

ECONOMICS

Anesthesiology

1999; 90:1171-5

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Individualized Feedback of Volatile Agent Use Reduces Fresh Gas Flow Rate, but Fails to Favorably Affect Agent Choice

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Background: Cost reduction has become an important fiscal aim of many hospitals and anesthetic departments, despite its inherent limitations. Volatile anesthetic agents are some of the few drugs that are amenable to such treatment because fresh gas flow rate (FGFR) can be independent of patient volatile anesthetic agent requirement.

Methods: FGFR and drug use were recorded at the temporal midpoint of 2,031 general anesthetics during a 2-month preintervention period. Staff and residents were provided with their preintervention individual mean FGFR, their peer group mean, and educational material regarding volatile agent costs and low-flow anesthesia. FGFR and drug use were remeasured over a 2-month period (postintervention) immediately after this information ($N = 2,242$) and again 5 months later (delayed follow-up), for a further 2-month period ($N = 2,056$).

Results: For all cases, FGFR decreased from 2.4 ± 1.1 to 1.8 ± 1.0 l/min (26% reduction) after the intervention and increased to 1.9 ± 1.1 l/min (5% increase of preintervention FGFR) at the time of delayed follow-up. Use of more expensive volatile agents (desflurane and sevoflurane) increased during the study period ($P < 0.01$). In a subgroup of 44 staff members with more than five cases in all study periods, 42 members decreased their

mean FGFR after intervention. At delayed follow-up, 30 members had increased their FGFR above postintervention FGFR but below their initial FGFR. After accounting for other predictors of FGFR, the effectiveness of the intervention was significantly reduced at follow-up (28% reduction), but retained a significant effect compared to preintervention FGFR (19% reduction).

Conclusions: Although individual feedback and education regarding volatile agent use was effective at reducing FGFR, effectiveness was reduced without continued feedback. Use of more expensive volatile agents was not reduced by education regarding drug cost, and actually increased. (Key words: Attitude of health personnel; cost savings; healthcare costs; inhalation anesthesia.)

ANESTHESIOLOGISTS are aware of the current importance of hospital drug cost-minimization efforts. Yet, little information is available regarding more appropriate cost-utilization or cost-benefit analyses for nearly all anesthetic drugs. Because volatile agent use can be independent of drug delivery to the patient, there is an opportunity for cost minimization, without an apparent reduction in patient benefit or an increase in adverse events.

Reduction in anesthetic drug use has been attempted previously using practice guidelines, educational programs, and incentivized or restrictive drug purchasing.¹ Few studies have evaluated the effectiveness of feedback of an anesthesiologist's drug use on overall resource utilization,^{1,2} and fewer still have evaluated the effect of subsequently removing the feedback upon the effectiveness of cost minimization.^{2,3} Because of difficulties with recording volatile agent use, no previous study has evaluated the effectiveness of individualized feedback with the subsequent removal of that feedback on volatile agent use. This study was undertaken to assess the importance of information regarding a person's drug use and cost upon volatile anesthetic agent use and drug choice. The specific aims of the study were to determine the effectiveness of an education program on volatile agent use and drug choice, and to quantify the extent of

This article is featured in "This Month in Anesthesiology." Please see this issue of ANESTHESIOLOGY, page 7A.

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Received from the Departments of Anesthesia and Pharmacy, Brigham and Women's Hospital, Harvard Medical School, Boston, Massachusetts. Submitted for publication July 20, 1998. Accepted for publication December 1, 1998. Support was provided solely from institutional and/or departmental sources. Dr. Philip received lecture honoraria and travel reimbursement from Ohmeda Pharmaceuticals, Inc., Deerfield, Illinois, Abbott Laboratories, Inc., Chicago, Illinois, and Zeneca Pharmaceuticals, Inc., Wilmington, Delaware.

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regression or retention of effectiveness in the absence of further education.

Methods

With Institutional Review Board approval, the hard-copy anesthesia records of all patients undergoing surgery at Brigham and Women's Hospital during September and October 1996 (preintervention period) were evaluated for the volatile agent used and fresh gas flow rate (FGFR) at the temporal midpoint of the anesthetic. Patients were excluded from analysis if they underwent anesthesia for cardiac surgery, childbirth or its complications, or anesthesia at a non-operation room location, did not undergo general anesthesia, or were administered two volatile anesthetic agents. Staff and residents were not advised of the initial data collection.

