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A Copula-Based Approach for the Assessment of Severity of Illness and Probability of Mortality: An Exploratory Study Applied to Intensive Care Patients

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Abstract : Continuous improvement of both the quality and safety of health care is an important goal in Australia and internationally. The intensive care unit (ICU) receives patients with a wide variety of and severity of illnesses. Accurately identifying patients at risk of developing complications or dying is crucial to increasing healthcare efficiency. Thus, it is essential for clinicians and researchers to have a robust framework capable of evaluating the risk profile of a patient. ICU scoring systems provide such a framework. The Acute Physiology and Chronic Health Evaluation III and the Simplified Acute Physiology Score II are ICU scoring systems frequently used for assessing the severity of acute illness. These scoring systems collect multiple risk factors for each patient including physiological measurements then render the assessment outcomes of individual risk factors into a single numerical value. A higher score is related to a more severe patient condition. Furthermore, the Mortality Probability Model II uses logistic regression based on independent risk factors to predict a patient's probability of mortality. An important overlooked limitation of SAPS II and MPM II is that they do not, to date, include interaction terms between a patient's vital signs. This is a prominent oversight as it is likely there is an interplay among vital signs. The co-existence of certain conditions may pose a greater health risk than when these conditions exist independently. One barrier to including such interaction terms in predictive models is the dimensionality issue as it becomes difficult to use variable selection. We propose an innovative scoring system which takes into account a dependence structure among patient's vital signs, such as systolic and diastolic blood pressures, heart rate, pulse interval, and peripheral oxygen saturation. Copulas will capture the dependence among normally distributed and skewed variables as some of the vital sign distributions are skewed. The estimated dependence parameter will then be incorporated into the traditional scoring systems to adjust the points allocated for the individual vital sign measurements. The same dependence parameter will also be used to create an alternative copula-based model for predicting a patient's probability of mortality. The new copula-based approach will accommodate not only a patient's trajectories of vital signs but also the joint dependence probabilities among the vital signs. We hypothesise that this approach will produce more stable assessments and lead to more time efficient and accurate predictions. We will use two data sets: (1) 250 ICU patients admitted once to the Chui Regional Hospital (Kyrgyzstan) and (2) 37 ICU patients' agitation-sedation profiles collected by the Hunter Medical Research Institute (Australia). Both the traditional scoring approach and our copula-based approach will be evaluated using the Brier score to indicate overall model performance, the concordance (or c) statistic to indicate the discriminative ability (or area under the receiver operating characteristic (ROC) curve), and goodness-of-fit statistics for calibration. We will also report discrimination and calibration values and establish visualization of the copulas and high dimensional regions of risk interrelating two or three vital signs in so-called higher dimensional ROCs.

Keywords : copula, intensive unit scoring system, ROC curves, vital sign dependence
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