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Medication errors in anesthesia: an 8-year retrospective analysis at an urban university hospital

Mamoru Yamamoto[1], Seiji Ishikawa[2], and Koshi Makita[2]

[1] Department of Anesthesia, Soka Municipal Hospital, Saitama, Japan
[2] Department of Anesthesiology, Tokyo Medical and Dental University, Graduate School of Medicine, 1-5-45 Yushima, Bunkyo-ku, Tokyo 113-8519, Japan

Abstract
Purpose. The Japanese Society of Anesthesiologists (JSA) has investigated critical events in several fields of anesthesiology. However, the types, frequency, and characteristics of medication errors related to anesthesia have not been investigated. By analyzing incident reports retrospectively, we investigated medication errors that occurred during anesthetic practice over the past 8 years at our institution.
Methods. Incident reports related to medication errors that occurred between May 1999 and March 2007 were analyzed retrospectively using a questionnaire published by the JSA in the "Survey of medication errors related to anesthesia". During these 8 years, 233 incidents were reported, in a total of 27454 anesthesia cases conducted during this period. Of these incidents, 61 (26.2%) were anesthetic drug administration errors. In these 61 incidents, clerical error (e.g., erroneous prescription writing), and pre-error (defined as any incident with the potential to become an error) were excluded from the analysis. Consequently, 13 incidents were excluded and 48 incidents were analyzed.
Results. Medication errors due to overdose were the most frequent kind of error (25%), followed by substitution (23%), and omission (21%). Errors due to an incorrect route of administration were rare. The drugs most frequently involved in these errors were antibiotics and muscle relaxants. Most of the patients involved in the incidents were, fortunately, not harmed seriously. The total frequency of medication errors in the survey period was 0.175% (48 incidents in 27454 total anesthesia cases).
Conclusion. We found that overdose, substitution, and omission were the main causes of anesthesia-related medication errors in our department.

Key words Medication error · Incident report · Overdose · Substitution · Omission

Address correspondence to: S. Ishikawa
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Introduction

Many of the drugs used in anesthesia produce direct and rapid effects on the circulatory, respiratory, and nervous systems. Administration errors involving these drugs can have potentially severe effects on patients. Because anesthesiologists have to make instantaneous decisions regarding the dose and type of drugs to be administered, we often encounter cases where administration errors such as substitution, incorrect dose, or an incorrect route of administration of these drugs occur, especially in emergency cases.

Although medication errors related to anesthesia have been recognized as a serious problem, it seems that there are no foolproof measures to prevent such errors.

The Japanese Society of Anesthesiologists (JSA) has investigated critical cases in several fields of anesthesiology [1]. Although these surveys deal with critical cases, the types and incidence rates of drug administration errors in anesthesia have not been clarified. Since 2005, the JSA has started maintaining a record of untoward anesthetic incidents via the Survey of Medication Errors Related to Anesthesia.

As a first step in taking measures to reduce incidents related to anesthetic drug administration errors, we decided to find trends in the misapplication of drugs by analyzing our incident and accident data. The objective of the present study was to investigate retrospectively the type, frequency, and severity of drug administration error-related incidents during anesthesia that occurred at Tokyo Medical and Dental University (TMDU) Hospital Faculty of Medicine.

Patients, materials, and methods

Incidents and accidents related to medication errors that occurred at the operating center of TMDU Hospital Faculty of Medicine between May 1999 and March

2007 were retrospectively analyzed. Because there was no formal incident reporting system at TMDU Hospital from May 1999 to August 2000, we acquired data for this period from our incident record notebook in which anesthesiologists voluntarily reported untoward anesthetic incidents. Since September 2000, we have had an incident report system in place, covering the entire TMDU Hospital, in which incidents are reported in a formal form. The questionnaire in the "Survey of medication errors related to anesthesia" published by the JSA was used to analyze our data in the present study.