In late March 1997, a detailed and physician-specific period of education was provided to all staff members and residents. Each was advised by letter from the department chairman of their mean FGFR, an estimate of volatile agent cost, and their relation to peer-group mean, derived from data from the preintervention period. Individuals were advised to use low-flow anesthesia and were provided with education regarding the suitability and economics of low-flow anesthesia and information on individual volatile agent cost. Individuals were advised to reduce FGFR to 1 l/min for isoflurane and desflurane and 2 l/min for sevoflurane. The flow rates were arbitrarily set and not developed by consensus, to avoid consensus-group membership as a confounding variable. The use of isoflurane, instead of sevoflurane or desflurane, was also advised. No specific indications for desflurane use were offered to the staff or residents, because consensus was not sought or obtained. The use of sevoflurane was requested to be only in outpatients and those undergoing a volatile agent induction. No other practice guidelines for volatile agents were provided during the study period. Individuals were advised that further data collection would be undertaken at a later, unspecified time.

In April and May 1997 (postintervention period) and September and October 1997 (delayed follow-up period) anesthesia records were again evaluated. Between the postintervention period and the delayed follow-up period, no further educational or provider-specific information was provided to individuals. Vaporizers for isoflurane and desflurane were available in every operating room. Sevoflurane vaporizers were available in 18 of 34

operating rooms, and additional vaporizers were available for any room on request. Company representatives were not informed of the study and were not permitted to have direct contact with the staff or residents.

Statistical Analysis

Two types of analysis were performed. First, all eligible patients were analyzed to estimate effectiveness of the intervention on all staff and residents (postintervention period) and to assess the regression or retention of effectiveness of the intervention over time (delayed follow-up period). Second, a group of 44 staff members were identified who had more than five patients in each study period, to quantify analysis across all three time periods.

Summary information is described as mean \pm SD. Comparisons were made using Student *t* test and two-way analysis of variance, as appropriate. Accounting for multiple comparisons was performed by Tukey-Kramer HSD. A multivariable model of FGFR was performed using forward stepwise linear regression. Variables were included based on perceived clinical relevance and an entry *P* value < 0.05 . Exit *P* value was defined as 0.01. Staff and residents were treated as random-effects variables, and interactions and potential confounding between variables were evaluated. All tests were two tailed and significance was assumed at *P* value < 0.05 . Statistical analysis was performed using JMP Software (Version 3.2.2; SAS Institute, Cary, NC).

Results

From the three time periods 12,856 patients who underwent surgical procedures were identified. After application of the exclusion criteria, 7,821 patients were eligible for entry into the study population. Data were available for 6,329 patients who were administered anesthesia by 76 staff anesthesiologists. Data were not available in the remaining 1,510 (19%) patients because of missing charts and missing or illegible data. Patients for whom data were not available were more likely to be outpatients ($P < 0.01$) and to have undergone shorter surgery ($P < 0.001$) than those for whom data were available. There was no difference in distribution across the surgical services between those for whom data were available and those for whom data were not.

Inpatients comprised 73% of the study population, with 6% of all patients undergoing operations less than 60 min in duration and 14% undergoing operations less

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Table 1. Comparison of Volatile Agent Utilization between the Three Time Periods for All Patients (N = 6329)

	Preintervention Period (N = 2031)	Postintervention Period (N = 2242)	Delayed Follow-up Period (N = 2056)
Flow (l/min)			
Mean \pm SD	2.4 \pm 1.1	1.8 \pm 1.0*	1.9 \pm 1.1*
25 th , 50 th , 75 th percentiles	2.0, 2.0, 3.0	1.0, 1.7, 2.0	1.0, 2.0, 2.5
≤ 1 l/min (%)	270 (13%)	656 (29%)*	585 (29%)*†
≤ 2 l/min (%)	1081 (53%)	1736 (77%)*	1483 (72%)*†
Flow (l/min)			
Isoflurane	2.4 \pm 1.0	1.8 \pm 0.9*	2.0 \pm 1.0*‡
Desflurane	2.0 \pm 1.1	1.3 \pm 1.0*	1.4 \pm 1.0*
Sevoflurane	2.7 \pm 1.1	2.2 \pm 0.9*	2.4 \pm 1.0*†
Inpatient drug use			
Isoflurane	1137 (76%)	1179 (73%)§	1039 (68%)‡§
Desflurane	256 (17%)	358 (22%)§	403 (26%)‡§
Sevoflurane	94 (6%)	88 (5%)	86 (6%)
N	1487	1625	1528
Outpatient drug use			
Isoflurane	186 (34%)	206 (33%)	187 (35%)
Desflurane	156 (29%)	160 (26%)	125 (24%)§
Sevoflurane	202 (37%)	251 (41%)	216 (41%)
N	544	617	528

