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Critical Incidents Associated with Intraoperative Exchanges of Anesthesia Personnel

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It is a common practice for anesthetists to substitute for one another, especially for short breaks during long surgical procedures. The assets and liabilities of this practice of relief have not been examined previously. In the course of gathering 1,089 reports of preventable errors and failures associated with anesthesia management, we identified 96 which involved a relief anesthetist. This subset was examined in search of common characteristics and patterns of cause and discovery of errors.

In 28 incidents, the relief anesthetist discovered an error or the cause of an error. In 10 incidents, the process of relief was identified as having contributed to the commission of an error. Although 70 of the 1,089 incidents were associated with substantive negative outcomes, *e.g.*, death, cardiac arrest, or extended ICU stay, none of those incidents was caused by a relieving anesthetist. There is a strong implication that relief is beneficial more often than not even aside from the presumed beneficial effect on the vigilance of the primary anesthetist (the latter effect was outside the scope of this study). From the descriptions of the causes and discoveries of errors in these relief-related incidents, guidance can be drawn for the safe and effective conduct of the intraoperative exchange of anesthesia personnel. (Key words: Anesthesia: complications. Complications: accidents.)

IT IS COMMON for anesthetists to substitute for one another during anesthesia management, especially for short breaks during long surgical procedures. Yet, there is no direct evidence as to whether this practice has effects that decrease or increase anesthetic risk. There are conflicting arguments. On the one hand, the anesthetist's commitment to and knowledge of the patient may seem to preclude exchange of personnel in all but dire circumstances. Conversely, prolonged monitoring or fatigue may diminish vigilance enough to increase the likelihood of a serious error.

From September 1975 to September 1980 we gathered descriptions of preventable anesthesia-related mishaps and near mishaps using a form of the critical incident technique.[1,2] Some of the reports involved either the temporary or permanent exchange of one anesthetist for another in a given case. These relief-associated mishaps or near mishaps were analyzed separately in order to characterize how the process of replacement may either increase or decrease anesthetic risk apart from the presumed beneficial restorative effect on vigilance. The objective of the analysis was to identify desirable and undesirable features associated with various relief practices in order to guide the design of a safe and effective replacement protocol.

Methods

Reports of anesthesia-related human errors and equipment failures were gathered from 48 anesthesiologists, 30 residents, and 13 nurse anesthetists from four hospitals in the Boston metropolitan area. Two of the hospitals had extensive teaching programs. The remaining two hospitals were staffed primarily by nurse anesthetists supervised by groups of anesthesiologists in private practice.

Contact with each of the anesthesia groups began with a lecture presentation of objectives by one of the investigators. Individuals were then asked by letter to participate in the study. Volunteers were interviewed privately, by a non-anesthetist investigator. Each interviewee was asked to describe directly observed incidents which involved a preventable human error or equipment failure during anesthesia care. The interviewer did not request examples of any specific type of error or equipment failure during anesthesia care. But, if the interviewee required prompting to recall incidents, the interviewer asked questions, from a prepared list, which included three questions designed to encourage recall of relief-related problems.

In addition to incidents collected from these studies at four hospitals, a second type of investigation was conducted at one of the two teaching hospitals. Again, volunteers were solicited from the department. During an introductory interview, participants were asked questions, from a prepared list, about specific types of incidents, such as disconnections in the breathing circuit or drug administration errors, and two questions about re-

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lief-related incidents. These 48 "trained observers" (18 anesthesiologists, 21 residents, and 9 nurse anesthetists) then were asked to report subsequent incidents as soon as possible after occurrence. Reports were made by telephone to the same interviewer.

Interviews and most telephone reports were tape-recorded, a summary transcript of each incident prepared, and the tapes erased. Information was then coded for computer-aided storage and analysis. The type of information collected and a brief description of the coding system have been presented elsewhere.[1] We classified a reported occurrence as a "critical incident" according to the following definition: A critical incident is a human error or equipment failure that could have led (if not discovered or corrected in time) or did lead to an undesirable outcome, ranging from increased length of hospital stay to death. Reports not meeting specific criteria for completeness and detail were discarded.

