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Auditory Alarms during Anesthesia Monitoring

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The trend in anesthesia care is toward increasing use of technologic non-invasive monitors. The American Society of Anesthesiologists has recently published recommended standards for basic patient monitoring, which include arterial blood pressure, electrocardiography, an oxygen analyzer, and a ventilator disconnection alarm.‡ Monitors that are encouraged, but not mandatory, include pulse oximetry, capnography, and spirometry. Most monitors are fitted with alarm systems, usually with preset and modifiable thresholds, which produce an auditory signal when a high or low limit is passed. This survey evaluates the significance of auditory alarms that sound during routine anesthetic management.

MATERIALS AND METHODS

After institutional approval, 50 patients were studied, ASA physical status I–III, ages 1 month to 10 yr. These were all elective general surgical, ophthalmic, dental, or orthopedic cases; no patient had any significant cardiac or respiratory disease. Five monitors with auditory alarms were routinely used: electrocardiography (ECG) (Datascope™ model 870, Paramus, NJ), automatic oscillometric blood pressure (BP) (Critikon Dinamap™ 847, Tampa, FL), oxygen analyzer (Ohio™ oxygen monitor 401, Madison, WI), pulse oximetry (Nellcor™, Hayward, CA), and ventilator low inspiratory pressure (disconnect alarm) (Ohio, Madison, WI). Non-monitoring equipment with auditory alarms commonly used included intravenous infusion pumps and electrocautery. The initial alarm limits are shown in table 1. Once one of the upper alarm limits had sounded, new upper alarm limits could be set by the anesthesiologist in charge of the case. The lower alarm limits could not be

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TABLE 1. Initial Monitor Alarm Limits

	Lower Alarm Limits	Upper Alarm Limits
Electrocardiogram	75 bpm	175 bpm
Pulse oximeter arterial saturation	85%	100%
Pulse oximeter heart rate	55 bpm	140 bpm
Mean blood pressure	30 mmHg	100 mmHg
Ventilator disconnect	7 cm H_2O	
Inspired oxygen	30%	100%

TABLE 2. Definition of Alarm Categories

Alarm Category	Alarm
Patient risk	Arterial oxygen saturation < 85% Mean arterial blood pressure < 30 mmHg ECG: heart rate < 75 bpm Ventilator disconnect alarm Inspired oxygen < 30%
Change above upper alarm limits	ECG: heart rate > upper limit Pulse oximeter heart rate > upper limit Mean arterial pressure > upper limit
Spurious	Any alarm caused by: patient movement, interference, mechanical problems

changed. An independent observer recorded all the alarms that sounded, the times at which they did so, and classified them into one of the three categories defined in table 2.

RESULTS

Seventy-five percent of all the alarms that sounded were spurious alarms, while only 3% indicated risk to the patient (fig. 1). Ninety-nine percent of all the alarms were from the pulse oximeter, ECG, or BP monitors; the only other alarms that were recorded were from intravenous infusion devices or the electrocautery

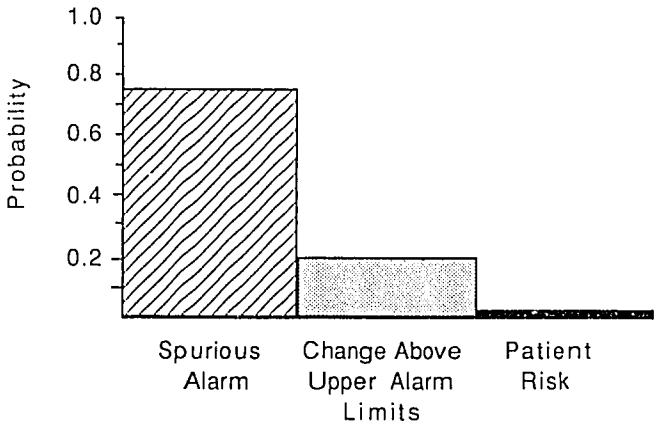

FIG. 1. The probability that an auditory alarm will be a spurious alarm, a patient risk, or a change above upper alarm limits. See table 2 for definition of these categories.

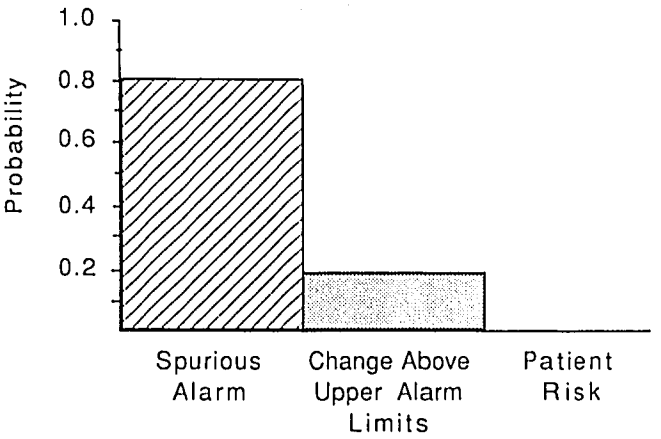

FIG. 2. The probability that an ECG alarm will be a spurious alarm, a patient risk, or a change above upper alarm limits.

grounding alarm. There were no alarms for bradycardia, hypotension, low inspired oxygen, or ventilator disconnection in this study.

