Title: AN APPROACH TO "SMART ALARMS" IN ANESTHESIA MONITORING

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Introduction. Lack of monitoring alarm integration often leads to a cacophony of auditory input which usually represents false positives. As initial steps toward "smart alarms" (expert systems/artificial intelligence) we have 1) surveyed alarms during typical cases in our operating rooms, 2) designed a computerized central console for input, display and integration, and 3) formulated some preliminary diagnostic "rules" compatible with our console display format.

Methods. 1) Alarm Survey. With Human Subjects Committee approval, alarms during 25 surgical procedures were monitored by an independent observer (KM). Patients were ASA I-III, and anesthetics were classified as predominantly volatile (isoflurane or enflurane) narcotic based (sufentanil, demerol, fentanyl with nitrous oxide) or regional (epidural, spinal, axillary blocks with lidocaine, tetracaine, or bupivicaine).

Results. Alarm Survey. During 25 cases covering 32.3 hours of anesthesia, 103 alarms occurred. This averaged 3.2 alarms per hour and 4.1 alarms per case. There were 4.4 ± 0.8 (S.E.M.) alarms per hour during volatile anesthetic cases, 3.2 ± 0.4 alarms per hour during narcotic/nitrous cases, and 1.3 ± 0.5 alarms per hour during regional cases. These groups were different ($p < 0.05$) by analysis of variance. Of all alarms, 60.2 percent were considered valid (non-artifactual) and 36.9 percent were considered to indicate potential patient danger.

2. Centralized Console. Our computerized console is compatible with noninvasive or invasive blood pressure, pulse oximetry, EKG, temperature, oxygen concentration, airway pressures, end tidal CO_2, ventilatory rate and volume. The grid format display is shown in Figure 1 with alarm limits in hatched areas, and specific patient values in asterisks. The values shown are from a high spinal with bradycardia, hypotension, and an inoperative pulse oximeter.

3. Interactive Rules. Figure 2 shows preliminary examples of interactive rules based on anesthesia monitors interfaced to our centralized console. Values which exceed the alarm limit "envelope" can activate rule-based combination loci leading to presumptive diagnoses.

Discussion. Anesthesia monitoring may be a fertile area for rule based expert systems which can potentially minimize unnecessary alarm events, consolidate alarm information, and offer presumptive diagnoses. While such systems will be initially superfluous, they are likely to eventually become entrenched in anesthesia practice as a means to optimize vigilance.

Figure 1.

AF (cm H2O)	Vent Rate (bpm)	ET CO2 (cm H2O)	EKG HR (bpm)	Pulse Ox. HR (bpm)	BP HR (bpm)	Temp 1 (°C)	Temp 2 (°C)	FiO2 (%)	PaO2 (%)	Sys. BP (mmHg)	Dia. BP (mmHg)	Mean BP (mmHg)	BP cycling (Y/N)	ESU cycling (Y/N)
100	50	100	250	250	250	50	50	100	100	250	250	250		
90	45	90	225	225	225	45	45	90	90	225	225	225		
80	40	80	200	200	200	40	40	80	80	200	200	200		
70	35	70	175	175	175	35	35	70	70	175	175	175		
60	30	60	150	150	150	30	30	60	60	150	150	150		
50	25	50	125	125	125	25	25	50	50	125	125	125	Y	Y
40	20	40	100	100	100	20	20	40	40	100	100	100	N	N
30	15	30	75	75	75	15	15	30	30	75	75	75		
20	10	20	50	50	50	10	10	20	20	50	50	50		
10	5	10	25	25	25	5	5	10	10	25	25	25		

Figure 2.

HR	BP	Sa02	Fi02	ET CO2	TMP	VLP	Other Conditions	Implication
/\	\/							Hypovolemia
\/	\/						Spinal/Epid.	Spinal/Epid. too high
			\/				Electro-cautery	Interference from ECU
			\/	/\				Pneumo/hemothorax
		\/	\/					Decreased C.O.
						\/		Disconnect in circuit
						\/		NG tube in trachea
						/\		Airway/circuit obstruction
\/	\/							Deep anesthesia
\/	\/							Vagal stimulation
\/	/\							Brain herniation
/\	/\							Light anesthesia
			\/			\/		Patient shivering
			\/	\/				Disconnect
			\/				BP cuff cycling on same arm as Sa02	Interference
/\				/\	/\			Malignant hyperthermia
/\	\/			/\	/\			Sepsis
/\	/\			/\	/\			Thyrotoxic storm
/\	/\			/\				Faulty valve closure