A total of 1,089 critical incidents suitable for analysis were collected. Two hundred thirty-nine of these incidents were reported by the trained observers. Incidents either caused or discovered by anesthetists who had assumed or were about to assume responsibility for anesthesia management of a patient from an anesthetist already providing anesthesia care were designated as relief-associated. These incidents were examined individually in search of common characteristics and classified into one of four categories based on the effect, if any, of the relief process on anesthetic risk. These categories were given the labels *favorable, unfavorable, neutral,* and *other*. Definitions of the four categories are given in table 1. Three of the investigators reviewed all relief-associated critical incidents and independently assigned the labels described.

Within each category, other characteristics of incidents were extracted and summarized in search of causal relationships. These included the type of error or failure, the omission in procedure which allowed the incident to occur or to be perpetuated through the relief process, and the symptoms or findings leading to discovery. Routine descriptive characteristics were also summarized, such as the reasons given for relief, the experience and training of personnel involved, incident-related postoperative sequelae, time of day, and length of operative procedure. However, each characteristic was not available for every incident.

TABLE 1. Definitions of the Categories of Relief-associated Incidents

Favorable Incident: The replacement anesthetist was not responsible for initiating the incident but discovered either the existence of the problem during the process of replacement,* or the cause of the problem, either of which had not yet been discovered by the anesthetist who had been or was being replaced.

Unfavorable Incident: Some aspect of the process of exchanging personnel was implicated as contributing to the cause of the incident.

Neutral Incident: There was no relationship between the exchange of personnel and either the cause or the discovery of the incident.

Other Incident:

(1) An error was perpetuated by the relief anesthetist, *i.e.*, a problem existed at the time of the personnel exchange that was not discovered during the process of replacement.†

(2) There was insufficient information to fix the actual time of occurrence, *i.e.*, the incident was discovered by the replacement anesthetist but there remains doubt as to whether the problem existed prior to the replacement.

(3) The incident could not be placed exclusively in any of the above categories, *e.g.*, nonconsensus among the investigators.

* The time period of the process of replacement begins when the replacement anesthetist enters the room and ends after the initial checkout or inspection, whether the original anesthetist is or is not still present.

† These are referred to as "perpetuated incidents" in the text. This is a special class of errors that had both favorable and unfavorable attributes contributing to the effect of the incident on risk.

Results

The search process produced 96 relief-associated critical incidents in 92 cases. Of these, 30 had been reported by the trained observers. The relief incidents occurred in relatively long procedures (6 hours estimated mean length, 5 hours median, for 50 cases where length was reported) with none less than 1 hour. Most often (68 cases), the relief was temporary to provide the original anesthetist with a break for coffee, a short rest, or a meal. In 20 cases, relief was given for the remainder of the operative procedure, to allow the original anesthetist to go home, attend a conference, etc. In 19 incidents, the anesthetist solely responsible for the error was a staff physician, in 18 incidents it was a CRNA, and in 31 incidents it was a resident. Responsibility was assigned to more than one anesthetist in 11 incidents and could not be clearly assigned in 17 incidents. There were 28 favorable incidents, 10 unfavorable incidents, and 27 neutral incidents (table 2). Thirty-one incidents fell in the other category.

Most often, favorable and unfavorable incidents involved a human error (35/38, 92 per cent). Eleven disconnections of the breathing circuit which were discovered at the time of the relief exchange were classified as other since, with no change in vital signs, it was not possible to determine if the disconnection occurred prior to the entry of the relieving anesthetist. Eight additional disconnections were clearly neutral as they occurred many minutes after the relief exchange, thus not apparently resulting from the relief process.

The favorable incidents are listed in table 3, along with key events leading to discovery. Twenty-two were reported by the relieving anesthetist and six by the anesthetist who had been relieved. The discoveries occurred in three different phases of the development of the problem: (1) discovery of a problem that had not yet led to

TABLE 2. Distribution of Incidents by Relief Category and Type

Type of Failure	Number of Incidents (Per Cent of Column*)					
	Relief Incidents					
	Favorable	Unfavorable	Neutral	Other	Total	All Non-Relief Incidents
Equipment Failure	0 (0)	0 (0)	0 (0)	4 (13)	4 (4)	130 (13)
Human Error	26 (93)	9 (90)	18 (67)	12 (39)	65 (68)	736 (74)
Disconnection†	1 (4)	0 (0)	8 (30)	14 (45)	23 (24)	121 (12)
Other	1 (4)	1 (10)	1 (4)	1 (3)	4 (4)	6 (1)
Total Incidents	28	10	27	31	96	993

* Percentages have been rounded off.

