Effect of Low-flow Anesthesia Education on Knowledge, Attitude and Behavior of the Anesthesia Team

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The aim of this study was to evaluate the effect of education on the knowledge, attitude and behavior of anesthesiology staff and residents towards low-flow anesthesia. The staff and residents in the Department of Anesthesia and Reanimation, Zonguldak Karaelmas University were given theoretical and practical training in delivering low-flow anesthesia. To evaluate their attitudes and behaviors toward low-flow anesthesia, we collected data during the 6 months before training, during the first 3 months after training, and at 4–6 months after training. Anesthesia follow-up records, operation time, volatile anesthetic agent used, and the amount (in liters) of fresh gas flow mid-anesthesia were recorded in all three stages. A total of 3,158 patients received general anesthesia and inhalation anesthesia was used in 3,115 of these patients. Our study group consisted of 2,752 patients who had no absolute or relative contraindications to low-flow anesthesia. While the mean fresh gas flow was 4.00 ± 0.00 L/min before training, this level dropped to 2.98 L/min in the first 3 months after training, and to 3.26 L/min in the following 3 months. The mean fresh gas flow was significantly lower at the two post-training assessments than before training ($p < 0.05$). In conclusion, low-flow anesthesia may be used more frequently if educational seminars are provided to anesthetists. The use of low-flow anesthesia may increase further by allocating more time to this technique in anesthesia training programs provided at regular intervals.

Key Words: education, fresh gas flow speed, low-flow anesthesia

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Low-flow anesthesia is a technique that uses a rebreathing system to return at least 50% of the exhaled gases to the lung of the patient after eliminating CO_2 [1,2]. Its popularity and use is increasing worldwide owing to the increasing importance of cost control, increased environmental awareness, and the availability of advanced anesthesia equipment [3–7].

Due to Turkey's changing health system, health expenses have increased rapidly since 2000. While the proportion of total public and private health sector expenses in relation to the gross national product was 6.1% in 1999, this figure rose to 6.6% (8,248 million Turkish Lira; 6,723 million US$) in 2000 [8,9]. These expenses increased to 7.4% of gross national product in 2005 and 8.0% in 2007. From 2005 to 2007, the increase in health spending was disproportionately larger than the country's growth, such that the fraction of the gross national product devoted to such purposes

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increased by 30% [8]. These rapidly increasing health expenses and the high costs associated with modern inhalational anesthetic agents have made cost-control an increasingly critical requirement in delivering anesthesia [10,11].

Anesthesia in Turkey is typically administered with comprehensive monitoring using advanced anesthesia machines and systems compatible with EN 740 standards [3]. However, the mean maximum level of fresh gas flow in this country is also rather high at 6 L/min and the advantages of rebreathing are not fully utilized [3]. By merely changing clinical practice, it may be possible to achieve more efficient use of existing equipment [3].

In our study, we aimed to evaluate the impact of a low-flow anesthesia seminar on the low-flow anesthesia knowledge, attitude and behaviors of anesthesiology staff and residents towards low-flow anesthesia at Zonguldak Karaelmas University.

Methods

Our study was conducted between April 25, 2007 and April 24, 2008, with the approval of the Zonguldak Karaelmas University Hospital Ethics Committee. Within the scope of the study, a theoretical and practical low-flow anesthesia training seminar was provided for the five staff and 13 residents working at the Anesthesia and Reanimation Department on October 24, 2007 (Figure 1). Anesthesia training was included in the regular resident curriculum in the Anesthesia and Reanimation Department at Zonguldak Karaelmas University. The theoretical seminar was based on the low-flow anesthesia book edited by J.A. Baum [12] and constituted a 60-minute lecture. During the following week, all assistants were given one-to-one practical training with a patient. None of the residents or anesthesia staff received additional training on low-flow anesthesia at any point after the official training session. Anesthesiology residents and staff were not pre-informed about the study; hence, their routine anesthesia practices were not affected. All operating theaters had isoflurane, sevoflurane and desflurane vaporizers. Data were collected after April 24, 2008.

