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My Thoughts/My Surgical Practice

Artificial neural networks in surgical research

Clinical surgical research typically attempts to find associations among identifiable factors and particular events. Examples of such would be risk factors and a particular outcome (e.g., patient comorbidities and postoperative complications), or a surgical procedure and clinical result (e.g., lymph node dissection and survival after a cancer operation). Such research is based on direct associations of the presence of these factors with the occurrence of the outcome of interest. For example, clean surgical wounds had an incidence of postoperative infection of 2%, while dirty wounds had an infection rate of 25%. These associations are typically discovered or verified using statistical methods, such as regression for discovery and Chi-square or student's t-test for verification. The drawback of statistical methods is their requirement for specific data or error distributions, which are often ignored.

Machine learning computer programs are capable of taking data sets and "learning" the best associations among the data to predict a particular outcome.[1] One such method is the artificial neural network (ANN). ANN's are nonparametric machine learning programs based on modeling the neuronal activity of the human brain.[2] Neuronal activity is simulated using processing elements referred to as neurodes that are arranged in layers and connected to neurodes in subsequent layers through a connection which carries a weight value. The weighted values of the connections indicate the strength of the neuronal signal from one neurode to the next. ANNs can develop predictive models based on the program's ability to "learn" through adjustment of the weight values on the interlayer connections. ANN learning enables the ANN to model nonlinear and, importantly, interactive relationships between factors related to a clinical problem and the clinical problem's results. ANNs have been shown to be universal approximators for arbitrarily complex linear and nonlinear problems.[2] Learning occurs by comparing the value aggregated at the output neurodes against known real world values and the difference is then propagated backwards through the entire system to adjust the connection weights in order to minimize the prediction difference. This process continues until the average difference or error in the ANN output value and the correct value is smaller than a pre-specified value, typically measured using root mean squared error.

There are various ANN learning methods including both supervised learning and unsupervised learning. We focused on supervised learning in this article. In addition to being a machine learning method able to learn solutions to arbitrarily complex problems, ANNs have several other advantages over regression and other statistical methods that serve to improve medical model prediction performance, including: they are nonparametric thus data is not required to fit specific prerequisite requirements and therefore surgeons do not have to have advanced statistical analysis training, all variable interactions do not need to be predefined since they are discovered through machine learning, they scale well and can work with very large amounts of data, and once trained they are highly resistant to noise or errors in the data for the input variables.

The principle drawback of ANN models in medicine is their black box nature and subsequent difficulty in determining which input variables are most significant. Several techniques exist for trying to determine the explanatory value of input variables, such as iteratively leaving out select variables or summing the connection weights.

Previous research provides an example of using ANNs to evaluate new associations. A supervised learning ANN model was developed to predict the probability of the occurrence of a pulmonary embolism (PE) for surgical patients.[3] Using the method of leaving out and adding in variables, the ANN model determine that combining reactive glucose results with d-dimer was a much better predictor than just using the d-dimer, as was the current practice. This ANN would save unnecessary invasive testing for PE and could result in an annual savings in 2006 of $182,000.

Our research using ANN's illustrates the broad range of problems amenable to this type of analysis. We have shown that ANN can enhance prediction of pancreatic cancer survival using clinical and pathologic data,[4] identify malignant intraductal papillary mucinous neoplasms based on transformed computed tomographic and magnetic resonance images into radiomic data,[5] prediction of surgical site infections based on clinical data and antibiotic compliance,[6] and need for perioperative blood transfusion based on clinical data and laboratory data that is available preoperatively.[7] These investigations and others by other authors attest to the versatility of ANN methodology.

Machine learning methods can provide insights that conventional statistical methods cannot. For example, Bronsert, et al.[8] using an elastic-net model to predict complications with 88% specificity, 83% sensitivity, 97% negative predictive value, and 52% positive predictive value. Loftus et al.[9] reviewed the literature on patients who arrest on the surgical ward and found that prearrest instability signs are subtle, giving machine deep learning methods an opportunity to better identify such patients.

In conclusion, our thought is that ANN is an underutilized method of developing predictive models in surgical research. We believe surgical researchers should take more advantage of this methodology. Several guidelines and tutorials for developing ANN models have been written and can serve as a resource for clinicians

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interested in further exploring ANN models.[10]

Declaration of competing interest

The authors declare no conflicts of interest in relation this this work.

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