The questions answered were: (1) "What was the type of the incident?"; (2) "What was the drug you intended to administer?" (in cases of substitution: "What was the drug you should have administered?"); (3) "In cases of substitution, what was the drug you actually administered"?; (4) "What was the route by which you intended to administer the drugs? (in cases of incorrect route: "What was the correct route?"); and (5) "In cases of incorrect route, what was the route by which you actually administered the drugs?" In addition to these questions, the outcome of each incident was determined according to a classification of incident levels. Furthermore, the ranks and positions of the anesthesiologists who were involved in each incident were determined according to the staff classification at our hospital. Because this was a retrospective study, uncertain issues (e.g., the mental state of the anesthesiologists at the time of the incident in each case) were not analyzed.

Incidents due to clerical errors (e.g., erroneous prescription writing) and pre-errors (defined as any incident with the potential to become an error) were excluded from the analysis. χ^2 analysis was used to analyze differences in the frequencies of medication errors between years.

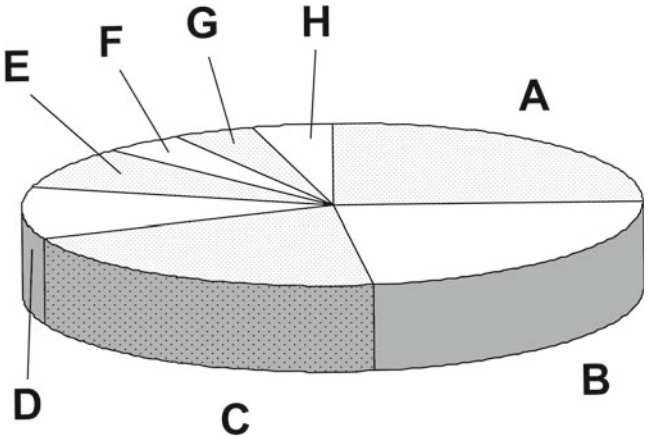

Fig. 1. Types of medication errors. *A*, Overdose (n = 12); *B*, substitution (n = 11); *C*, omission (n = 10); *D*, incorrect route (n = 5); *E*, incorrect time (n = 4); *F*, underdose (n = 2); *G*, leakage out of vein (n = 2); *H*, others (n = 2)

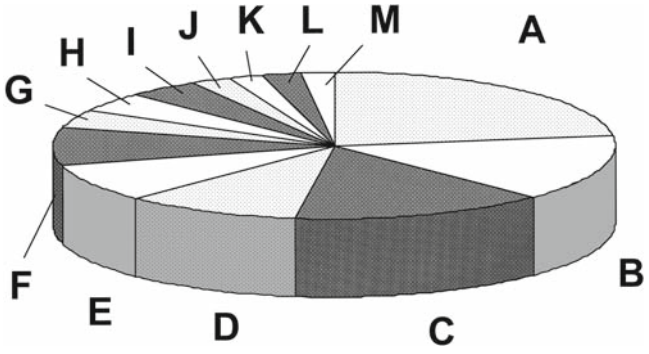

Fig. 2. Types of drugs that were involved in incidents (in cases of substitution, the drugs that were intended to be used). *A*, Antibiotics (n = 11); *B*, muscle relaxants (n = 7); *C*, vasopressors/heart stimulants (n = 7); *D*, venous anesthetic drugs other than opioids (n = 5); *E*, hormonal drugs (n = 4); *F*, others (n = 4); *G*, local anesthetic drugs (n = 2); *H*, coagulation inhibitors (n = 2); *I*, reversal agents (n = 2); *J*, inhalational agents (n = 1); *K*, opioids (n = 1); *L*, vasodilators (n = 1); *M*, antiarrhythmia drugs/β-blockers (n = 1)

Results

The total number of incidents over the 8-year analysis period was 233 (in a total of 27454 anesthesia cases), of which the number of incidents related to anesthetic drug administration errors was 61 (26.2%). Of these, 13 cases were excluded because they were clerical errors (n = 8) and pre-errors (n = 5). Consequently, a total of 48 incidents was analyzed.