* Significantly different from pre-intervention period ($P < 0.001$).† Significantly different from post-intervention period ($P < 0.05$).‡ Significantly different from post-intervention period ($P < 0.001$).§ Significantly different from pre-intervention period ($P < 0.01$).

than 120 min in duration. Volatile agent use was not randomly distributed across cases of different surgical durations, being longer for isoflurane (318 ± 210 min) than desflurane (244 ± 152 min) and sevoflurane (140 ± 93 min) ($P < 0.001$). Furthermore, admission status was predictive of volatile agent choice and FGFR ($P < 0.001$, table 1). There was an increase in the frequency of staff-only anesthesia during the study (10 vs. 27 vs. 23%; $P < 0.001$).

For all patients, mean FGFR was reduced after the intervention by 26% ($P < 0.001$, table 1). Mean FGFR increased in the delayed follow-up period by 5% of the preintervention FGFR ($P < 0.05$), and remained significantly reduced from the preintervention FGFR ($P < 0.01$). Conformation to flow guidelines increased after intervention (19 to 38%; $P < 0.001$) and remained increased at delayed follow-up (37%). There was a statistically significant trend for increased desflurane use for inpatients during the study, with an equivalent reduction in isoflurane use (table 1). Outpatient use of desflurane decreased with equivalent nonsignificant increases in sevoflurane and isoflurane. Overall, the use of more expensive volatile agents increased throughout the study (35 vs. 38 vs. 40%; $P < 0.01$).

Analysis of staff with more than five cases ($N = 44$), performed with or without residents, during all three

periods, revealed that in 42 individuals mean FGFR decreased after intervention. At delayed follow-up, 30 individuals increased their FGFR above postintervention flows. A linear regression model of FGFR in this group of 44 individuals was derived to determine whether the observed FGFR reduction, ascribed to the intervention, was due to confounding by patient or other factors that varied across the time periods. Although the intervention was an important determinant of FGFR, several other factors, including volatile agent used ($P < 0.001$), admission status ($P < 0.0001$), anesthesia provider ($P < 0.0001$), and anesthesia duration ($P < 0.0001$), also independently predicted FGFR, but did not confound the effect of the intervention on FGFR. There was an interaction between staff and period that was also predictive in the model ($r^2 = 0.33$). After accounting for these factors, there was a significant reduction in FGFR after the intervention from a mean of 2.4 ± 2.0 to 1.8 ± 1.8 l/min (28% of baseline; $P < 0.001$) and a significant increase in FGFR in the delayed follow-up period to 2.0 ± 2.1 l/min (9% of baseline; $P < 0.01$), but it remained significantly reduced from preintervention FGFR ($P < 0.01$). Staff and residents both independently determined FGFR. However, on average, staff had the same mean FGFR when working with residents, or alone.

Discussion

This study shows that education and provider-specific feedback of volatile agent use reduced volatile agent FGFR, but failed to reduce the frequency of use of more expensive volatile agents (sevoflurane and desflurane). Furthermore, this study found that a significant reduction in intervention effectiveness occurred when no further feedback was provided, but rates did not return to preintervention FGFR. Other investigators demonstrated greater reductions (55%) in FGFR (8 to 4 l/min) using only provider education,⁴ but lesser reductions in FGFR when trying to achieve flow rates of 1 l/min or less.^{1,3,5} These levels of cost reduction are important because anesthesia drug costs are approximately 5.6% of total hospital surgical costs⁶ and volatile agent costs are approximately 25% of total anesthesia drug costs.⁵ Educational programs have been shown to be less effective than practice guidelines for reducing most drug costs.^{3,7} Practice guidelines, however, have been shown to be less effective for volatile agents than for other drugs. Individual feedback further reduces drug cost.¹ At institutions in which feedback is ongoing, there is maintenance of the effectiveness of cost-reduction programs,¹ except where increased marketing efforts reduce effectiveness.³ Our observation that, without continued feedback, intervention effectiveness was diminished with time is consistent with previous literature for other anesthetic drugs.¹⁻³ Continued feedback is probably necessary to obtain greater, and more sustained, improvements in drug use.

