International Journal of Clinical Monitoring and Computing **8**: 259–262, 1992.

Knowledge engineering using retrospective review of data: a useful technique or merely data dredging?

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Accepted 16 December 1991

Key words: knowledge engineering, computers, medical decision making, expert system, hemodynamics, ARDS, critical care

Abstract

The process of extracting the knowledge or rules for medical decision making is not an easy task. One approach to knowledge engineering is to carefully review how decisions were made in the past with the goal of extracting the rules. The purpose of this project was to use previously collected data from ICU patients to derive the rules for the definition of hemodynamic stability.

97 ICU patients between 9/9/86 and 7/29/90 were included in the analysis. All of these patients had adult respiratory distress syndrome. Their mechanical ventilation was managed by a set of computerized protocols. We retrospectively searched the HELP system database for instructions that were not followed due to hemodynamic reasons. For each patient, we also chose one randomly selected therapy instruction which was followed to act as a control. For each instruction we then selected the corresponding hemodynamic data set. The data was then used in a stepwise logistic regression to determine the rules used for defining hemodynamic instability.

We found that several of the hemodynamic parameters we had anticipated to be important were not even measured most of the time. The blood pressures and heart rate were almost identical between the hemodynamicly stable and unstable data sets. We conclude that the decision making process used by physicians has great variation, both between and within physicians. This makes knowledge engineering using retrospective techniques such as this prone to error and probably not very fruitful.

Introduction

The process of extracting the knowledge or rules behind medical decision making is not an easy task. There is a wide variety of intangible variables which are used in the decision making process and the rules are often physician specific. Even for a given physician the rules may change from day-to-day and for a specific patient. One approach to knowledge engineering is to carefully review how decisions were made in the past with the goal of extracting the rules. The hypothesis behind this approach is that given a large group of physicians over a long time and many different patients that a central tendency can be observed. This central tendency will reflect some common set of rules.

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Methods

Ninety-seven ICU patients between 9/9/86 and 7/29/90 were included in the analysis. All patients had adult respiratory distress syndrom (ARDS). Their mechanical ventilation was managed by a set of computerized protocols which have been described in detail elsewhere [1–3]. These protocols have now been used for over 30,000 hours in 101 patients. These protocols generate specific treatment instructions of which 94% were followed. If the clinician does not feel that the instruction is valid the software will request the clinician to choose a reason from a list. One of the reasons is hemodynamic instability.

In order to examine the data that led to the classification of hemodynamic instability we retrospectively searched the HELP system [4] database for instructions that were not followed due to hemodynamic reasons. For each patient, we also chose one randomly selected positive end-expiratory pressure (PEEP) increase instruction which was followed to act as a control. For each instruction we then selected the following data set:

- Systolic Blood Pressure
- Diastolic Blood Pressure
- Mean Blood Pressure
- Heart Rate
- Mixed Venous Oxygen Saturation (S_VO_2)
- Cardiac Output (Qt)
- Pulmonary Artery Pressure (PA)
- Pulmonary Artery Wedge Pressure (PAW)

The search was conducted between the time of the instruction −2 hours and time of the instruction +10 minutes. The value closest to the time of the instruction was chosen. It was felt that data more than 2 hours old was not representative in a critically ill ARDS patient.

The data was analyzed using the BMDP statistical package. A stepwise logistic regression was performed to generate a model for the classification of hemodynamic instability. The data description (module P1D) and the stepwise logistic regression package (PLR) were used. The alpha level was set at 0.05.

Table 1. Sample sizes for each variable

Variable	Stable		Unstable	
	N	%	N	%
Sys BP	97	100%	36	100%
Dia BP	97	100%	36	100%
Mean BP	97	100%	36	100%
HR	97	100%	36	100%
S_VO_2	29	30%	11	31%
Qt	23	24%	4	11%
PA	56	58%	18	50%
PAW	56	58%	18	50%

Results

Ninety-seven patients with 36 noted hemodynamic instabilities were included in the analysis. There were 97 measurement sets in the control (stable hemodynamics) data and 36 measurement sets in the hemodynamic instability data. Table 1 is a summary of the sample sizes for the variables included in the search (shown are N and percent of total N, either 97 for stable or 36 for unstable). Because S_VO_2, Qt, PA and PAW were available less than 58% of the time it was felt that these parameters could not have been uniformly used in the decision making process and were excluded from further analysis. Table 2 documents the mean and the standard error of the mean for each of the variables in both the stable and unstable hemodynamic states. This data is visually compared in figure 1.