Detailed analysis of the types of medication errors showed that, among the 48 cases, overdose (n = 12; 25%) was the primary cause of error, followed by substitution (n = 11; 23%) and omission (n = 10; 21%; Fig. 1). Several causes of overdose were found, including misunderstanding of the appropriate dosage of the drug (n = 2), mistaking units ("mg" vs "ml" [n = 1], 4 units vs 40 units [n = 1]), misinterpretation of the laboratory result (n = 1), misuse of an infusion pump (n = 2), administration of the same dose of the same drug by two separate doctors (n = 1), giving the adult dose to pediatric patients (n = 2), and misunderstanding of the drug concentration in the ampoule (n = 2). The reported causes of substitution errors were the use of an incorrect antibiotic, incorrect drugs given due to the similarity of ampoules, and mistaking ketamine intended for intramuscular (IM) use with that intended for intravenous (IV) use.

Antibiotics seemed to be the most frequently involved agents (n = 11; 23%) in the 48 cases of drug administration errors, followed by muscle relaxants (n = 7; 15%), and vasopressors/heart stimulants (n = 7; 15%; Fig. 2).

In the 11 substitution cases, incorrect antibiotics ($n = 3$; 27%) were administered most frequently (Table 1).

Regarding the route of administration, incidents most frequently occurred when drugs were administered as IV boluses ($n = 20$) and IV infusions ($n = 19$) (Fig. 3). There were five cases in which drugs were administered through an incorrect route. They were mistakenly administered by IV infusion instead of intraarterial infusion ($n = 1$) and by IV infusion instead of intraepidural infusion ($n = 2$); intraepidural infusion instead of IV infusion ($n = 1$); and others (bolus in artery instead of bolus in vein [$n = 1$]).

The incident levels were defined on the basis of severity of the outcome due to the erroneous administration; as level 1, harmless; level 2, requiring observation of vital signs; level 3a, requiring easy care and treatment; level 3b, requiring intensive care and treatment; level 4, patients suffered from permanent injury; and level 5, patients died. At our hospital, there were 12 level 1 cases, 31 level 2 cases, 3 level 3a cases, 2 level 3b cases, and no level 4 or 5 cases. The 3 level 3a cases were caused by an overdose of noradrenaline due to the misuse of an infusion pump, an overdose of insulin (40 U instead of 4 U), and the unintended stopping of dobutamine infusion, due to disconnection of the route. The 2 level 3b cases were caused by the substitution of neostigmine with noradrenaline, and an overdose of noradrenaline due to excessive flushing with an infusion pump.

Regarding the personnel involved in the incidents, we found that 6 instructor anesthesiologists, 8 staff anesthesiologists, 17 residents, and 20 doctors who visited from other departments for training (rotators) were involved. The total number of doctors involved in the incidents was greater than the number of incidents because, in some cases, more than one doctor and member of staff were involved.

The frequency of medication errors in different years is shown in Fig. 4. There were no statistically significant

Table 1. Drugs that were actually administered in substitution cases

Type of drug	Number of cases
Antibiotics	3
Vasopressors / Heart stimulants	2
Local anesthetics	2
Venous anesthetics	1
Parasympathetic nerve blockers	1
Hormonal drugs	1
Others	1

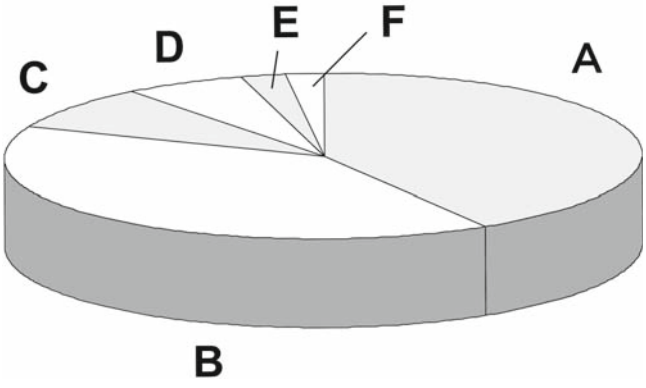

Fig. 3. Route by which errors occurred (in cases of incorrect route, routes by which drugs were intended to be administered). *A*, IV bolus ($n = 20$); *B*, IV infusion ($n = 19$); *C*, others ($n = 4$); *D*, inhalation ($n = 3$); *E*, epidural catheter bolus ($n = 1$); *F*, epidural catheter infusion ($n = 1$)