Uniquely, we were unable to show any reduction in use of more expensive volatile agents (sevoflurane and desflurane), with desflurane use actually increasing after the intervention. We cannot explain why anesthesia providers did not reduce expensive volatile anesthetic agent use, despite the request to do so. Possibly, they chose a more expensive volatile agent because of a belief of greater clinical benefit, or because there was a belief that low-flow anesthesia is more easily conducted with desflurane.⁸ Cost reduction is most successful when strategies for flow reduction and the use of cheaper volatile agents are implemented. Thus, to be effective, a reduction in the use of expensive volatile agents may best be achieved by limitation of drug availability, initiation of strong institutional guidelines, and provision of educational material and individualized feedback. Because education and individualized feedback were ineffective at reducing use of more expensive volatile agents, alternative strategies should be devised and tested.

Cost-minimization programs can be effective at reducing anesthetic drug use, but may potentially increase adverse outcomes.⁹ We believe that patient adverse outcomes caused by low-flow anesthesia should have been equally low compared to high-flow anesthesia in this study. This is because there is no evidence of adverse patient outcomes with low-flow anesthesia, or when one volatile agent is chosen *versus* another, except perhaps in specific situations.¹⁰⁻¹² Prolonged postanesthesia care unit (PACU) duration is an adverse and potentially costly event. Low-solubility agents are able to provide more rapid induction, changes in anesthetic depth, and return to psychomotor recovery, even at low FGFRs.¹³⁻¹⁷ However, although emergence and duration in the PACU may be modified by volatile agent choice, with current models, PACU costs are semifixed, unless there is delay in PACU discharge.¹⁸ Furthermore, no study has shown a reduction in PACU cost attributable to volatile agent choice.^{19,20}

Despite its limitations, we chose a study methodology using a prospective cohort, instead of a randomized trial consisting of treatment and control groups. It was thought to be impractical to separate staff and residents into control and feedback groups, because the control group would have been contaminated by awareness of the study and by working with staff or residents from the feedback group, and would perhaps modify their practice. It is possible that volatile agent FGFRs may have decreased because of increasing general awareness of cost issues and heightened awareness of the literature. To minimize the influence of other forms of education on volatile agent use, we included a postintervention delayed follow-up period. There were other cost-containment programs in action throughout the entire study period. These were limitations to the use of colloids, ondansetron, propofol, and expensive short-acting, non-depolarizing muscle relaxants. There were other limitations to this study. Volatile agent use was not validated against volatile agent stock levels within the operating room because we were recording maintenance flows only, and the operating room volatile agent stocking system was too haphazard to be useful. We did not record vaporizer dial, inspired, or end-tidal volatile agent concentrations because these figures were inconsistently charted and subject to error, even though vaporizer concentration is an important determinant of cost. These data and flow rates throughout the entire duration of the case would have enabled an accurate cost assessment.

This study shows that education and individual feed-

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back reduces volatile agent FGFR but does not reduce the use of more expensive volatile anesthetic agents. In the absence of further feedback, the effectiveness of the intervention was significantly reduced with time, but the effect persisted compared to preintervention FGFRs.

The authors thank the students of Northeastern University School of Pharmacy: Rachel Bongiorno, Rena Bonomi, Kelly Brott, Theresa Byrne, Erin Callahan, Brenda Dietz, Elizabeth Dodds, Barry Graime, Randa Hanania, Christos Iorio, Sophie Lanjuin, Ling Liao, AnnaLisa Lubrano, William McFadden, Keri Netto, Jimmy Palatty, Ashley Quan, Nevien Sorial, Jennifer Thomas, Daniela Varbaro, Michele Volingavage, Melissa Walker and notably, Rebecca Velez.

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