A Model-Based Simulator for Testing Rule-Based Decision Support Systems for Mechanical Ventilation of ARDS Patients

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A model-based simulator was developed for testing rule-based decision support systems that manages ventilator therapy of patients with the Adult Respiratory Distress Syndrome (ARDS). The simulator is based on a multi-compartment model of the human body and mathematical models of the gas exchange abnormalities associated with ARDS. Initial testing of this system indicates that model-based simulators are a viable tool for testing rule-based expert systems used in health-care.

INTRODUCTION

During the past decade, researchers at LDS Hospital have developed a series of computerized decision support systems for managing the mechanical ventilation of patients with ARDS. These protocols, as they are called, are data and time driven, rule-based expert systems which suggest changes in mechanical ventilator therapy based on current and past respiratory therapy and laboratory data. These protocols run within and directly access the integrated patient database of LDS Hospital's HELP system [1, 2]. The complexity of the protocol system makes the testing of the underlying logic and its exact implementation difficult and confusing. In the past, the only way to test the computerized protocols was to manually enter all of the necessary data into the computer in real-time. This is neither an elegant nor efficient means of testing. The objective of this work was to develop a new type of tool for testing rule-based expert systems: a model-based simulator of the human body. Model based simulators are able to dynamically adjust to the suggestions and requests of a rule-based expert system and are therefore an improvement over previous testing methods.

METHODS / RESULTS

The simulator is based on a multi-compartment model of the human body. The various compartments represent various physiologically distinct body tissues, such as arterial and venous blood pools, musculoskeletal system, central nervous system, and the three compartments of the Riley-Cournand lung. [3] The gas exchange abnormalities associated with ARDS were modeled using mathematical models describing the time-course changes sizes of the shunt fraction and dead space compartments of the Riley-Cournand lung. Gas exchange was also corrected for Positive End Expiratory Pressure (PEEP), cardiac output, and pH. [3, 4] It is important to understand the simulator compresses time to speed up the testing process. Time compression is achieved by starting the simulation's clock at a point in the past and then processing the model's equations rapidly enough that the simulator's clock moves faster than real clocks. This is a change from previous testing methods which were limited by the normal passage of time.

Since February 1, 1994, the simulator has been tested for more than 2000 simulated hours. The simulator's modeled physiologic responses were similar to those of ARDS patients treated in LDS Hospital's intensive care unit. During this period, fifteen individual patients were simulated and more than 900 instructions generated. The simulator dynamically changed the disease process model and made protocol-suggested therapy adjustments. Initial tests of the simulator uncovered two small programming syntax errors in portions of the protocols which deal with clinically rare conditions. These errors were quickly and easily corrected before they could cause any problems in the clinical use of the protocols.

Model-based simulators are an untapped, important, and useful addition to the toolbox of anyone who develops and tests expert systems used in health care .

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