There were two patterns of alarm responses from the individual monitors (figs. 2–5). The ECG and the saturation alarm on the pulse oximeter showed a pattern similar to the overall pattern, with the majority of their alarms being spurious. The BP monitor and the heart rate alarm on the pulse oximeter showed a different pattern of significance, with the majority of their alarms recorded as a change above the upper alarm limits. This, in practice, meant that the mean arterial pressure exceeded 100 mmHg or the heart rate on the pulse oximeter exceeded 140 bpm; both of these limits are automatically preset initial alarm limits of those particular monitors, both of which were exceeded relatively frequently.

The frequency with which the alarms sounded at various stages during anesthesia and surgery is shown in figure 6. A mean of ten alarms sounded per case, with a mean frequency of one alarm every 4.5 min. The main causes of spurious alarms are shown in table 3.

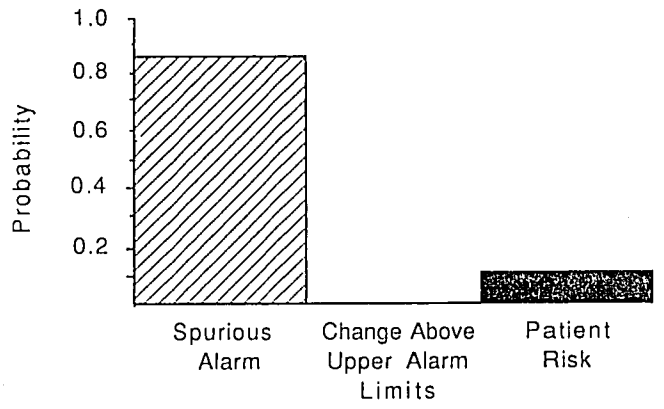

FIG. 3. The probability that a saturation alarm on the pulse oximeter will be a spurious alarm, a patient risk, or a change above upper alarm limits.

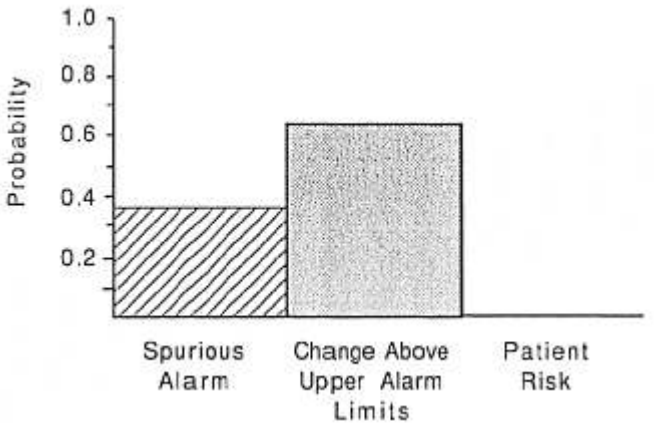

FIG. 4. The probability that a BP alarm will be a spurious alarm, a patient risk, or a change above upper alarm limits.

DISCUSSION

In this study, we quantified the number of auditory alarms that sounded during routine anesthesia monitoring, and assessed one aspect of alarm systems, the *specificity* of alarms—when an alarm sounded, what did it mean. We did not investigate the other aspect of alarm systems, the *sensitivity*—whether an alarm was sounding whenever a patient was in jeopardy.

Our results show that 75% of all auditory alarms during routine anesthesia monitoring did not originate from changes in the physiological variables for which the monitor was designed, and only 3% represented any patient risk. Similar findings have been reported from an Intensive Care Unit.[1] A common response to frequent false alarms is to disable them altogether.[2,3] Of the Canadian anesthetists surveyed by McIntyre,[3] 57% said they had deliberately inactivated an audible alarm, and the most common reason was too many false alarms. However, a study of breathing system disconnections reported that "the ease of disabling ventilator

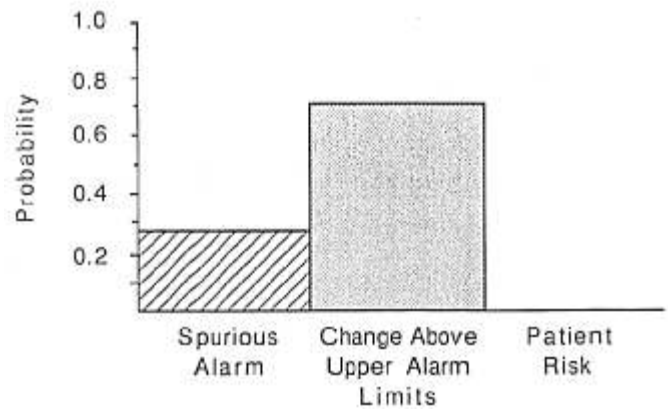

FIG. 5. The probability that a heart rate alarm on the pulse oximeter will be a spurious alarm, a patient risk, or a change above upper alarm limits.

