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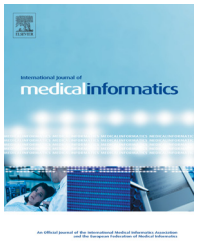

Reducing unnecessary lab testing in the ICU with artificial intelligence

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ABSTRACT

Objectives: To reduce unnecessary lab testing by predicting when a proposed future lab test is likely to contribute information gain and thereby influence clinical management in patients with gastrointestinal bleeding. Recent studies have demonstrated that frequent laboratory testing does not necessarily relate to better outcomes.
Design: Data preprocessing, feature selection, and classification were performed and an artificial intelligence tool, fuzzy modeling, was used to identify lab tests that do not contribute an information gain. There were 11 input variables in total. Ten of these were derived from bedside monitor trends heart rate, oxygen saturation, respiratory rate, temperature, blood pressure, and urine collections, as well as infusion products and transfusions. The final input variable was a previous value from one of the eight lab tests being predicted: calcium, PTT, hematocrit, fibrinogen, lactate, platelets, INR and hemoglobin. The outcome for each test was a binary framework defining whether a test result contributed information gain or not.
Patients: Predictive modeling was applied to recognize unnecessary lab tests in a real world ICU database extract comprising 746 patients with gastrointestinal bleeding.
Main results: Classification accuracy of necessary and unnecessary lab tests of greater than 80% was achieved for all eight lab tests. Sensitivity and specificity were satisfactory for all the outcomes. An average reduction of 50% of the lab tests was obtained. This is an improvement from previously reported similar studies with average performance 37% by [1–3].
Conclusions: Reducing frequent lab testing and the potential clinical and financial implications are an important issue in intensive care. In this work we present an artificial intelligence method to predict the benefit of proposed future laboratory tests. Using ICU data from 746 patients with gastrointestinal bleeding, and eleven measurements, we demonstrate high accuracy in predicting the likely information to be gained from proposed future lab testing for eight common GI related lab tests. Future work will explore applications of this approach to a range of underlying medical conditions and laboratory tests.

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1. State of the art

Laboratory testing occurs frequently in hospitalized patients [4]. This is especially so for patients in intensive care, where frequent blood draws are associated with general phlebotomy complications [1,5]. While part of this testing reflects changes in the intrinsic critical status of ICU patients, other tests are run by default, following general guidelines and not driven by patient-specific clinical questions [6,7]. Excessive use of laboratory blood tests increases resource utilization, contributes to blood loss, and may lead to incorrect diagnosis and treatment. In addition, laboratory tests in the ICU are sometimes obtained without a physician order, which hinders proper documentation [1]. However, modifying test-ordering practices in the ICU is challenging, mainly because of the pre-assumption that critical patients take a benefit from frequent testing, the ease of blood drawing from indwelling arterial and central venous catheters, and the difficulty of implementing durable changes of practice in a multidisciplinary environment such as the ICU.

Studies [8] and [9] have shown that general ward admissions average 1.1 draws per day per patient, extracting 12.4 ml of blood per day, resulting in 175 ml of blood drawn per hospitalization. These numbers are increased for an average ICU admission where there are 3.4 draws per day per patient, and 762.2 ml for the entire admission, and even more for ICU patients with an arterial line inserted, where there are 4.0 draws per day per patient, and 944 ml during the whole admission. Depending on the patient's condition and the underlying reasons for admission, the cumulative amount of blood drawn for laboratory testing purposes might warrant transfusion replacement, an expensive and risky practice in itself.

Among the reasons for over-testing, one may find that many tests are ordered as part of a panel. Many factors contribute to this practice, including lack of awareness of the consequences of over-testing, arising from the medical culture promoting "more visible" care, the medico-legal environment and financial incentives arising from a fee-for-service reimbursement scheme [10]. Previous studies have shown that a significant percentage of the tests requested are medically unnecessary [11].

New guidelines for laboratory testing in surgical ICU patients have been defined to enhance the decision-making process for a test requirement, limit unnecessary testing and provide appropriate documentation of physician orders. In [1] it was concluded that decreasing the number of tests is not associated with additional morbidity, and decreasing the number of tests may decrease blood transfusions. Overall, in [1] it was found that the number of laboratory tests performed decreased by 37%. The reduction in the number of specific laboratory tests targeted by the guidelines paralleled the overall results. Blood glucose, arterial blood gas, chemistry, coagulation tests, and cardiac enzymes decreased by 51.4, 43.9, 37.6, 30.5, and 23.2%, respectively. The most important finding of [1] is that the introduction of new laboratory testing guidelines in a surgical ICU resulted in a significant decrease of the number of tests performed, and a significant increase in the number of tests obtained with a proper physician order. These results, sustained over time, were associated with no detectable morbidity, and may have resulted in a decrease of red blood cell transfusions. Other research works about unnecessary lab tests reduction have obtained similar results [2,3].

In related research [12], hematological monitoring data were interpolated by cubic spline and the interpolated data were estimated from their correlation with actual data by way of a leave-one-out cross validation (LOOCV). Furthermore, an attractor plot was applied as time series analysis in order to clarify the tendency of the interpolated hematological monitoring data. The hematological data of three patients who had received S-1 (a drug that is being studied for its ability to enhance the effectiveness of fluorouracil and prevent gastrointestinal side effects caused by fluorouracil when treating cancer) administration over 2 years period were investigated. White blood cell (WBC) count, red blood cell (RBC) count, hemoglobin (Hgb), hematocrit (Hct), mean corpuscular hemoglobin (MCH), mean corpuscular hemoglobin concentration (MCHC), platelets, coefficient of variation of the red blood cell distribution width (RDW-CV), platelet distribution width (PDW) and mean platelet volume (MPV) were interpolated by cubic spline. Those lab tests with small variances, such as RBC, were well predicted by this method. However, tests with higher variances, such as WBC, MCHC, PLT, and PDW were poorly predicted. Cubic spline was the best approach of various interpolation methods in this study. The importance of [12] relies in the fact that it is possible to predict future values of lab tests even using very rudimentary models.

A further laboratory risk is false positives associated with over-testing [13,14]. The probability of false positives (lab results out of the normal range, when in fact the real values are normal) is dependent on many things including laboratory equipment, employee training and correct phlebotomy technique. However, the incidence of false positives increases with the number of tests run [13]. For example, if a given lab test randomly misclassifies people as diseased at a 1% rate (i.e. the test is 99% accurate), then the probability of having a false positive in the healthy population after an arbitrary 50 lab tests is

$$P_w(n) = 1 - [P_r(n)]^n \tag{1}$$

$$P_w(50) = 1 - [0.99]^{50} = 0.40$$

where n is the number of lab tests, $P_w(n)$ is the probability of obtaining one wrong result (in this case, a false positive) in n lab tests and $P_r(n)$ is the probability of obtaining inaccurate result in a given lab test. One strategy to reduce this increasing probability of obtaining false positives is to avoid testing when no additional information is expected or, in other words, to reduce n.

2. Objectives

The objective of this paper is to propose a strategy to reduce unnecessary lab testing in the ICU. This is a retrospective study using data acquired from intensive care unit (ICU) patients. In this paper, we consider a specific group of patients at the ICU, gastrointestinal bleeding patients (GI bleeds). Although there might be different criteria for testing that evaluates the