The first aim of the study was to examine the knowledge of anesthesiology staff and residents regarding low-flow anesthesia. A 100-point theoretical test was administered before the seminar (October 23, 2007) (Appendix). The test was administered to the same residents 3 months (January 24, 2008) and 6 months (April 24, 2008) after the first test to assess short-term and long-term changes in their knowledge (Figure 1).

The attitudes and behaviors of anesthesiology staff and residents toward low-flow anesthesia were assessed by evaluating anesthesia records [4]. The operation time, volatile anesthetic agent used, and mid-anesthesia fresh gas flow (in liters) were determined from anesthesia records. Patients with absolute or relative contraindications to low-flow anesthesia [12], those undergoing cardiac surgery or receiving two volatile anesthetics, and newborns or infants intubated via an uncuffed tube were not included in this analysis.

The fresh gas flow for mid-anesthesia during the 6-month pre-training period (from April 25, 2007 to October 24, 2007) was determined from the anesthesia records. The post-training period was divided into two stages: the early stage (first 3 months: from

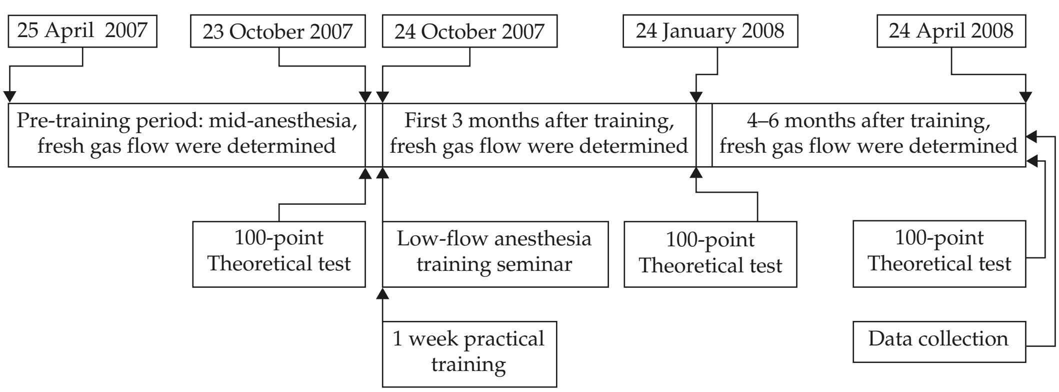

Figure 1. *Study design.*

October 24, 2007 to January 23, 2008) and the late stage (second 3 months: from January 24, 2008 to April 24, 2008). The anesthesia records of eligible patients who received anesthesia were used to identify mid-anesthesia total fresh gas flow (Figure 1).

All data obtained during the study were coded and computed using SPSS version 11.0 (SPSS Inc, Chicago, IL, USA). Results are given as mean ± standard deviation, while categorical data are presented as number and percentages. Continuous variables, including fresh gas flow during the three stages of the study and test scores, were assessed using *t* tests. Categorical data were assessed using χ^2 tests. A value of $p < 0.05$ was considered statistically significant.

Results

A total of 4,265 patients underwent operations during the study period. The anesthesia records of all patients showed that 743 patients received regional anesthesia while 364 received sedation and monitorized anesthesia care. Thus a total of 3,158 patients (74%) received general anesthesia during the study period. Forty-three patients received total intravenous anesthesia and 3,115 patients received inhalation anesthetics. In accordance with the exclusion criteria, 363 patients were ineligible for the analysis. Thus the study population comprised 2,752 patients (Figure 2).

The duration of anesthesia was shorter than 60 minutes or 90 minutes in 74 (2.7%) and 280 (10.2%) of the patients, respectively. During general anesthesia with inhalational anesthetics, 73% of the patients received sevoflurane, 24% received desflurane and 3% received isoflurane; the latter was most frequently used in neurosurgical cases.

A significant difference was found in terms of the use of volatile anesthetics among the three study periods ($p < 0.001$) (Table). After training, the use of isoflurane and desflurane increased, while the use of sevoflurane decreased. The use of desflurane increased significantly in the first 3 months after training when the use of low-flow anesthesia increased (Table) ($p < 0.001$).

