

Title: ANESTHESIA SIMULATION IN AN ACTUAL OPERATING ROOM ENVIRONMENT

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**INTRODUCTION:** Mishaps during anesthesia remain a significant source of morbidity and mortality. The ability of anesthesiologists to prevent and handle problems has rarely been studied. We have developed an anesthesia simulator system which substantially mimics virtually all aspects of the operating room environment for use in studying the problem solving abilities of anesthesiologists.

**METHODS:** The simulator system (Figure) provides inputs to most commonly used monitors during anesthesia. ECG and blood pressure waveforms are provided by a Datasim 6000 simulator driving a Marquette Surgical 7000 RA monitor system. This simulator provides multiple normal and abnormal rhythms with incremental control of heart rate in each rhythm. Automatic pressure tracking of premature and post-premature beats is provided. To allow complete control of the amplitude of invasive pressure waveforms we constructed a digitally controlled amplifier/attenuator for each pressure channel. This allows amplitude adjustment of mean arterial pressure from 0 - 150 mm Hg in increments of 1 mm Hg; similar adjustments for pulmonary artery and central venous waveforms are implemented with appropriate scale reductions. A Nellcor N-100 pulse oximeter is driven by an oximetry simulator provided by Nellcor, Inc. Non-invasive blood pressure data are displayed on a functional replica of the Datascope Accutorr implemented on a Macintosh computer screen. Each of the above simulators is controlled via serial communications (RS-232C) from a central computer (Compaq Plus). A serial port expander is used to allow communication with at least 3 serial devices. The central computer software was written in the language ASYST which allowed high level computation, A/D and D/A conversion, and digital and analogue outputs with a Keithley Instruments Data Acquisition System. Two temperature channels are simulated to 0.1 degrees Celsius resolution using ten turn potentiometers.

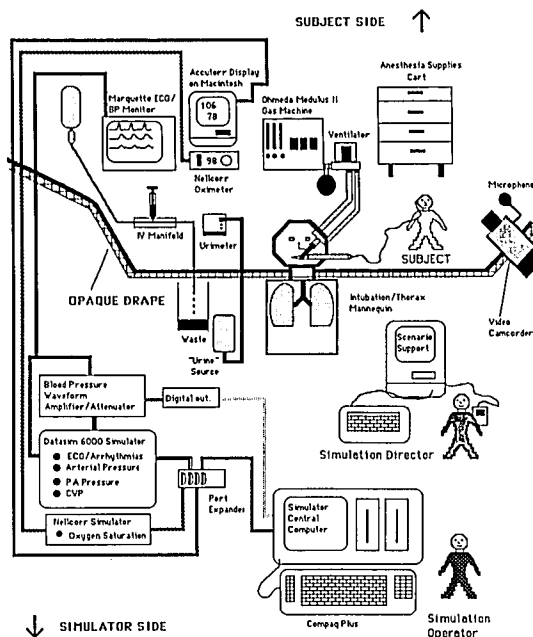
An intubation/thorax mannequin is used for simulation of airway manipulations including endotracheal intubation. The mannequin has two "lungs" which can be occluded preferentially. Breath sounds can be heard in the mannequin both externally and via an esophageal stethoscope. Gastric regurgitation can be simulated by pressure infusion into the mannequin's esophagus. Intravenous lines drain into a waste container and can be occluded or disconnected. Urine output is simulated by volumetrically controlled infusion of dyed solution into a urine measurement bag.

A standard Ohmeda Modulus II anesthesia machine is utilized for gas flow and automatic ventilation. Intravenous drugs must be drawn up and administered into the IV tubing to be effective. Our standard multi-drawer drug cart is used to provide all customary anesthesia supplies.

Simulator responses are determined by a fully

trained anesthesiologist using a script and guidelines given by scenario support software (implemented on a Macintosh Plus computer in APL) which lists active problems, indicates acceptable solutions, and calculates appropriate responses to drug administration.

**DISCUSSION:** Simulators for general anesthesia have been developed before but were unable to replicate the full range of monitored variables<sup>1</sup> or were implemented solely on a computer screen.<sup>2</sup> Our system uses actual operating room monitors and equipment to more realistically simulate the environment faced by anesthesiologists, making it possible to investigate the cognitive demands and problem solving skills involved in safe anesthesia care. In addition, our system is novel in that waveforms are generated using off-the-shelf simulators, reducing the complexity and cost of software development for the central computer. Besides its use as a research tool for investigation of human factors during anesthesia administration such a simulator system may eventually be useful for training of new anesthesia personnel, for board certification, or continuing education.



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