† Disconnections were in either breathing circuit components or intravenous apparatus.

a measurable change in vital signs (10 incidents, *e.g.*, partially open pop-off-valve or endobronchial intubation), (2) discovery of a physiological change that was error-induced but not yet recognized by the original anesthetist (four incidents, *e.g.*, tachycardia caused by obstructed tracheal tube or oliguria induced by hypovolemia), and (3) identification of the undiscovered cause of an error-related variation in vital signs or other peculiarity observed by the original anesthetist (10 incidents, *e.g.*, an empty vaporizer leading to tachycardia or an endobronchial intubation responsible for abnormal blood-gas values). In 11 favorable incidents, the original anesthetist had already left the room before the problem was discovered. In six other favorable incidents, communication that took place between the original anesthetist and relieving anesthetist helped to identify the problem or its cause. Hypovolemia and endobronchial intubation accounted for 11 (39 per cent) of the favorable incidents. In many of these, the relieving anesthetist became aware of the problem quickly, simply by inspection.

In only three of the favorable incidents was fatigue specifically mentioned as a factor related to the original anesthetist's error. However, information about the original anesthetist's rest state was not always elicited from or known by the reporting anesthetist. (Fatigue, inattention, or boredom was mentioned in 24 per cent of the 997 non-relief incidents.) In 17 of the 25 other favorable incidents, at least one human factor, *e.g.*, inexperience in anesthesia or with the surgical technique, poor lighting, or complacency, also was mentioned as possibly related to incident occurrence or delayed detection. Inspection of the anesthetic record for trends in vital signs, for fluid balance, or for consistency between measured and recorded values was pivotal in many discoveries by relieving anesthetists.

The individual unfavorable and "perpetuated" other incidents are listed in table 4. For each of these, we identified one or more potential actions that could have prevented the error (in unfavorable incidents) or allowed prompt detection of the error during the relief exchange (in "perpetuated" other incidents). Among the 1,089 incidents (involving 1,013 patients), there were 70 incidents (involving 67 patients) which directly resulted in or possibly contributed to a substantive adverse outcome (mortality, cardiac arrest, extended intensive care, extra hospital stay, or cancelled operative procedure). As indicated in table 5, none of these were attributable to the relief process.

Discussion

The critical incident method is an established technique for collecting information about human performance[3] which has been applied infrequently in medicine.[4] Validation has been obtained in certain applications.[5] However, the method is based on self-reporting and the potential for bias always exists. Objectivity must be supported by rigorously defining criteria for data entry and classification. The reports cannot be used as a statistical basis for estimating population characteristics. The utility of this data collection method is in gathering sensitive information from which one can identify mechanisms of failure in human performance. Occasionally, judgment of the relative frequency or importance of certain problems is possible because the data exhibit striking, distinguishing features. In a preliminary study, our results suggested that relief was beneficial more often than not.[1] This more focused analysis of a larger collection of incidents from a broader sample of hospitals, with closer scrutiny of the details of incidents, supports that suggestion and also gives us insight into both the potential benefits and potential hazards of specific relief practices.

Since questions about relief-associated problems were often asked in the retrospective interviews, the number of relief incidents is *not* an indication of their true fre-

quency among all critical incidents. However, 13 per cent (30/239) of the reports by trained observers involved a relieving anesthetist. To the best of our knowledge, there was no bias towards such reports introduced by the design of that study. This suggests to us that relief is an important factor in the processes of error and discovery.