An assessment of the operation time where volatile anesthetics were used showed that isoflurane (192.43 ± 97.89 min) was preferred over desflurane (135.05 ± 32.72 min) and that desflurane was preferred over sevoflurane (121.83 ± 37.90 min) in longer operations, during each of the three study periods ($p < 0.001$). No significant relationship was found between the study period and operation time.

Before training, the mean fresh gas flow was 4.00 ± 0.00 L/min, which decreased to 2.98 ± 1.20 L/min in the first period and to 3.26 ± 1.12 L/min in the second period. The mean fresh gas flow was significantly lower during both periods than that before training ($p < 0.001$). Comparison of the first and second time periods after training revealed that the use of mean fresh gas flow increased by 9% in the second period ($p < 0.001$) (Table).

Before training, the mean fresh gas flow was 4.00 ± 0.00 L/min for isoflurane, sevoflurane and desflurane; decreasing to 3.20 ± 1.16 L/min, 3.17 ± 0.99 L/min

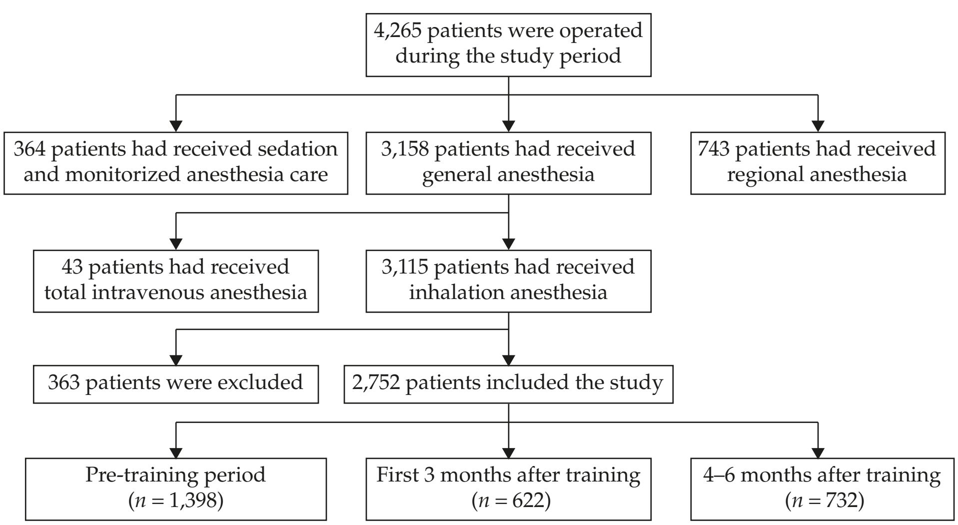

Figure 2. *Patient disposition.*

Table. Fresh gas flow and volatile anesthetics used at all stages ($n = 2{,}752$)*

	Pre-training ($n = 1{,}398$)	0–3 months post-training ($n = 622$)	4–6 months post-training ($n = 732$)
Flow (L/min)	4.00 ± 0.00	$2.98 \pm 1.20^{\dagger}$	$3.26 \pm 1.12^{\dagger\ddagger}$
≤2	0 (0)	183 (29.4)†	154 (21.0)†‡
≤1	0 (0)	89 (14.3)†	79 (10.8)†‡
Flow (L/min)			
Isoflurane	4.00 ± 0.00	$3.20 \pm 1.16^{\dagger}$	$2.84 \pm 1.27^{\dagger\ddagger}$
Sevoflurane	4.00 ± 0.00	$3.17 \pm 0.99^{\dagger}$	$3.51 \pm 0.86^{\dagger\ddagger}$
Desflurane	4.00 ± 0.00	$2.64 \pm 1.42^{\dagger}$	$2.60 \pm 1.43^{\dagger}$
Anesthetic used			
Isoflurane	11 (0.8)	35 (5.6)†	44 (6.0)†‡
Sevoflurane	1,113 (79.6)	362 (58.2)†	514 (70.2)†‡
Desflurane	274 (19.6)	225 (36.2)†	174 (23.8)†‡

