Title EXPERT ALARMS AND AUTOPILOT IN AN ANESTHESIA WORKSTATION

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Introduction: An anesthesia workstation is needed to help gather and record data, to detect critical events and to control the delivery of anesthetics. A workstation's decision-making capability would help make anesthesia safer; the control features would help make anesthesia simpler and easier to manage.

Equipment: A prototype workstation (Fig. 1) includes nine custom-built pressure sensors (#1-9), a pneumotach, an infrared anesthetic agent analyzer, a mainstream CO_2 analyzer, a polarographic oxygen monitor, a ventilator bellows position sensor, and three mass flow controllers. Custom programs written in PASCAL acquire, filter and display the data (Fig. 2). If an unexpected event is detected by the expert alarm system, the central display shows a diagram of the failed component (Fig. 3), and one of 43 possible alarm messages. In the Autopilot mode, the fresh gas flow rate, F_IO_2 and end-tidal anesthetic concentration are specified by the user and the computer electronically controls the fresh gas flows to achieve the set points.

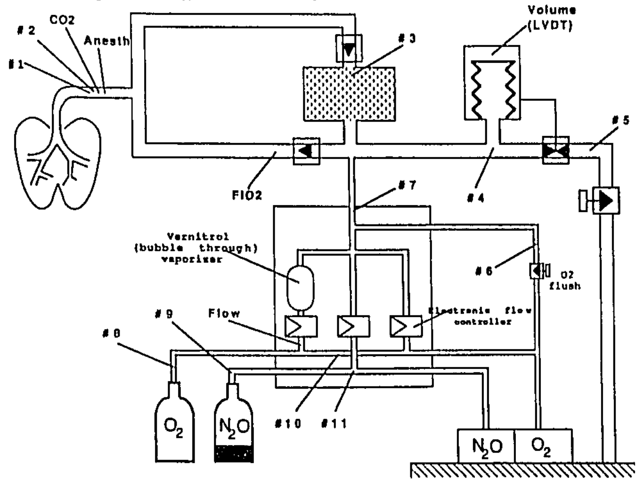
Methods: The expert alarm system was bench tested to see if it properly identified 26 different critical events during high flow and closed circuit anesthesia with large and small test lung volumes. The autopilot was tested for the time to reach a desired level of inhalation anesthesia.

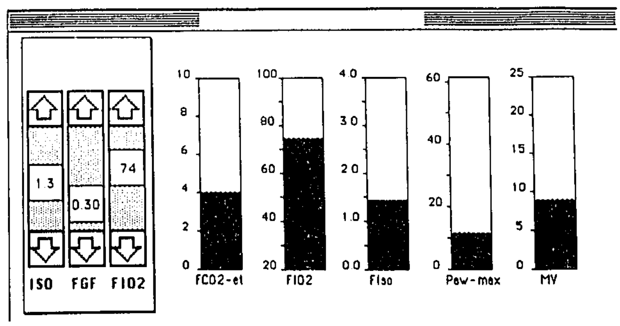
Results: The expert alarm system correctly identified 619 of the 660 simulated critical events. Eight of the false negative mistakes were failures to recognize a fresh gas hose disconnect; five were failures to see an open inspiratory valve. Wrong messages appeared 28 times; 14 times an open inspiratory valve was given the message "High End-tidal CO_2" and 14 times an open expiratory valve was interpreted as "Ventilator Failure". Eight false positive alarms occurred during the 20 hours of testing; four "Leak Around Endotracheal Tube" alarms, three "Partial Obstruction Distal to Y" and one "Fresh Gas Outlet Obstructed".

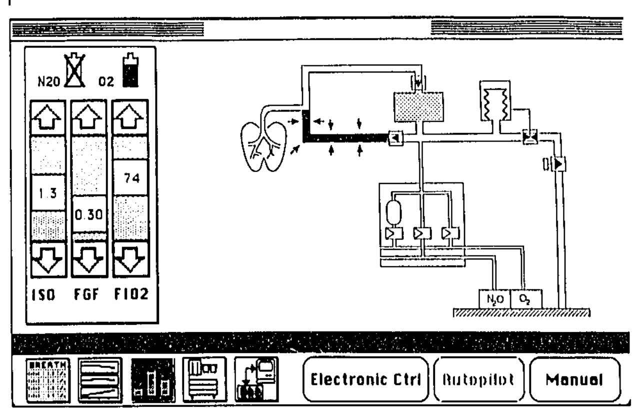
The autopilot induced inhalation anesthesia in a lung model reaching the end-tidal set point in 4.4 $\pm$ 1.4 min (mean $\pm$ SD); Smith has shown it takes experienced anesthesiologists 10.6 $\pm$ 4.2 min to perform the same task [1]. The autopilot held the agent concentration to within .002 vol% of the desired value; with manual control the variability was 5 times greater. After a disconnect the autopilot restored circuit volume in 28 $\pm$ 4 sec and kept the oxygen within $\pm$ 0.2 vol% of the desired concentration.

Discussion. The workstation expert alarm system produced more meaningful and more diagnostic alerts than did the oxygen, CO_2, agent or pressure high/low monitor alarms The graphic and text message should significantly reduce reaction time to critical events. The expert system's ability to automatically set alarm thresholds may avoid mistakes made when multiple alarm limits are set manually.

The present rule-based expert alarm system needs further refinement to correct the "fresh gas hose disconnect" rule, to better reject artifact and to more specifically identify flutter valve failures. A rule-based production system implementation of the existing rules is seen as the way to improve alarm accuracy through self-adaptive features.







Reference:
1. Smith NT, Anesth Analg 1984; 63:715.