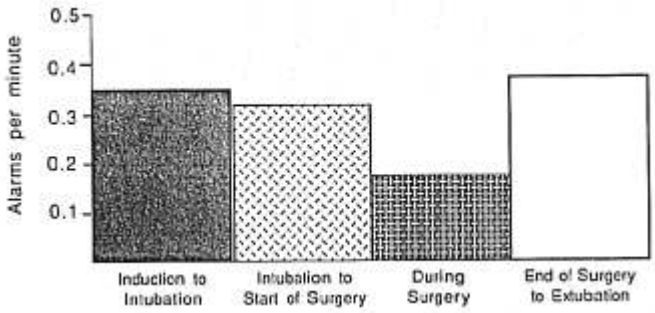

FIG. 6. The frequency of auditory alarms at various stages during anesthesia and surgery.

alarms either deliberately or inadvertently is overall the most important contributory factor in injuries."[4]

Two sources of interference with proper functioning of the monitors in our study were interference from the electrocautery or operating room lights; both of these were causes of spurious alarms. The reverse situation has also been reported in which interference stopped an alarm from indicating a hazardous situation. Pulsatile signals from certain surgical lighting can mimic the physiological signal detected by the Nellcor pulse oximeter; one report cites a case in which this phenomena resulted in falsely high and acceptable oxygen saturations while the patient was actually cyanotic, due to unrecognized accidental tracheal extubation.[5]

Auditory alarms have their derivation from alarms that sound on submarines about to dive; most alarms emit a harsh, unpleasant noise. Manufacturers provide intrusive and aggressive alarms in an attempt to ensure that their equipment cannot be faulted for failing to alert the clinician to a deteriorating situation.[6] The Emergency Care Research Institute has published a series of recommendations for the manufacturer of alarms on monitors of *critical* variables. These include the inability to permanently silence the alarm, a visual as well as an auditory indication, and initial alarm limits at values likely to provide reasonable protection.[5] New alarm sounds have been proposed,[7] which would consist of a sequence of notes, similar to a segment of bird song. These sounds would be composed of at least four harmonics to aid localization, and would sound once and be followed by a period of silence of 20–30 s to avoid the

TABLE 3. Causes of Spurious Alarms

	Patient Movement or Mechanical Problems	Interference from Electrocautery	Interference from Operating Room Lights
Pulse oximeter	75%	23%	2%
Electocardiogram	73%	27%	
Arterial blood pressure	100%		

need to silence the alarm before searching for the cause. If the cause has not been remedied in this period, then the alarm is repeated, and urgency is indicated by an alarm that repeats its signal at faster speed and higher pitch, rather than louder. The total number of such sounds would be limited, since studies in civil aviation have shown diminished ability to recall the significance of more than seven sounds,[7] and pilots believe that all noncritical alarms should be silenced during high workload periods.[8]

Since heart rate, arterial blood pressure, and oxygenation are such fundamental aspects of patient care that anesthesiologists should be continually aware of these variables, it is questionable that these monitors actually need auditory alarms that are so often spurious. If these monitors are fitted with alarms, then the results of this study would suggest that the situation could be improved by using the newer type of alarm sounds outlined in the previous paragraph. This is in contrast to alarm devices such as disconnection alarms or inspired oxygen monitors, which rarely sound, but, when they do so, are likely to denote extreme patient hazard. With an integrated approach to monitoring and alarm systems as a whole, some alarms may be able to be omitted, with a reduction in the number of auditory alarms and an increase in their significance. Gaba *et al.*[9] stated that this approach needs to be validated, and alarms improved so that their benefits clearly outweigh their annoyance and potential confusion. The anesthesiologist's vigilance and ability to integrate information remains the most important source of patient monitoring. We conclude that there is an unacceptably high incidence of spurious alarms during routine anesthesia monitoring.

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Prevention of Hypokalemia during Axillary Nerve Block with 1% Lidocaine and Epinephrine 1:100,000

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We observed a patient in whom a decrease in amplitude of the T wave on the ECG occurred after axillary block with 1% lidocaine and 1:100,000 epinephrine with associated hypokalemia.

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Key words: Anesthetics, local: lidocaine. Anesthetic techniques: axillary; regional. Ions: hypokalemia. Sympathetic nervous system: catecholamines; epinephrine.