Are Automated Anesthesia Records Better?

David N. Thrush, MD*

Department of Anesthesiology, University of South Florida College of Medicine, Tampa, FL.

Study Objective: *To determine whether data recorded by an information management system is significantly different from that recorded manually.*
Design: *A comparison was made between 13 handwritten and 13 computer-generated anesthesia records by calculating the frequency with which recorded variables were outside predetermined acceptable ranges. Five physiologic variables [systolic blood pressure (SBP), diastolic blood pressure (DBP), heart rate (HR), end-tidal partial pressure of carbon dioxide ($P_{ET}CO_2$), and oxygen saturation by pulse oximeter (SpO_2)] were compared during the initial 1½ hours of operation.*
Setting: *Surgical suite at a university-affiliated hospital.*
Patients: *Thirteen adult patients scheduled for operations that required general anesthesia for longer than 1½ hours.*
Intervention: *In addition to the traditional handwritten anesthesia records, an information management system (ARKIVE Patient Management System, DIATEK, San Diego, CA) was used to collect data from each case.*
Measurements and Main Results: *No significant differences were found between the methods in the frequency of elevated SBP, elevated DBP, and tachycardia. However, the manual records showed low SBP, DBP, and HR with a significantly lower frequency (2%, 11%, 1%, respectively) than the automated records (6%, 26%, 5%, respectively;* $p < 0.01$*). The automated $P_{ET}CO_2$ readings were higher than the upper limit (40 mmHg) with a higher frequency (18%) than the manual records (3%;* $p < 0.01$*). On the automated records, SpO_2 was noted to be 90% or less on two occasions, but significant desaturation was noted only once on the manual charts.*
Conclusions: *Observer bias, missed readings, and errors of memory, which affect manual anesthetic records, may cause significant inaccuracy and may be avoided by using automated records generated by information management systems.*

Keywords: Anesthesia, computerized; records, handwritten; monitoring, automatic.

*Assistant Professor

Address reprint requests to Dr. Thrush at the Department of Anesthesiology, University of South Florida College of Medicine, MDC Box 59, 12901 Bruce B. Downs Blvd., Tampa, FL 33612-4799, USA.

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Introduction

The need for accurate recording of vital signs during anesthesia has led to the development of anesthesia records produced by information management systems.[1] Comparisons of traditional and computer-generated anesthesia records matched for time have demonstrated both qualitative and quantitative differences in the data in a large number of cases.[2–4] However, comparing data from the manual and automated records, point by point, may lead to artificially large discrepancies because the measurements were made at different times. Comparing the frequency that values exceeded defined limits eliminates cumbersome data point comparisons and can aid effective evaluation of these two recording methods.

We compared the frequency that vital signs appeared outside defined limits on manual records and records generated by the ARKIVE Patient Management System (DIATEK, San Diego, CA). We hypothesized that deviation from the ranges would be recorded with comparable frequency by the anesthesiologist and the computer.

Materials and Methods

Adult patients scheduled for operations that required general anesthesia for longer than 1½ hours were included in the study. An anesthesia team consisting of a resident and a staff anesthesiologist was responsible for caring for patients and producing handwritten anesthesia records. The ARKIVE Patient Management System was used to collect data from each patient. ARKIVE was operated by an anesthesiologist who did not participate in patient care. He verified that the vital signs that appeared on the various monitors matched the vital signs displayed on the computer screen. He also identified artifacts on the record and printed a hard copy of the data.

A multichannel patient monitor (Hewlett-Packard 78534C, Palo Alto, CA) routinely used at Tampa General Hospital displayed systolic blood pressure (SBP), diastolic blood pressure (DBP), and heart rate (HR) for all patients. End-tidal partial pressure of carbon dioxide ($P_{ET}CO_2$) and oxygen saturation by pulse oximeter (SpO_2) were monitored with a capnograph/pulse oximeter (N-1000, Nellcor, Hayward, CA). From the automatic recording device, data were transferred to a central processing unit for storage, display, and printing. The computer was programmed to display the median value of each monitored variable every 3⅗₁₀ minutes. The time interval for manual notation was 5 minutes. A similar 5-minute time interval was not available on the computer program. The preprinted scale divisions on the manual record represented 10 mmHg for SBP and DBP and 10 beats per minute (bpm) for HR; values were read to the nearest 5 mmHg or 5 bpm (i.e., one-half of the chart division). $P_{ET}CO_2$ and SpO_2 were recorded numerically every 15 minutes. Both $P_{ET}CO_2$ and $SpCO_2$ were interpreted from the record to the nearest mmHg and percent, respectively. Data collection began with induction of anesthesia and ended 1½ hours later.

The defined acceptable ranges for the recorded variables are shown in *Table 1*. The frequency that a given variable was recorded outside this range was calculated for each recording method and the values were compared with Fisher's exact test. For example, the acceptable range for SBP was 90 to 120 mmHg. If 5 of 10 SBP measurements were automatically recorded above 120 mmHg and none was recorded manually above this limit, the frequencies 50% and 0% were compared.