The 28 favorable incidents (see table 3) illustrate that one of the benefits of the relief process is that of the "second opinion" offered from the perspective of a fresh anesthetist.[6] The 10 unfavorable (see table 4) relief-associated incidents illustrate the potentially harmful effects of relief practices. We attach limited significance to the reporting of fewer unfavorable than favorable incidents, since there may be some human bias toward reporting favorable incidents. That so many favorable incidents were reported by the reliever (22 of 28) may support such a suggestion, with individuals reporting their own successes. However, anesthetists who were relieved often had left the room before discovery of the particular problem. Thus, one could not expect them to have become aware of their own errors in all cases and to have been able to report them. Regardless of bias in reporting one type of relief incident over another, it is striking that none of the adverse outcomes in the entire database was attributable to the relief process. We do not know the frequency of relief interventions against which this result should be measured. However, we do know that relief was a common practice at all of the hospitals involved in the study. Thus, the suggestion is that, overall, relieving anesthetists do more good than harm even setting aside the other potential benefits of relief on vigilance and morale. And, this is despite the fact that no formally defined protocol existed in any of the sampled hospitals for either scheduling or conducting the practice of relief.

The unfavorable incidents seemed to follow a distinct pattern of cause, *i.e.*, in most cases, the error most likely would have been avoided by review of the status of anesthetic management, *e.g.*, equipment, drugs or anesthetic record, at the time of personnel exchange (table 4). Errors in drug administration were involved in five of the ten incidents. In three of these, there was a strong suggestion that the error was encouraged by a lack of standardization in drug labeling or dilution.

There are six incidents in table 4 for which the potential preventive action is cited as "not obvious" or "use

TABLE 3. Failures and Their Discovery in the 28 Favorable Relief Incidents

Failure	Number of Incidents	Actions by Reliever Leading to Incident Discovery (One Case Each, Except Where Noted)*
Hypovolemia	8	—Review of vital signs (persistant tachycardia untreated) —Review of fluid balance (unrecognized blood loss) (two cases) —Sighting of unrecognized extensive blood loss —Review of vital signs/fluid balance —Remeasurement of BP, noting discrepancy with last recorded value —Observation of lack of urine output —Unknown†
Endobronchial intubation	3	—Check of breath sounds (two cases) —Unknown†
Partially open exhaust valve with mechanical ventilation	2	—Inspection of equipment (exhaust valve) —Unknown†
Light anesthesia	2	—Interpretation of vital signs —Inspection of equipment (vaporizer)
Breathing circuit misconnection	2	—Attempt to inflate reservoir bag —Inspection of equipment (connections)
Breathing circuit disconnection	1	—Inspection of equipment (connections)
Extra vaporizer on	1	—Detection of anesthetic aroma
Empty vaporizer	1	—Inspection of equipment (vaporizer)
High N_2O flow	1	—Check of record and rotameter
Partially disconnected pipeline supply	1	—Check of cylinder & pipeline pressures
Empty N_2O cylinder	1	—Inspection of equipment (rotameters)
Drug swap (vials)	1	—Review of record/drug-setup
Kinked nasotracheal tube	1	—Review of vital signs
Inhalation anesthetic OD‡	1	—Review of vital signs
Hypoventilation	1	—Interpretation of vital signs
Humidifier condensate in airway	1	—Observation of patient skin color

* The action by the reliever is the key event of the discovery process for each incident.

† For action = unknown, there was insufficient information to determine the key event.

‡ OD = overdose.

TABLE 4. Failure and Potential Actions for Prevention in 10 Unfavorable and Eight Perpetuated Relief Incidents

Failure	Potential Actions for Prevention
Drug OD (unlabeled dilution)	—Use of standard concentrations
Drug OD (unlabeled dilution)	—Use of standard concentrations
Drug OD (mislabeled dilution)*	—Use of standard concentrations
Drug OD (unlabeled syringe)	—Review of medications
Drug OD (wrong IV line flushed)	—Review of medications
Drug OD (decision based on mischarted information)*	—Not obvious
Mislabeled dilution (drug not administered)	—Use of standard concentrations
Wrong drug (mislabeled syringe)*	—Not obvious
Switch to contraindicated technique	—Review of medical status/ history or conference with A_o† before altering course
Switch to contraindicated technique	—Conference with A_o† before altering course
Hypovolemia	—Assurance of appropriate experience of reliever
Hypovolemia	—Review of medical status/ history
Wrong blood transfused	—Review of patient name
Undiscovered blood pressure manometer malfunction*	—Check of vital sign consistency with record and review with A_o†
Open "pop-off" valve with mech. ventilation*	—Check of equipment status
Undiscovered ventilator malfunction*	—Check of equipment status
N_2O disconnected from wall*	—Check of equipment status and settings *vs.* record
High kettle O_2 flow*	—Check of equipment status and settings *vs.* record

