Chapter 2.16
Nonparametric Decision Support Systems in Medical Diagnosis:
Modeling Pulmonary Embolism

Steven Walczak
University of Colorado at Denver and Health Sciences Center, USA

Bradley B. Brimhall
University of Colorado School of Medicine, USA

Jerry B. Lefkowitz
University of Colorado at Denver and Health Sciences Center, USA

ABSTRACT

Patients face a multitude of diseases, trauma, and related medical problems that are difficult to diagnose and have large treatment and diagnostic direct costs, including pulmonary embolism (PE), which has mortality rates as high as 10%. Advanced decision-making tools, such as nonparametric neural networks (NN), may improve diagnostic capabilities for these problematic medical conditions. The research develops a backpropagation trained neural network diagnostic model to predict the occurrence of PE. Laboratory database values for 292 patients who were determined to be at risk for PE, with almost 15% suffering a confirmed PE, were collected and used to evaluate various NN models' performances. Results indicate that using NN diagnostic models enables the leveraging of knowledge gained from standard clinical laboratory tests, specifically the d-dimer assay and reactive glucose, significantly improving overall positive predictive value, compared to using either test in isolation, and also increasing negative predictive performance.

INTRODUCTION

Medical and surgical patients today face a variety of conditions that are both difficult and costly to

diagnose and to treat. With ever skyrocketing medical costs (Benko, 2004), the use of information technology is seen as a much-needed means to help control and potentially to reduce medical direct costs (Intille, 2004). Deep vein thrombosis (DVT) and pulmonary embolism (PE) are medical conditions that are particularly difficult to diagnose in the acute setting (Mountain, 2003). Frequent usage of costly clinical laboratory tests to screen patients for further treatment is commonplace. All too commonly, hospitals provide treatment to patients without PE as a preventative measure (Mountain, 2003). Furthermore, patient mortality, morbidity, and both direct and indirect costs for delayed diagnosis of these conditions also may be substantial. Recent studies show that 40% to 80% of patients that die from PE are undiagnosed as having a potential PE (Mesquita et al., 1999; Morpurgo, Schmid, & Mandelli, 1998).

DVT may occur as the result of patient genetic and environmental factors or as a side effect of lower extremity immobility (e.g., following surgery). When a blood clot in the veins of a lower extremity breaks away, it may travel to the lungs and lodge in the pulmonary arterial circulation causing PE. If the clot is large enough, it may wedge itself into the large pulmonary arteries, leading to an acute medical emergency with a significant mortality rate. Approximately 2 million people annually experience DVT, with approximately 600,000 developing PE and approximately 10% of those PE episodes resulting in mortality (Labarere et al., 2004, Mesquita et al., 1999). Documented occurrence of DVT in postoperative surgical populations ranges from 10% (Hardwick & Colwell, 2004) to 28% (Blattler, Martinez, & Blattler, 2004).

Direct costs associated with DVT and PE come from the expensive diagnostic and even more expensive treatment protocols. It may be possible to lower these direct costs, especially when additional testing or treatment may be ruled out due to available knowledge. Nonparametric neural network (NN) systems enable the eco-

nomic examination (Walczak, 2001) and nonlinear combination of various readily available clinical laboratory tests. Laboratory tests typically performed on surgical patients (e.g., blood chemistry) form the foundation for analysis and diagnostic model development.

One such test is the D-dimer assay that measures patient plasma for the concentration of one molecular product released from blood clots. When blood vessels are injured or when the movement of blood is too slow through veins of lower extremities, blood may begin to clot by initiating a series of steps in which fibrin molecules are cross-linked by thrombin to form a structure that entraps platelets and other coagulation molecules — a blood clot. As healing begins to occur, plasmin begins to break down the clot and releases, among other things, D-dimer molecules. D-dimers are actually small fragments of cross-linked fibrin and provide the basis for assessing blood-clotting activity. Patients with DVT and PE frequently have elevated levels of D-dimer in their plasma. Consequently, many hospitals now employ the D-dimer assay as a first test in the diagnostic pathway for these conditions. Usage of the results of a D-dimer assay effectively reduces the direct costs of DVT by reducing the requirement for downstream testing and treatment, specifically Doppler ultrasound tests (Wells et al., 2003). The use of nonparametric models enables the analysis of laboratory tests without regard to the population distribution, which may be a problematic factor when combining more than one laboratory test for the diagnostic prediction. Additionally, NNs provide nonlinear modeling capabilities that may be beneficial in combining pathology tests.

The research reported in this article will examine the efficacy of using NN models to predict the likelihood of a PE in surgical patient populations. A corollary research question is whether less invasive and less costly diagnostic methods are both available and reliable in predicting PE. The benefit of the reported research is twofold. First, the reported research examines

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