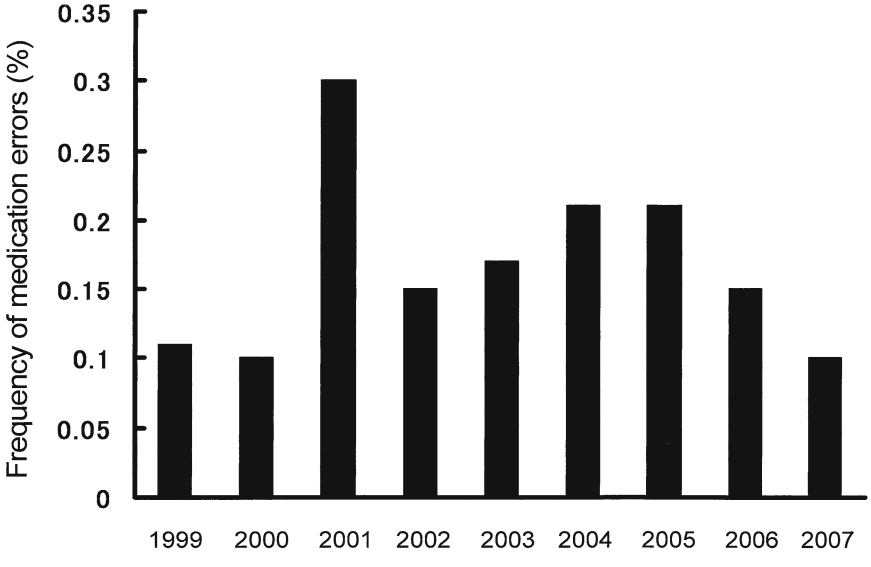

Fig. 4. Frequency of medication errors in each year. There was no statistically significant difference between years

differences between the years ($P = 0.6934$). The total frequency of medication errors in the survey period was 0.175% (48 incidents per 27454 anesthesia cases).

Discussion

We assessed the type, frequency, and characteristics of medication errors related to anesthesia by analyzing incident and accident reports retrospectively, and we found that overdose, substitution, and omission were the main causes of anesthesia-related medication errors in our department.

Several studies have addressed the characteristics of medication errors in the field of anesthesiology. A study by Webster et al. [2] analyzed anesthetic drug-related incidents at two hospitals. In their study, anesthetists were asked to return a study form anonymously for every anesthetic, indicating whether or not a drug administration error or pre-error had occurred; the study revealed that the two main causes of anesthetic drug administration incidents were dose error and use of the wrong drug. The rate of drug administration error of all types in their study was 0.75% (1 case per 133 anesthesia cases) and the rate of pre-errors was reported to be 0.4%.

Some studies have reported a lower incidence of anesthetic drug-related accidents. The study of Craig and Wilson [3] reported that the rate of any mishap, regardless of whether it was major or minor, was 0.14% (12 cases per 8312 anesthesia cases), and the study of Chopra et al. [4] reported that the rate of fault in drug administration was 0.012% (14 cases per 113074 anesthesia cases). The study of Barker et al. [5], conducted in hospital wards, on the other hand, reported a medication error rate of 19%. The incidence rate at our hospital (0.175%), thus falls between those of some other operating room rates [2–4], and is much lower than the rate in wards [5].

One possible reason for the different incident rates among these studies is the method of data accumulation. The study of Craig and Wilson [3], and the study of Chopra et al. [4] were based on the retrospective analysis of incident/accident reports. The writing of incident/accident reports depends on the person writing the report. It is likely that minor medication errors were overlooked and that reports were neglected or forgotten. The study of Barker et al. [5] was prospective and was based on results witnessed by observers during the study period. Hence, the number of incidents overlooked would have been small. Consequently, their results are probably accurate. The study of Webster et al. [2] was prospective, and was based on analyzing study forms for every anesthetic used [2]; hence, it is unlikely that drug-related errors and pre-errors were neglected or forgotten. Anonymity may be another important factor that can explain the higher rate of drug errors in their study [2] compared with that in the present study.