* = Perpetuated incidents.
† A_o = original anesthetist.

of standard concentrations." For these, we could not identify any practical measure that could have been taken at the time of the exchange that would have been likely to prevent the error (or promptly detect the existing error). These demonstrate the inherent risk in any personnel exchange that some potentially vital information will not be communicated despite the best of efforts or that an otherwise innocuous error by the original anesthetist, *e.g.*, a charting error will entrap an unsuspecting but thorough relief anesthetist. The use of standard drug concentrations is a strategy that, if undertaken before relief, would have prevented four of these six incidents.

The occurrence of so many breathing circuit disconnections within the neutral and other groups is further evidence of the severity of this particular problem in anesthesia management.[7] Some of those in the other category may actually have been favorable, with the disconnection occurring before the exchange. Others may actually have been unfavorable with the disconnection occurring because of the exchange. However, we could not distinguish with the available information. In most of these, had a careful examination of apparatus been conducted at the time of the exchange, the observations necessary to resolve these uncertainties, and expedite any discoveries, would have been made.

From study of the relief-associated incidents, we suggest that a defined protocol be followed whenever a personnel exchange occurs. The objectives of such a protocol are largely self-evident. The relieving anesthetist should establish familiarity with the status of the patient, progress of the surgical procedure, trends in the anesthetic course, significant medical history, anesthetic plan, and arrangement of equipment, apparatus, drugs, and fluids. The original anesthetist should not leave the room until the relief anesthetist is in command of the situation and has all necessary information. Care should be taken to communicate any special knowledge not on the record or not available by inspection. Special attention to conveying the logic behind the anesthetic plan is required if the original anesthetist does not expect to return to the case. Under normal conditions, the reliever should not substantially alter the course of anesthetic management without recalling and conferring with the original anesthetist. Before reassuming control, the original anes-

TABLE 5. Distribution of Substantive Adverse Outcomes Among Relief and Non-Relief Incidents*

Outcome	Number of Incidents		
	Unfavorable Relief Incidents (n = 10)	Balance of Relief Incidents (n = 86)	All Non-Relief Incidents (n = 993)
Death	0	0	25
Cardiac arrest (resuscitated)	0	2	17
Cancelled procedure (and none of the above)	0	0	11
Extra stay in recovery room, ICU or hospital >1 day (and none of the above)	0	1	11
	0	3†	64

* An outcome was associated with an incident only if there was sufficient information to clearly establish a cause-and-effect relationship between the error and the outcome. If an outcome was associated with more than one incident, only one case is indicated, *i.e.*, each incident included here represents a different patient.
† These three adverse outcomes were associated with one neutral and two other relief-associated incidents.

thetist should take whatever steps are necessary to renew perspective of the patient and the procedure, including any changes that have taken place during the relief.

The findings and suggestions presented here may be used in the generation of a specific relief-exchange protocol in a given department. But, we must caution that a definitive answer on the cumulative effects of relief practices does not yet exist. It may prove very difficult to provide more rigorous or more complete data on the effects of relief on the risk of anesthesia. For instance, it is possible that additional use of relief would have prevented some of the 244 non-relief associated incidents in which fatigue, inattention, or boredom were reported. Other errors might have occurred if less relief had been used. And, we cannot assess the restorative effect of relief in anesthesia practice.

The variation in vigilance performance among individual anesthetists, the large variety of surgical cases and patients' conditions, and the relative diversity of anesthetic equipment and practices imply that the need for relief and the efficacy of relief will depend heavily on specific circumstances. Clearly, if relief is employed, precautions must be taken to avoid the specific pitfalls detected in this study. For at least the foreseeable future, judgment, guided by observational studies such as this, must serve in choosing the proper balance.

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