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1. Introduction
Modern anesthesia methods and techniques for complicated surgery, e.g. open-heart surgery, put a high workload on the information processing capability of the anesthesiologist. Therefore it is necessary to support the anesthesiologist with an appropriate information system. For this purpose Trispel, Klocke and Rau /2,5/ developed the anesthesia information system AIS. AIS has features such as clear-arranged information displayed on a high resolution color graphics monitor, automatic data registration from patient monitors, easy interaction via touch input and on-line documentation (anesthesia record).

AIS is currently being extended by a knowledge-based decision support facility, AES-2. AES-2 is focussed as an example on the field of hemodynamics during aortocoronary bypass surgery. During anesthesia, AIS provides AES-2 with all recorded information, e.g. the values of the patient’s vital parameters, drug administration, etc. Based on these data, AES-2 assesses the patient’s hemodynamic state with respect to so-called state variables, i.e. myocardial contractility, afterload, preload, heart frequency, and anesthetic level. Since most of these variables cannot be measured directly, AES-2 applies certain rules to conclude their status, e.g.:

"Afterload may be too high, if systolic blood pressure is above normal and left atrial pressure is below normal".

If a state variable leaves the range of normal, AES-2 indicates this to the user ("intelligent alarm") and, on request, generates appropriate therapy recommendations. These functions are discussed more detailly in /6,7/. This paper is focussed on simulation techniques that support the design process of AES-2, i.e. knowledge acquisition and validation.

2. Why Simulation?
It is well known that there are several difficulties in performing the tasks of knowledge acquisition /8/ and validation /4/. Therefore the process of designing AES-2 iterates through many prototype versions. This process is supported by simulation techniques that (1) enable a knowledge
engineer to preoptimize AES-2 before asking an anesthesiologist to comment on the performance of a new knowledge base prototype, and (2) provide an opportunity to let an expert anesthesiologist perform his task in a laboratory environment (thereby reducing the amount of knowledge acquisition in the operating room, which can distract the anesthesiologist from the patient).

During simulation the knowledge-based system AES-2 is provided with situation sequences as test cases. These test cases should be reproducible and most realistic. Furthermore, they should cover most situations that can occur in reality, and the contents of the knowledge base should be tested completely. In practice, a single simulation technique cannot meet these requirements simultaneously. Therefore, we have designed 3 different simulators that complement each other. Each simulator applies a different method for generating test data. During simulation, one of these simulators is selected and connected to the AES-2, thereby replacing the information system AIS (each simulator uses the same protocol as AIS for information exchange with AES-2).

3 Interactive Play Back of an Anesthesia Record
This simulation technique requires a precise recording of a surgical procedure which can only be produced by an advanced anesthesia information system as the AIS (see 1.). A thus acquired anesthesia record is then used as a source of test data for the knowledge-based system. For this purpose the system AIS was extended by a simulation component that facilitates working through an anesthesia record interactively.

Fig. 1 presents the display of AIS including an interaction component that controls the simulation. Its design is consistent with the usual interactive control of AIS. The simulation functions are similar to those of a commercial video recorder, therefore the design of the interaction with the simulator is oriented at those common concepts. The functions comprise specification of the start time of the simulation ("<<"), "PLAY" (">"), single step ("STEP"), time acceleration (">>") and stop.

The main advantage of this simulation technique is that the produced data sequences are very realistic. However, there are 2 major shortcomings: The elements of the knowledge base are tested to different degrees of intensity. In particular, testing with rare situations, which is very important for assessing the performance of the decision support system, leads to very high recording efforts. This shortcoming is compensated by the scenario simulator (see below). A further shortcoming is the lack of feedback from the decision support system to the course of the surgical procedure. This shortcoming can be compensated for by application of an appropriate patient model (see below).