In general, opioids and muscle relaxants were reported to be misused most frequently [6,7]. In the present study, opioids were seldom wrongly administered, antibiotics and muscle relaxants being more frequently misadministered. We assume that the system at our hospital may have been one of the causes of these results. Initially, at our hospital, rotators or anesthesia residents administered antibiotics according to the orders of the surgeons after the patient had entered the operation room. These instructions being verbal, errors in communication may have been responsible for some of these errors. The system has, however, been reformed, and antibiotics are now administered according to the written prescriptions of surgeons. However, other types of errors, including misreading of the prescription, substitution of a prescription for that of an other patient, and the substitution of one type of antibiotic with another type of antibiotic were seen once or twice a year even after the system was reformed. It seems very difficult to find effects of the reform on the frequency of medication errors related to antibiotics, because, recently, antibiotics have been more frequently prescribed than before.

Regarding errors with muscle relaxants in our study, there were five cases in which only the diluent solution was administered, without any active drug. According to the Japanese law related to the storage of medicinal poisons, muscle relaxants should be strictly stored in a locked storage area. At our institution, anesthetists have to dissolve the muscle relaxant and prepare the syringe in front of the storage area, which is outside the operating room, and then they bring the drug-containing syringes to the operation room. Compared with preparing the syringes immediately before administering the drugs in the operating room, drug preparation errors are more likely to occur with this system.

Many of the doctors involved in the incidents were residents and rotators. Their inexperience may have contributed to the errors. According to our previous study, the less experienced a doctor, the more medication errors he/she is likely to make [8].

At our hospital, incident surveys have been performed since 1999 to raise the medical safety level. Based on the data obtained from these surveys, we have taken certain measures to prevent incidents. Some of these measures include: (1) withdrawing ampoules that closely resemble each other from anesthesia carts, (2) placing frequently used drugs at the front of the drawer of the cart, (3) placing drugs that resemble each other apart from each other, (4) reading aloud the drug name before opening the ampoule and administering the

drug, (5) double-checking between doctors before the administration of drugs which cause severe harm to the patient with an accidental overdose (e.g., insulin), (6) double-checking before administering drugs according to the prescriptions of surgeons, (7) double-checking of ampoules between doctors after the administration of drugs. Furthermore, since 2004, when we requested the clinical training center to teach residents how to use infusion pumps, residents have had such training during their orientation program, before coming to the operating room.

In conclusion, we retrospectively investigated anesthetic drug-related incidents and found that the main causes of drug-related medication errors were overdose, substitution, and omission. The drugs most frequently involved in these events were antibiotics and muscle relaxants.

References

1. Irita K, Kawashima Y, Iwao Y, Seo N, Tsuzaki K, Morita K, Obara H. Annual mortality and morbidity in operating rooms during 2002 and summary of morbidity and mortality between 1999 and 2002 in Japan: a brief review (in Japanese with English Abstract). Masui (Jpn J Anesthesiol). 2004;53:320–35.
2. Webster CS, Merry AF, Larsson L, McGrath KA, Weller J. The frequency and nature of drug administration error during anesthesia. Anaesth Intensive Care. 2001;29:494–500.
3. Craig J, Wilson ME. A survey of anaesthetic misadventures. Anaesthesia. 1981;36:933–6.
4. Chopra V, Bovill JG, Spierdijk J. Accidents, near accidents and complications during anaesthesia. A retrospective analysis of a 10-year period in a teaching hospital. Anaesthesia. 1990;45:3–6.
5. Barker KN, Flynn EA, Pepper GA, Bates DW, Mikeal RL. Medication errors observed in 36 health care facilities. Arch Intern Med. 2002;162:1897–903.
6. James RH. One thousand anaesthetic incidents: experience to date. Anaesthesia. 2003;58:856–63.
7. Abeysekera A, Bergman IJ, Kluger MT, Short TG. Drug error in anaesthetic practice: a review of 896 reports from the Australian Incident Monitoring study database. Anaesthesia. 2005;60:220–7.
8. Ishikawa S, Murai K, Yokoyama K, Masuda A, Nakazawa K, Makita K. Retrospective analysis on misapplication of anesthesia-related drugs in the early stage of anesthesia training. J Anesthesia. 2006;20(Suppl):265.