*Data presented as mean ± standard deviation or n (%); †$p < 0.05$ versus pre-training; ‡$p < 0.05$ versus first 3 months after training.

and 2.64 ± 1.42 L/min, respectively in the first 3 months after training. The mean fresh gas flow was significantly lower when desflurane was used than when sevoflurane or isoflurane were used ($p < 0.001$). In the second 3-month period, the mean fresh gas flow for isoflurane, sevoflurane and desflurane was 2.84 ± 1.27 L/min, 3.51 ± 0.86 L/min and 2.60 ± 1.43 L/min, respectively. In this period, the mean fresh gas flow for sevoflurane was significantly higher than that using isoflurane or desflurane ($p < 0.001$).

The mean test score of staff and residents ($n = 13$) before training was 26.96 ± 11.35, which significantly increased to 65.86 ± 9.16 at 3 months ($p < 0.05$), and remained high (62.07 ± 8.90) at 6 months after training.

Discussion

Education is the core activity of academic anesthesia departments [13]. In our study, we significantly reduced our hospital's use of fresh gas flow during the 3 and 6 months after training. Using a practical and theoretical education program, we achieved a 25% reduction in mean fresh gas flow compared with the pre-training period. Low-flow anesthesia applications at a fresh gas flow rate of ≤2 L/min represented 29% of all anesthesia applications in the first 3 months and 21% for the next 3 months, whereas gas flow of ≤1 L/min was used in 14% and 11% of applications, respectively.

Owing to its low cost, low-flow anesthesia is becoming increasingly widespread. Body et al [4] reported that the fresh gas flow rate used in their hospital was 1.8 L/min. Tohmo et al [7] reported that the frequency of rebreathing system use for anesthesia practice in Finland increased from 62% in 1995 to 83% in 2002, while the fresh gas flow rate decreased from 3 L/min to 1–2 L/min at the same time. Kennedy et al [6] assessed the changes in fresh gas flow in a training hospital in New Zealand in 2001 and 2006, and reported that the mean fresh gas flow rate was 1.5 L/min in 2001 and decreased to 1.27 L/min in 2006, representing a 35% reduction in fresh gas flow over 4 years. In contrast, in a tertiary care center in India, low-flow anesthesia was used in only 4.1% of all routine anesthesia cases [14]. In our study, the mean fresh gas flow decreased from 4.00 L/min to 2.98 L/min after the training program. In addition, the prevalence of low-flow anesthesia in routine anesthesia practice increased from 0% to 35% after training.

Desflurane is an ideal agent for low-flow anesthesia owing to its pharmacokinetic properties. Many studies have reported that using desflurane in combination with low fresh gas flow decreases the overall costs, giving this expensive agent some advantages compared with other cheaper inhalation agents [3,15–18]. We observed an increase in the use of desflurane, which was proportional to the increase in use of low-flow anesthesia in our department. In our study, the mean fresh gas flow when using desflurane was significantly lower than that observed when using sevoflurane. A possible explanation for this observation is that the lowest sevoflurane flow suggested by the US Food and Drug Administration is 2 L/min, as used in our hospital. The common belief that low-flow anesthesia can be more effective with desflurane might be another reason for the significantly lower fresh gas flow obtained with desflurane [4]. This could explain why the use of low-flow anesthesia with sevoflurane was largely discontinued at 4–6 months after training in our study, despite the lack of any changes in fresh gas flow when using desflurane.

However, an increase in the mean fresh gas flow was seen in the latter 3-month period. Similarly, Body et al [4] reported an increase in mean fresh gas flow at 6 and 7 months after a training seminar. They reported that educational programs are less effective than practice manuals. However, the practice manuals for volatile anesthetics are said to be less effective than those for other drugs [4]. It was demonstrated that enhanced education and individualized feedback can change anesthesiologists' practice patterns [4]. In addition to training programs, researchers also emphasize the need for regular feedback about anesthetic agent preferences, fresh gas flow and cost-cutting programs [4,19,20]. However, the importance of frequent theoretical and practical training sessions on the positive impact on practice and behavior patterns should be noted. The findings in our study and those of Body et al [4] regarding efficiency are noteworthy. In clinics such as ours, where more priority should be given to low-flow fresh gas anesthesia, regular training should encourage its use in regular clinical practice.

