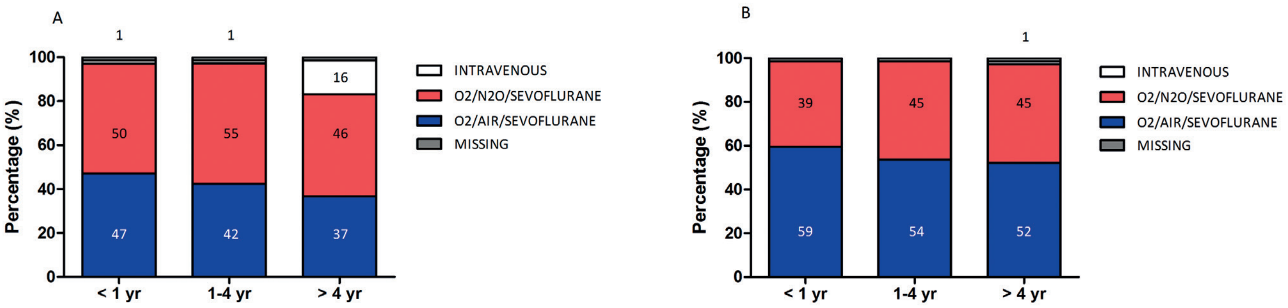

Fig. 3. — Induction agent and maintenance agent, stratified by age. Anesthetic mixture in the different age categories during induction (A) and during maintenance (B). Data are presented as percentages (rounded off). Missing data were equal to 1.4% in all groups, except for the induction at <1 y. (1.5%) and are not depicted in the figures. Data above the bars represent values for Intravenous agents.

of anesthesiologists in the UK and that the circle system only appears to be popular for maintenance, particularly in older children (1). In contrast, use of a circle system for induction of neonates and young children was less frequently reported in this survey compared to ours (respectively 2% versus 16% and 5% versus 27%). This difference may be explained by the implementation of improved modern pediatric circle systems in daily practice. These are considered to be safe and efficient breathing systems for small infants and neonates (9).

According to this survey, waste anesthetic gases concentration measurements were conducted in only 25% of all Belgian hospitals. These results are in line with a USA survey published by Boiano et al. in 2016 (10). In this survey, only 30% of respondents confirmed that waste anesthetic gases measurements were conducted in USA hospitals on a continuous or periodic basis (10). We found a strong relationship between use of gas scavenging during mask induction and implementation of waste anesthetic gases concentration measurement in the operating room. This implies that implementation of waste anesthetic gases concentration measurement may increase the awareness for occupational exposure to waste anesthetic gases and may promote the implementation of gas scavenging systems in pediatric anesthesia.

Mapleson B and C systems are the most inefficient Mapleson systems (very high fresh gas flow rates are needed to prevent rebreathing), especially during spontaneous ventilation, resulting in maximum environmental pollution (11). Nevertheless, these are the circuits of choice in almost half (44%) of Belgian hospitals. A possible reason might be historical and the fact that these circuits tend to be more compact when performing a mask induction. Furthermore, these circuits are used without a waste anesthetic gases scavenging system connected to the breathing system in more than half of these hospitals, resulting in a huge occupational health risk in Belgian hospitals.

This survey offers an insight into the Belgian practice of sedation and general anesthesia performed in children outside of the operating room.

We believe occupational exposure to waste anesthetic gases outside of the operating room may carry a potential health risk since gas scavenging systems are available in less than 20% of these remote locations in Belgian hospitals. Therefore, in order to overcome these health risks, the use of total intravenous anesthesia techniques has been advocated for pediatric non-operating room anesthesia (12).

Pediatric anesthesiologists are at higher risk of exposure to waste anesthetic gases, especially during inhalational induction (2). Gauger et al. suggest that this might cause a higher prevalence of spontaneous abortion in pediatric female anesthesiologists (13). A recent systematic review also states that occupational exposure to waste anesthetic gases is associated with a statistically significant increase in genotoxic and mutagenic damage among operating room personnel (14).

Finally, immunological research also suggests an increase in pro-inflammatory cytokines production (IL-6, IL-8) associated with chronic occupational waste anesthetic gases exposure (15).

Obviously, the type of breathing system used and the presence of scavenging have an influence on waste anesthetic gases exposure (2).

This survey demonstrates that the preferred induction agent varies markedly with age. Almost every child between 0 and 4 years old in Belgium is induced with sevoflurane in a mixture of air/oxygen or N_2O/oxygen, whereas 16% of respondents indicate the use of an intravenous induction for children older than 4 years old. A UK survey published in 2015 by Sury et al. also found that an inhalational induction with sevoflurane was preferred for infants and preschool age children. In contrast, 73% of all UK school age children were induced with propofol (16).

According to this survey, N_2O use in Belgium is highest during induction and in patients between 1 and 4 years old. Sury et al. also showed that N_2O is used most frequently during induction and in preschool age children in the UK (more than 50%) (16). The ADARPEF survey also showed a high rate of co-administering N_2O during induction and maintenance of anesthesia by 74% and 71% respectively (17). In contrast, Husum et al. concluded in a Scandinavian survey that use of N_2O is decreasing in Scandinavian countries despite significant differences in the anesthetic practice regarding N_2O between different countries (18). This survey however did not differentiate between adult and pediatric anesthesia.

Our study shows some limitations. First, this is a questionnaire-based survey and the response rate was 75.5%. Hence, there is a possible danger of selection bias. Still, the response rate is similar to other questionnaire-based surveys. Second, this survey was not addressed to the entire cohort of Belgian anesthesiologists but only to the chairmen of the Belgian departments of anesthesiology. However, since pediatric anesthesia is uniformed in most Belgian hospitals according to this survey, we believe this data reflect well the current practice in pediatric anesthesia. Furthermore, it is the task of the head of the department to coordinate the policy regarding occupational waste anesthetic gases exposure. Third, we divided our study population in three groups based on age and not on the weight, which might have caused difficulties for some responders in choosing the right category of breathing system. Fourth, some responders might not have understood completely the different Mapleson systems despite the fact a drawing of the different systems was included in the survey. Hence, there may be a risk of response bias.

In conclusion, despite significant improvements in modern circle systems, the open system without gas scavenging remains the most commonly used breathing system in pediatric anesthesia in Belgium, especially during induction. Furthermore, although its use has been a subject of controversy, N_2O seems to remain a common component of an inhalational technique in pediatric anesthesia in Belgium. We advocate for the implementation of standardized European exposure limits, maximal use of scavenging in and outside the operating room and frequent waste anesthetic gases measurements in the operating room in order to reduce occupational chronic waste anesthetic gases exposure and the risk of corresponding adverse health outcomes.

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