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Computers in Biology and Medicine 36 (2006) 585–600

Computers in Biology and Medicine

www.intl.elsevierhealth.com/journals/cobm

Stochastic model for outcome prediction in acute illness

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Received 16 December 2004; accepted 14 March 2005

Abstract

The aims were to apply a stochastic model to predict outcome early in acute emergencies and to evaluate the effectiveness of various therapies in a consecutively monitored series of severely injured patients with noninvasive hemodynamic monitoring. The survival probabilities were calculated beginning shortly after admission to the emergency department (ED) and at subsequent intervals during their hospitalization. Cardiac function was evaluated by cardiac output (CI), heart rate (HR), and mean arterial blood pressure (MAP), pulmonary function by pulse oximetry ($SapO_2$), and tissue perfusion function by transcutaneous oxygen indexed to FiO_2, ($PtcO_2/FiO_2$), and carbon dioxide ($PtcCO_2$) tension. The survival probability (SP) of survivors averaged $81.5 \pm 1.1\%$ (SEM) and for nonsurvivors $57.7 \pm 2.3\%$ ($p < 0.001$) in the first 24-hour period of resuscitation and subsequent management. The CI, $SapO_2$, $PtcO_2/FiO_2$ and MAP were significantly higher in survivors than in nonsurvivors during the initial resuscitation, while HR and $PtcCO_2$ tensions were higher in the nonsurvivors. Predictions made during the initial resuscitation period in the first 24-hours after admission were compared with the actual outcome at hospital discharge, which were usually several weeks later; misclassifications were 9.6% (16/167). The therapeutic decision

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doi:10.1016/j.compbiomed.2005.03.006

support system objectively evaluated the responses of alternative therapies based on responses of patients with similar clinical-hemodynamic states.

Keywords: Stochastic (probability) analysis and control program; Outcome prediction; Noninvasive hemodynamic monitoring; Thoracic bioimpedance cardiac output; Tissue perfusion

1. Introduction

Invasive pulmonary artery (PA) thermodilution (Swan-Ganz^{R}) catheters provide the maximum circulatory data at the bedside, but require intensive care unit (ICU) conditions. However, when invasive monitoring was started late in the course of illness after ICU admission for organ failure, there was no advantage of the PA catheter or goal-oriented therapy [1–5]. Since time is an important factor in resuscitation and management of critically ill emergency patients, early noninvasive monitoring with an outcome predictor may be a useful approach to identify and correct hemodynamic deficiencies as early as possible [6–19]. Similar to early diagnosis and therapy for cancer, early diagnosis and therapy for circulatory problems may be more cost-effective than therapy delayed until late stages. Previous studies have demonstrated an improved outcome prediction using discriminate function analysis [15].

Acute injury was selected for study because the onset of illness occurred shortly before admission and the course of circulatory events could be monitored from the time of admission [6,13]. Recently, Bayard et al. [20] developed a stochastic probability analysis and control model that uses a large database of noninvasively monitored hemodynamic variables to provide outcome prediction.

The present report applies this mathematical model to acute severely injured emergency patients under worst-case conditions. We were unable to find prior applications stochastic models to analysis of hemodynamic patterns in acute critical illness.

2. Materials and methods

2.1. Clinical series

We studied 177 severely injured patients by noninvasive hemodynamic monitoring that reflects cardiac, respiratory, and tissue perfusion functions together with a stochastic search and display program. In addition, the following data were included in the database: age, gender, presence of sepsis or activation of the systemic immune response system (SIRS), Glasgow coma score, injury severity score (ISS), primary injuries, hemodynamic patterns by invasive and noninvasive methods, organ failures, other complications, hospital days, ICU days, and hospital outcome. Table 1 lists the salient clinical features. The protocol was approved by the Institution's Review Board.

2.2. Noninvasive hemodynamic monitoring

Noninvasive hemodynamic monitoring displays continuous on-line real time cardiac, pulmonary, and tissue perfusion data in critically ill patients [17,18,21]. The data was downloaded at 30-s intervals, aver-