Results

A total of 13 manual and 13 computer records were generated. Nine cases were studied for 1½ hours; four were studied for 1 hour because of early initiation of CPB. Eleven data sets were collected from patients who required CPB. The twelfth set was from a patient who underwent a cranioplasty, and the thirteenth was from a patient who had excision of a wrist ganglion. Eight senior residents generated the manual records. One resident created three records, three residents created two records each, and four residents created one record each.

Table 1. The Defined Ranges for Recorded Vital Signs

Variable	Range
SBP (mmHg)	90 to 120
DBP (mmHg)	50 to 70
$P_{ET}CO_2$ (mmHg)	30 to 40
HR (bpm)	50 to 90
SpO_2 (%)	91 to 100

SBP = systolic blood pressure; DBP = diastolic blood pressure; $P_{ET}CO_2$ = end-tidal partial pressure of carbon dioxide; HR = heart rate; bpm = beats per minute; SpO_2 = oxygen saturation by pulse oximeter.

The frequencies of out-of-range values for each variable on the automated and manual records are shown in *Table 2*. The frequency of SBP values recorded manually above the 120 mmHg limit (38%) was not significantly different from the frequency (40%) recorded by the computer. The frequency of SBP values recorded below the 90 mmHg limit was 2% for the manual records and 6% for the automated records ($p < 0.001$). Twelve percent of the manually recorded DBP values were above 70 mmHg, compared with 13% for the automated records (not a significant difference). The automated records demonstrated a higher frequency (26%) of DBP values below the lower limit than did the manual records (12%; $p < 0.001$). The frequency of $P_{ET}CO_2$ values recorded above 40 mmHg was 3% for the manual method and 18% for the automated method ($p < 0.01$). The 16% of the $P_{ET}CO_2$ values below 30 mmHg recorded manually was not significantly different from the 28% recorded automatically. The percentage of HR values recorded above 90 bpm was similar for both methods, 6% manually *versus* 5% automatically. HR values below 50 bpm were found less frequently in the manual records ($p < 0.001$).

In the automated records, SpO_2 was noted to be 90% or less on two occasions, while the manual charts showed only one episode of desaturation. In one instance, SpO_2 was automatically recorded as 90% for 3 minutes, while the manual record showed an SpO_2 of 100%. In another case, the automatically recorded SpO_2 fell to 35% for 3 minutes, while the manually recorded value was 77% for 5 minutes. The patients suffered no significant morbidity.

Discussion

We compared the frequency of out-of-range vital signs recorded manually and automatically by an information management system. The manual records showed significant underreporting of hypotension, bradycardia, and

Table 2. Number and Percentage of Out-of-Range Values

	Manual Records			Automated Records			
	Out-of-Range Values (number)	Recorded Values (number)	Out-of-Range Values (%)	Out-of-Range Values (number)	Recorded Values (number)	Out-of-Range Values (%)	p*
SBP							
High	86	224	38	97	244	40	NS
Low	4	224	2	14	244	6	<0.001
DBP							
High	27	224	12	31	244	13	NS
Low	26	224	12	63	244	26	<0.002
SpO_2							
High	0	72	0	0	222	0	NS
Low	1	72	1	2	222	<1%	NS
$P_{ET}CO_2$							
High	1	38	3	23	125	18	<0.01
Low	6	38	16	35	125	28	NS
HR							
High	13	214	6	11	244	5	NS
Low	1	214	0	11	244	5	<0.001

*Fisher's exact test between frequencies.

SBP = systolic blood pressure; NS = not significant; DBP = diastolic blood pressure; SpO_2 = oxygen saturation by pulse oximeter; $P_{ET}CO_2$ = end-tidal partial pressure of carbon dioxide; HR = heart rate.

hypercarbia, with no difference in the reporting of hypertension, tachycardia, and hyperventilation.

Bias, missed readings, and errors in memory may be responsible for the discrepancies noted. Observer bias affects the accuracy of handwritten records because of the observer's reluctance to record extremes in physiologic variables, even when they are transient and inconsequential to the patient. Cook *et al.*[5] found that clinician bias resulted in less frequent recording of extremes in vital signs. Their study compared 48 handwritten and automatically derived blood pressure (BP) records and found that the highest automatically recorded BP frequently exceeded the highest manually recorded BP. In 19 cases, the automated BP exceeded the manual BP by 20 mmHg, and in 4 cases, the automated BP exceeded the manual BP by at least 40 mmHg. Similar discrepancies were demonstrated when high DBP values were compared. Differences between the lowest recorded DBP values were not as large as differences between the highest values. Cook *et al.* concluded that these discrepancies were not due to missed readings because, on average, the recording anesthetist had at least three chances to record an SBP greater than the one that was recorded. Bias as a result of an "unconscious defensive strategy" may have been responsible for the smoother handwritten records.[5]

Zollinger *et al.*[2] found the differences between manually and automatically recorded BP values during anesthesia to be greater during induction and emergence, when manual records are frequently generated from memory several minutes after the actual event. The authors postulated that the observed differences were primarily due to inattention to charting while the clinician was busy caring for the patient.