The stepwise logistic regression was performed with a removal limit of $p > 0.15$ and an enter limit of $p < 0.10$. The regression did not converge after 50 iterations. This indicated that there was no equation which fits this data well enough to explain much the observed variance. After 50 iterations the

Table 2. Hemodynamic data versus status

Hemo status	Sys BP	Dia BP	Mean BP	HR
Stable	120 ± 2.5	67 ± 1.5	86 ± 1.8	111 ± 2.7
Unstable	119 ± 4.6	66 ± 2.7	85 ± 3.2	113 ± 2.4

Shown are mean ± SEM

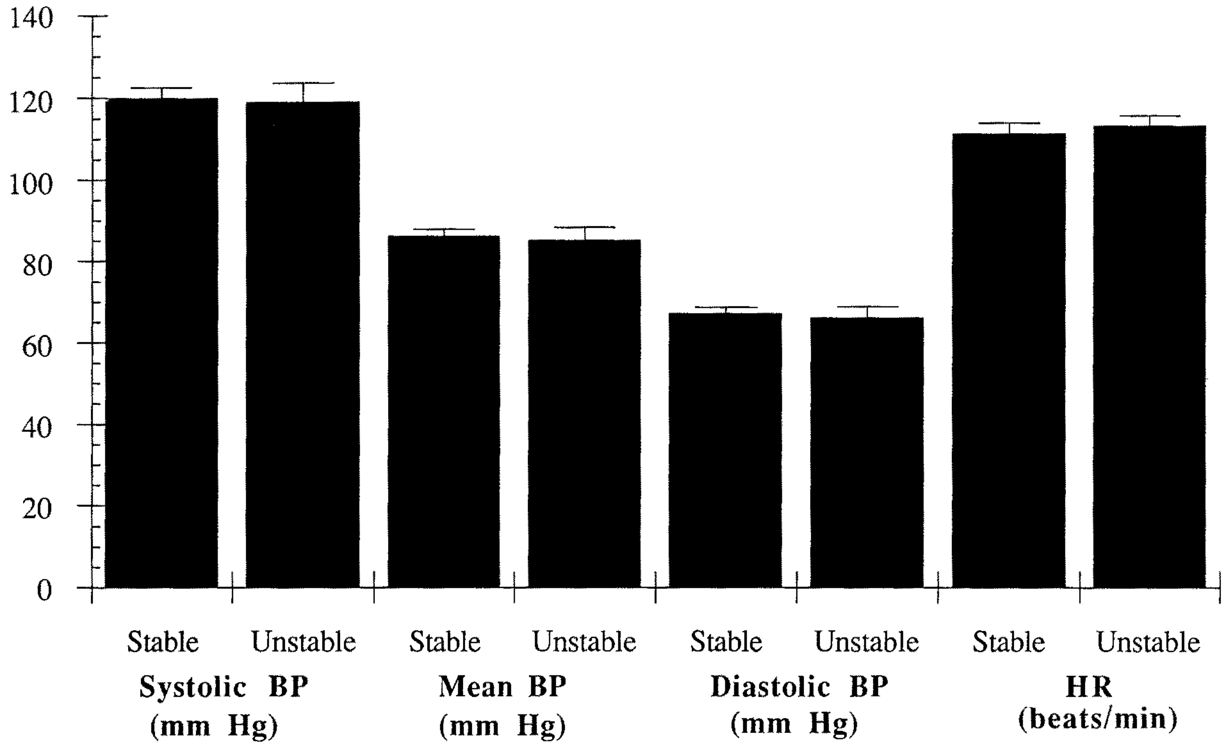

Fig. 1. Systolic, mean, and diastolic blood pressure and heart rate for both the stable and unstable states. Shown are the mean and SEM.

relative improvement in the log-likelihood ratio was -1×10^{-7}.

Discussion

Our overall observation was that even with a well constrained small problem with good data on the decision made by the clinician, there was no central tendency in any of the study variables that would indicate a rule for defining hemodynamic instability during ventilator management.

One conclusion is that the data set we had considered important for defining hemodynamic state included variables which were not routinely measured and, presumably therefore, not included in the decision making process. It was a surprise to find that S_VO_2, Qt, PA and PAW are not measured a majority of the time when making a decision on hemodynamic instability. It is possible that these variables were important at the time they were measured and in the particular circumstance under which they were requested; however, there was no evidence to suggest that they were a routine part of the decision making process. It was also not clear that there were any rules about when these particular variables were required in the decision making process.

Two different interpretations of our results are possible. First, that there is such wide variability in the rules used by individual physicians at different times and in different patients that it is impossible to use retrospective techniques such as this to derive a rule base. The second interpretation is that there are variables which are important in making this decision which we did not measure including whether or not certain measurements are performed. It is possible that the clinician at the bedside might be considering evidence from a physical exam such as nail-bed refilling time, evidence of pitting edema in the extremities, etc. We have asked several of the physicians how they made their decisions. They implied that some times they made these decisions based upon their 'feelings about the patient cardiac reserve'. Such a decision making process might include data such as the current level of vasopressor and fluid support. Essentially they were anticipating the adverse effects of the suggested therapy instruction. This type of a 'gut instinct' medical decision is very difficult to include in a knowledge base.

We feel that the retrospective use of data to derive knowledge is prone to error and probably not very reliable. We have found that the best approach seems to be to have a concensus group agree on a proposed set of rules. These rules are then put in place in the ICU. If the instructions generated at the bedside are felt to be incorrect then the reasons are logged and the concensus group can re-examine the logic behind the rules. This iterative process has enabled us to develop very successful protocols for management of mechanical ventilation. We are in currently using this approach to generate the rules defining hemodynamic instability.

Acknowledgements

Supported by Hamilton Ventilators (Bonaduz, Switzerland), NIH Grant HL36787 'Extracorporeal CO_2 Removal for ARDS', the Deseret Foundation (LDS Hospital) and the Respiratory Distress Syndrome Foundation.

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