A limiting factor in our study is that the attitudes and behaviors of senior anesthetists to low-flow anesthesia might influence the preference of residents.

In conclusion, low-flow anesthesia may be used more frequently if anesthetists are provided with regular training seminars. The use of low-flow anesthesia applications may increase further by allocating more time to this technique in anesthesia training programs provided at regular intervals.

References

1. Eger EI II. Uptake and distribution. In: Miller RD, ed. *Miller's Anesthesia*, 6th edition. Philadelphia: Elsevier Churchill Livingstone, 2005:131–53.
2. Baum JA, Aitkenhead AR. Low-flow anaesthesia. *Anaesthesia* 1995;50:37–44.
3. Tomatır E. Low-flow anesthesia and cost. *Anesthesia J* 2002;10:149–56. [In Turkish]
4. Body SC, Fanikos J, DePeiro D, et al. Individualized feedback of volatilee agent use reduces fresh gas flow rate, but fails to favorably affect agent choice. *Anesthesiology* 1999;90:1171–5.
5. Kennedy RR, French RA. An audit of anaesthetic fresh-gas flow rates and volatile anaesthetic use in a teaching hospital. *N Z Med J* 2003;116:U438.
6. Kennedy RR, French RA. Changing patterns in anesthetic fresh gas flow rates over 5 years in a teaching hospital. *Anesth Analg* 2008;106:1487–90.
7. Tohmo H, Antila H. Increase in the use of rebreathing gas flow systems and in the utilization of low fresh gas flows in Finnish anaesthetic practice from 1995 to 2002. *Acta Anaesthesiol Scand* 2005;49:328–30.
8. Economic Policy Research Foundation of Turkey, *Economic Stability Institute, Fiscal Monitoring Report 2008 February*. EPRFT, Ankara, 2008:21–35. [In Turkish]
9. Hamzaoğlu O, Özcan U. Finance of Health. *Health Statistics of Turkey 2006*, 1st edition. Ankara: Turkish Medical Association, 2005:93–105. [In Turkish]
10. Bach A, Böhrer H, Schmidt H, et al. Economic aspects of modern inhalation anesthetics with sevoflurane as an example. *Anaesthesist* 1997;46:21–8.
11. Boldt J, Jaun N, Kumle B, et al. Economic considerations of the use of new anesthetics: a comparison of propofol, sevoflurane, desflurane, and isoflurane. *Anesth Analg* 1998;86:504–9.
12. Tomatır E. Low flow anaesthesia: the theory and practice of low flow, minimal flow and closed system anaesthesia. In: Baum JA, ed. Tomatır E. tarns eds. 1st edition. Istanbul: Nobel Medicine, 2002. [In Turkish]
13. Dalsasso M, Grandis M, Innocente F, et al. A survey of 1000 consecutive epidural catheter placements performed by inexperienced anesthesia trainees. *Minerva Anestesiol* 2009;75:13–9.
14. Bangaari A, Bangia R, Puri GD. Prevalence of low-flow anesthesia and its cost comparison with other anesthesia techniques in an Indian tertiary care center. *Acta Anaesthesiol Taiwan* 2005;43:141–5.
15. Daniel M. Cost of volatile anaesthetic agents. *Br J Anaesth* 1996;76:45.
16. Bozkurt P. Low flow anaesthesia in clinical practice. In: Tomatır E. trans ed. *Low flow anaesthesia: the theory and practice of low flow, minimal flow and closed system anaesthesia*, 1st edition. Istanbul: Nobel Medicine, 2002: 250–3. [In Turkish]
17. Weiskopf RB, Eger EI 2nd. Comparing the costs of inhaled anesthetics. *Anesthesiology* 1993;79:1413–18.
18. Lee DJH, Robinson DL, Soni N. Efficiency of a circle system for short surgical cases: comparision of desflurane with isoflurane. *Br J Anaesth* 1996;76:780–2.
19. Cohen MM, Rose DK, Yee DA. Changing anesthesiologists' practice patterns. Can it be done? *Anesthesiology* 1996;85:260–9.
20. Rose DK, Cohen MM, Yee DA. Changing the practice of pain management. *Anesth Analg* 1997;84:764–72.

