Extending simulators to improve support for patient monitoring display research

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Introduction

In addition to being used for education and training [1], anesthesia simulators have been used to evaluate novel monitoring displays — specifically, how effectively displays convey physiological information to the anesthesiologist [2, 3].

Human factors evaluations using patient simulators can help researchers detect latent errors and design faults earlier in the equipment development cycle [4].

Methods

During our research on monitoring displays, we observed major shortcomings of existing high-fidelity simulators when used for display evaluations, including the following:

1. It can be difficult to manipulate patients in model-based simulators via indirect parameters (e.g. drugs and fluids) to achieve a specific pattern of physiological parameters.

2. Not all of the monitors used in the operating room are simulated; e.g. Body™ does not provide a plethysmography waveform and the METI ECS™ lacks gas monitoring.

3. High-fidelity simulators provide more fidelity at the expense of less control; e.g. P_ACO_2 can be directly manipulated on the METI HPS™, but not the capnograph.

4. Many important aspects of monitor use are not simulated, including probe disconnection, interference, leaks, and failures.

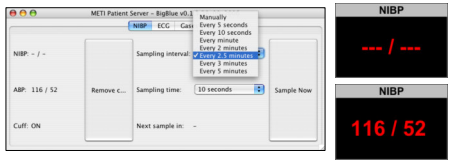
To mitigate these factors, we developed software extensions to the BODY™ and METI ECS™ simulators using the Java programming language. The vital signs data were broadcast to our auditory and head-mounted display-based monitor prototypes over a TCP/IP-based protocol.

Results

Our software extensions allowed us to incorporate the following five controller-driven simulated patient variables in our scenarios.

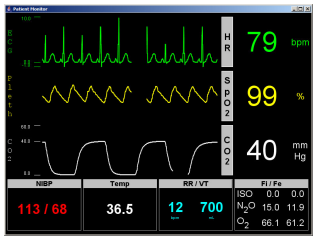
Non-invasive Blood Pressure

We developed an instructor-driven NIBP interface to supplement NIBP sampling, which is not supported on the METI Waveform Display™ (and not implemented in BODY™ DLL). Our implementation supports cuff placement and removal, automated sampling at regular intervals, sampling/cycling delays, and instant re-sampling.



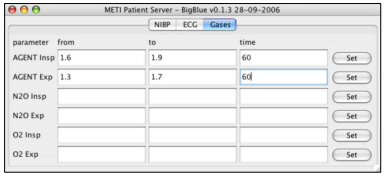
Pulse Oximetry Plethysmography Waveforms

The BODY™ simulator does not provide plethysmography waveforms. We re-scaled and calculated a "rolling average window" of the arterial blood pressure waveform to simulate a substitute.



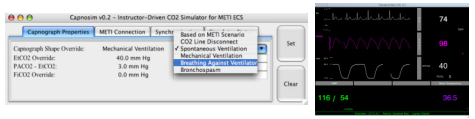
Instructor-driven Gas Analysis

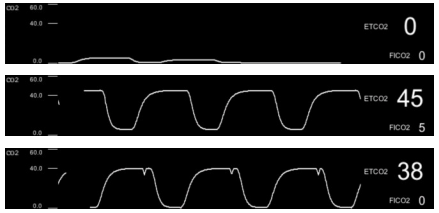
Software-based simulation of gas analysis on the monitoring display allows us to create gas events, e.g. empty or excessive volatile, more easily than using mechanical methods.



Capnography Waveforms

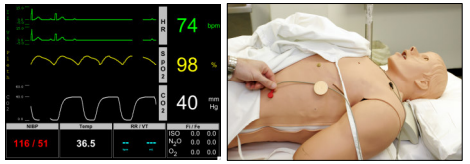
To provide greater flexibility simulating airway events, we developed a utility for instructor-driven capnography simulation on the METI simulators. The patient's breathing patterns are tracked in real-time to interpolate capnography waveforms.





ECG lead disconnection

It can be difficult for actors to disconnect the ECG lead whilst participants are watching them (to prevent "sabotage"). We developed a control room "override" function that allows the ECG lead to be physically disconnected at any time by the actors. The controllers can then make the ECG trace disappear at a later stage in the scenario.



Conclusions

These extensions have made our scenario design and development more flexible. They have allowed us to program a variety of events which include equipment events such as disconnections during scenarios and thus have made our simulator scenarios [5] more realistic.

References

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