Shibutani *et al.*[6] showed similar discrepancies in BP values recorded by the two methods. These discrepancies varied in magnitude and direction, with larger discrepancies for SBP than for DBP. They concluded that although discrepancies could result from errors of memory during induction, significant discrepancies during surgery could not be explained similarly.

Performing the current study during the initial phase of anesthesia may have increased the frequency of inaccurate reporting of vital signs. Evaluating records from a less intensive period when demands on the anesthesiologist are fewer would probably demonstrate a lower frequency of abnormal vital signs and more accurate manual recording. We deliberately chose a period of maximum activity for our study to support or refute clearly a need for automated record keeping. Our findings indicate a selective reporting bias rather than random inaccuracy of recall.

Automated recording of vital signs is not without disadvantages. Hardware and software problems may interfere with the continuity of recording, and patient motion or electrocautery may invalidate critical data. Yablok[7] found that the anesthetist was less likely to remember normal vital signs when using an information management system. When clinicians in the operating room were questioned about their patients' vital signs, more than one-fifth of the practitioners could not report the accurate value of one or more variables. Although he concluded that vigilance was impaired, vigilance—or the response time to an adverse event—was not measured. Poor recall of normal values during the anesthetic course may or may not be detrimental to patient care.

We recognize some shortcomings in our study. Discrepancies between the two recording methods were determined from a relatively small number of cases. Comparisons of larger numbers of patients representing different surgical procedures are required to provide a better representation of the general population. Also, the range for each vital sign was selected arbitrarily. Narrowing the limits could have decreased the differences in out-of-range values, while broadening the ranges could have had the opposite effect.

In addition, residents were responsible for completing the manual anesthetic records in this study. Although residents are trained to be compulsive and diligent when recording vital signs, a variety of factors may affect recording accuracy. During induction of anesthesia and prior to CPB, attention to patient care may affect the timeliness and accuracy of handwritten records. This effect may be more pronounced in less experienced residents. Some residents use the period of CPB to complete the chart. Retrospective completion of a record 30 to 40 minutes after the fact may result in inaccurate documentation.

During the study, the residents were told that a clinical evaluation of the information management system was being made for possible purchase. Although they were not aware that their manual records would later be compared with the computer records, it is possible that residents may have been encouraged to improve the timeliness and accuracy of their manual records because they were aware that data was being automatically recorded. However, such bias would lead to an underestimation of the true inaccuracy of manual records and thus would not alter our conclusions.

The manner in which recorded vital signs were selected affected the comparison of out-of-range values. Since an arterial waveform and digital display were available in each case, the manual recorders could choose any value that best represented the clinical course of the patient at that time. The computerized system calculated the median over the selected period. Both methods of recording can smooth the data and affect the frequency of out-of-range vital signs.

For the majority of vital signs recorded, the automated system documented values outside the defined limits with greater frequency. Accurate, unbiased, and complete records are necessary for meaningful review of anesthetic care, whether they are used to detect an abnormal response of a single patient, to enhance self-improvement of anesthesiologists, or to support a department's quality assurance program.[8,9] In addition, records produced by information management systems might help document the normal inconsequential variation in physiologic variables that occurs during anesthesia.

For these reasons, demonstration of the inaccuracy of manual charts should lead to the adoption of automated recording. Significant differences in the reporting of out-of-range vital signs in this study support the use of automated, rather than manual, anesthesia records.

References

1. McDonald CJ, Tierney WM: Computer-stored medical records: their future role in medical practice. *JAMA* 1988;259:3433–40.
2. Zollinger RM Jr, Kreul JF, Schneider AJ: Man-made versus computer-generated anesthesia records. *J Surg Res* 1977;22:419–24.
3. Logas WG, McCarthy RJ, Narbone RF, Ivankovich AD: Analysis of the accuracy of the anesthetic record [Abstract]. *Anesth Analg* 1987;66:S107.
4. Lerou JG, Dirksen R, van Daele M, Nijhuis GM, Crul JF: Automated charting of physiological variables in anesthesia: a quantitative comparison of automated versus handwritten anesthesia records. *J Clin Monit* 1988;4:37–47.
5. Cook RI, McDonald JS, Nunziata E: Differences between handwritten and automatic blood pressure records. *Anesthesiology* 1989;71:385–90.
6. Shibutani K, Bairamian M, Subhedar D, Kashiwagi N, Kubal K: Human factors affecting accuracy of hand-written arterial pressure record [Abstract]. *Anesthesiology* 1990;73:A1014.
7. Yablok DO: Comparison of vigilance using automated versus handwritten records [Abstract]. *Anesthesiology* 1990;73:A416.
8. Gravenstein JS: Essential monitoring examined through different lenses. *J Clin Monit* 1986;2:22–9.
9. Gibbs RF: The present and future medicolegal importance of record keeping in anesthesia and intensive care: the case for automation. *J Clin Monit* 1989;5:251–5.