Prediction Analysis in Imaging

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Prediction analysis encompasses a variety of techniques from statistics, data mining and game theory analyzing current and historical data to make predictions about future events. This broad set of analytical tools has been widely used across different disciplines and settings. Traditionally, these techniques used exploit patterns within the data to identify risks and opportunities. A classic application in the United States is credit scoring, using scoring models that combine consumer credit history, loan applications, demographic information, etc., to predict the likelihood of making future credit payments on time.

Applications in Medicine: There are several general models used in medicine: descriptive models, prognostic models, predictive models and decision models, with overlap between the application of these models.

<u>Descriptive Models</u> quantify relationships between the data or types of data in order to identify explanatory variables for a given disease state. For example, what are the risk factors for the development of squamous cell carcinoma of the head and neck?

<u>Prognostic Models</u> quantify relationships between explanatory variables in a disease and the outcome after a test or treatment. For example, is human papillomavirus (HPV) positive squamous cell carcinoma of the head and neck more likely to respond to therapy than HPV negative carcinoma?

<u>Predictive Models</u> quantify relationships between explanatory variables in a disease and the outcome after a specific test or treatment or course of treatment, particularly if there are competing tests or treatments. For example, is epidermal growth factor receptor (EGFR) expressing squamous cell carcinoma of the head and neck more likely to respond to chemotherapy + cetuximab, an EGFR inhibitor, or to chemotherapy alone?

<u>Decision Models</u> describe the relationship between all elements of a test or treatment decision in order to predict the results of the decision. These models can be used to optimize decision-making, maximizing certain outcomes while minimizing others. Cost-effectiveness analysis is a special application of decision modeling. For example, what is the effect of squamous cell carcinoma of the head and neck be tested for EGFR expression prior to initiating cetuximab on survival and cost-effectiveness?

Applications in Imaging:

Applications of decision analysis in imaging center on lesion classification using imaging characteristics, appropriate test/treatment assignment and increasing the appropriate use of imaging.

Lesion classification: prognostic models can be used to evaluate specific imaging characteristics to yield a specific diagnosis. These prognostic models range in level of complexity. For example, the model can use single imaging biomarkers, such as MR spectroscopic characteristics to classify a newly diagnosed lesion as either recurrent tumor or radiation injury in the setting of treated brain cancer; or can be expanded to include a range of imaging characteristics to derive a clinical diagnosis, such as the combination of intracranial hemorrhage, midline shift and cistern effacement to diagnosis traumatic brain injury. These models can also incorporate clinical information to improve lesion classification, e.g. the use of a history of hepatitis to predict likelihood of malignancy of a newly-detected hepatic lesion.

Appropriate test/treatment assignment: models can be extended and used to assign patients to a clinical strategy, for example, whether or not to obtain CT after a minor head trauma in an infant or small child or to assign a patient to treatment or to watchful waiting.

Appropriate use of imaging: at a population-level, models and decision rules can be used to aggregate clinical and demographic information to determine whether or not imaging should be performed balancing the risk of imaging (such as radiation or cost).

Implementation of Predictive Models and Decision Rules

To decrease the barrier to implementation of these models and improve their clinical relevance, they should be easy to use (for example, the Glasgow Coma Scale) or take advantage of decision support and computer algorithms particularly when there are multiple explanatory variables or to automate decision making and clinical ordering.

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