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TITLE: ADAPTIVE DIGITAL FILTER PROVIDES BETTER REAL-TIME PREDICTIONS OF EXPIRED ANESTHETIC GASES THAN CLASSIC PHYSIOLOGIC MODEL

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To time the awakening of a patient, an anesthesiologist makes an experienced guess at the expected decay curve of inhalational anesthetics during recovery from anesthesia. While multiple mathematical models have been developed, they are beyond mental calculation. We developed an online prediction system that measures inspired and expired isoflurane and uses a mathematical model[1] to predict the expired agent value for 30 min into the future, by mathematically continuing to use the current inspired value. This allows the user to briefly reduce the inspired value to near zero and to observe the expected decay of volatile anesthetic. In this prospective clinical monitoring study, which was approved and exempted from informed consent by the institutional review board, we compared the accuracy of the two models, one based on the earlier model (physiologic model) and one based on an adaptive digital filter (adaptive model).

Patients for elective surgery were monitored by an infrared gas analyzer, the analog output of which was digitized by the computerized system. Peak and minimum CO_2 points on analog waveforms were used to determine inspired and expired times. Physiologic and adaptive models were both used 6 times/min to predict the current expired value based on measured inspired agent, and the error between each model's prediction and the actual expired value was computed. A running mean-squared error was summed for each model based on these errors. Additionally, each model was extrapolated 30 min into the future by assuming constant inspired agent, and the resulting plots presented. Data collection every 5 min was stopped at the time the face mask was removed from the patient. The average error of the estimates of each model for the last 20 min (wake-up interval) was computed. Values are reported as mean $\pm$ SD; data were analyzed by paired t test.

Data from 8 patients, 44.5 $\pm$ 19.6 yr old and weighing 79.5 $\pm$ 9.5 kg, were attained. Operations lasted 4.6 $\pm$ 2.7 h. The average of the mean squared errors of the physiologic model was 0.00022 and of the adaptive model 0.0000559, the adaptive filter being more accurate ($p < 0.02$). Out of 483 data points, for 416 (86%), the adaptive model was more accurate than the physiologic model. The errors during the last 20 min were 0.14% for the physiologic model and 0.047% for the adaptive, the adaptive being more accurate ($p < 0.01$).

The adaptive model was significantly more accurate than the physiologic model in predicting each expired value, and more accurate during the last 20 min of the test than earlier in the test; thus, the adaptive model may be useful to compute an expected 30- min trend accurately. Further, the adaptive model does not require information about the patient's weight, which makes it easier to use than the physiologic model. Much of the accuracy of the adaptive model appears to result from its ability to adapt; a physiologic model that is also adaptive might be even more accurate than the nonphysiologic adaptive model.

Reference
1. ANESTHESIOLOGY 29:533-537,1968.

A497

TITLE: EVALUATION OF PHYSICIANS' ABILITIES TO RECOGNIZE MUSICAL ALARM TONES

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Introduction. The problem of accurate identification of alarm sounds in the operating room, recovery room, and intensive care environment has persisted for many years. Monitors made by different companies may have different alarm sounds for the same monitored variable, and similar alarm sounds for different variables.

Standardized alarm tones have been considered by international standard-making organizations. There have been attempts to develop alarm tones for six organ systems, namely oxygenation, ventilation, cardiovascular, temperature, artificial perfusion (*e.g.*, cardiopulmonary bypass), and drug administration systems (*e.g.*, intravenous infusion). Dr. Roy Patterson has proposed such a set of tones, similar to a set in use for aviation[1].

Methods and Materials. This study was exempt from institutional review in accordance with the relevant institutional guidelines. A system of six musical alarm tones was designed, with musical themes from popular songs used for the six organ systems. (See Table.) These tunes were played for a group of anesthesiologists and others at a national meeting. Those who heard the tunes were initially asked to guess the organ system for each tune. The answers were given, and after a short delay, the tunes were played again in a different order.

Results. Seventy-nine response sheets were collected. The maximum possible score was all six tones correct. The expected random score was 1.0 $\pm$ 1.0 correct. The observed score on the first hearing was 1.5 $\pm$ 1.6, $p = 0.01$ in comparison to random. The observed score on the second testing was 4.3 $\pm$ 2.2, $p = 0.001$ compared to the first hearing. On the second testing, 42/79 respondents (53%) got all six answers correct.

Discussion. Traditional study of alarm sounds has been done by human factors engineers and by psychoacousticians. Musicians and considerations of musical principles have been almost entirely excluded from the process. The use of music to associate meanings is obvious in many parts of life. One example is the nursery song "The Alphabet Song" for small children to learn the alphabet. In addition, it seems obvious that an alarm tone which could be hummed or whistled or sung, instead of a series of electronic beeps, could be learned more easily.

This study demonstrates the feasibility of musical alarm tunes for ready identification of alarm sounds in a complex environment. Because of the association of the tunes with a meaning, it is expected that most users could correctly identify each alarm tune after a brief training period.

TABLE

Oxygenation: "Love Is Blue," Paul Mariat and His Orchestra, 1968.
Ventilation: "The Wayward Wind," Gogi Grant, 1956.
Cardiovascular: "I Left My Heart in San Francisco," various artists, written in 1954.
Temperature: "Chariots of Fire - Titles," Vangelis, 1982.
Artificial perfusion (*e.g.*, cardiopulmonary bypass): "The Twist," Chubby Checker, 1960.
Drug administration (*e.g.*, intravenous infusion): Raindrops Keep Fallin' on My Head," B.J. Thomas, 1970.

Reference:
1. Civil Aviation Authority Report 82017.