Appendix. Assessment of the knowledge, attitude and behavior of anesthesiologists and residents regarding low-flow anesthesia

Name/last name: Seniority (months):

1. Which of the formulae below is used to calculate oxygen uptake of the patient, as calculated during anesthesia? (Points: 2.5)
   a. Brody Formula b. Severinghaus Formula c. Lowe Formula
   d. Conway Formula e. Bohr Formula

2. Which of the formulae below is used to calculate nitrous oxide uptake of the patient, as calculated during anesthesia? (Points: 2.5)
   a. Brody Formula b. Severinghaus Formula c. Lowe Formula
   d. Conway Formula e. Bohr Formula

3. Which of the formulae below is used to calculate volatile anesthetic uptake of the patient, as calculated during anesthesia? (Points: 2.5)
   a. Brody Formula b. Severinghaus Formula c. Lowe Formula
   d. Conway Formula e. Bohr Formula

4. Which of the below is the rate of fresh gas flow in low-flow anesthesia? (Points:2.5)
   a. 2 L/min b. 1.5 L/min c. 1L/min d. 0.5 L/min e. 250 mL/min

5. Which of the below is the fresh gas glow in minimal-flow anesthesia? (Points: 2.5)
   a. 2 L/min b. 1.5 L/min c. 1 L/min d. 0.5 L/min e. 250 mL/min

6. Which of the below is the fresh gas flow in closed-system anesthesia? (Points: 2.5)
   a. 2 L/min b. 1.5 L/min c. 1 L/min d. 0.5 L/min e. 250 mL/min

7. Write down the aims of the initial high-flow period administered in low-flow anesthesia:
   1 ________________ (Points: 4)/2 ________________ (Points: 4)
   3 ________________ (Points: 4)/4 ________________ (Points: 4)

8. Write down the suggested values for maximum flow rate and fresh gas flow. (Points: 2.5)
   ________________ L/min ________________ L

9. Explain the concept of "long time constant" in low-flow anesthesia. (Points: 5)
   ____
   ____

10. What are the inhalation anesthetics that have relatively positive and relatively negative relationships with low-flow anesthesia?
    Relatively positive: ________________ (Points: 2.5)/Relatively negative: ________________ (Points: 2.5)

11. Which of the below is the minimal fresh gas flow approved by the US Food and Drug Administration for sevoflurane? (Points: 2.5)
    a. 2 L/min b. 1.5 L/min c. 1 L/min d. 0.5 L/min e. 250 mL/min

12. Write down six of the alien gases that may accumulate in the anesthesia system while administering low-flow anesthesia:
    1 ________________ (Points: 2.5)/2 ________________ (Points: 2.5)/3 ________________ (Points: 2.5)
    4 ________________ (Points: 2.5)/5 ________________ (Points: 2.5)/6 ________________ (Points: 2.5)

13. Write down at least three of the absolute contraindications for low-flow anesthesia:
    1 ________________ (Points: 3)/2 ________________ (Points: 3)/3 ________________ (Points: 3)

14. Write down at least three of the relative contraindications for low-flow anesthesia:
    1 ________________ (Points: 2.5)/2 ________________ (Points: 2.5)/3 ________________ (Points: 2.5)
    4 ________________ (Points: 2.5)/5 ________________ (Points: 2.5)/6 ________________ (Points: 2.5)

15. Define the effectiveness coefficient (Q_{eff}) for volatile anesthetics and write down its formula:
    a. Definition (Points: 3)
    b. Formula (Points: 3)

16. What factors increase the cost of administering low-flow anesthesia? Write down at least three:
    1 ________________ (Points: 3)/2 ________________ (Points: 3)/3 ________________ (Points: 3)