Decision Analysis

- Decision analysis is a powerful research method that can identify optimal patient care strategies when multiple options are available.
- In decision analysis, investigators use mathematical models to estimate long-term patient outcomes for each patient care strategy under consideration, enabling options to be rigorously compared when randomized controlled trials are impractical.
- Investigators in radiology are actively expanding research efforts in decision analysis to compare new and existing imaging techniques, and to identify which imaging approaches can most benefit at-risk populations.

In many patient care scenarios, physicians rely heavily upon imaging tests to make critical treatment decisions. As such, improving imaging test performance (e.g., sensitivity and specificity) by advancing imaging technology has been the central goal of imaging research to date. At the population level, however, while imaging performance may affect long-term health outcomes, the relationship is indirect. Several key factors, including the underlying prevalence of the disease in question, the effectiveness of available treatments, and competing risks of mortality, heavily influence the extent to which any given imaging test can influence a populations' health.

The gold standard for determining the effectiveness of new versus existing healthcare technologies is the randomized controlled trial (RCT). However, RCTs are oftentimes impractical for investigating imaging technologies. Imaging tests provide additional information regarding a patient's clinical status at a low risk, if any, to the patient. Thus, from ethical and practical standpoints, withholding imaging in the setting of an RCT is difficult. Furthermore, even if ultimately influential to patient care, demonstrating the benefit of an imaging approach with statistical significance more often than not requires a long, costly trial, which, in turn, may be confounded by interval advances in imaging technologies.

When conducting decision analysis research in diagnostic imaging, investigators typically integrate test performance (true-positive, true-negative, false-positive, false-negative) and disease prevalence estimates for each strategy under consideration (Figure 1). Test-result-dependent treatment decisions are then applied to the affected population, and consequent patient courses are modeled. Ideally, the average life expectancy associated with each strategy should be computed. Patients' quality-of-life can be factored in, during and after treatment, to estimate quality-adjusted life-years. Lifetime cost implications of different care options can also be estimated to identify their relative cost-effectiveness.

The results from a decision analysis can yield data that are useful for guiding medical management at the individual patient or healthcare policy levels. Equally important, investigators always determine - alongside the primary analysis - which test, treatment, and patient factors are most influential to the analysis results, and highlight critical gaps in evidence to focus further research efforts.

Applications of Decision Analysis and Cost-effectiveness Analysis in Radiology

Decision analysis and cost-effectiveness analysis have been used to estimate the value of screening to detect pre-clinical disease, to predict the value of new imaging techniques that have not yet been adopted, and to obtain data on the comparative effectiveness of different imaging strategies. Below, we provide examples of decision analysis research in radiology.

In the field of breast imaging, screening mammography is known to detect early cancer and decrease breast cancer mortality, based on multiple randomized trials. However, compared with the general population, the
sensitivity of mammography is substantially lower in women with a BRCA1 or BRCA2 gene mutation, who have a significantly higher lifetime risk of developing cancer. MR imaging, compared with mammography, is more sensitive for the detection of breast cancer, but is less specific and more costly. Currently, no RCT has determined that breast cancer screening with MRI saves lives, nor is it likely that such a trial will be performed due to the extensive enrollment and follow-up that would be required to demonstrate a statistically significant mortality reduction, and the attendant resource requirements.

Using decision analysis and disease modeling techniques, investigators have projected the long-term health outcomes that would follow from breast cancer screening with clinical surveillance, annual mammography, annual MR imaging, and annual combined mammography and MR imaging. They concluded that annual combined screening would yield the highest proportion of cancers detected at an early stage (ductal carcinoma in situ and local, node-negative cancers) and that this strategy would have the biggest impact on diminishing death due to breast cancer. An additional finding of the study was that with MR screening strategies, a high proportion (82-84%) of women would have one or more false-positive screening tests and that at least 25% would undergo biopsies that revealed benign disease during their lifetimes.

In the field of lung cancer screening, single-arm studies have demonstrated a potential survival benefit when chest CT is performed to screen asymptomatic smokers for lung cancer. However, the results of single-arm studies in cancer screening are susceptible to well-known biases - namely, lead-time, length, and overdiagnosis biases - which can account for a majority of the benefits predicted. Using computer modeling techniques, investigators have estimated the health outcomes and onset of lung cancer in a population of smokers who received CT screening, and in a simulated population of smokers who did not, accounting explicitly for the aforementioned biases, false-positive results, and competing risks of mortality in smokers. In so doing, they found that while CT screening may reduce lung-cancer-specific mortality, its effect on overall mortality is relatively lower due to significant competing risks of mortality in smokers.

In the field of molecular imaging, new techniques have the potential to preclude invasive lymph node staging methods, but further investigation of their appropriate clinical use is needed. Investigators have used decision
analysis to evaluate the role of MR lymphangiography, an investigational lymphotropic nanoparticle-based imaging technique, in detecting axillary lymph node metastases in early breast cancer. Three different axillary nodal staging strategies for hypothetical patients with newly diagnosed, clinically node-negative breast cancer were compared: MR lymphangiography alone, sentinel lymph node (SLN) biopsy alone, and combined MR lymphangiography and SLN biopsy. Consequently, expected treatment decisions were incorporated, and long-term health outcomes and lifetime costs were estimated. The combination of SLN biopsy and MR lymphangiography was associated with the highest quality-adjusted life expectancy and cost, followed by SLN biopsy alone and MR lymphangiography alone. However, from a cost-effectiveness standpoint, MR lymphangiography strategies were preferable to SLN biopsy. The analysis results were sensitive to variability in some key parameters, including the test performance of MR lymphangiography - more studies establishing the sensitivity and specificity of this technique for axillary staging are needed prior to any changes in current care algorithms.

Conclusion

Decision analysis represents an actively expanding area in imaging research. Using this method, investigators can predict how the performance of an imaging test or strategy affects long-term patient outcomes, explicitly accounting for numerous patient, disease, and treatment-specific factors. In this era of health care reform, decision-analytic research can be used to identify high-yield diagnostic imaging strategies across a spectrum of diseases, as well as evidentiary gaps that preclude high-quality medical decision making, thus benefitting current health care decisions while also setting future research priorities.

Further Information

For further information on decision analysis, please contact Pari Pandharipande, MD, MPH at 617-724-4944. For a more comprehensive presentation of decision analysis and cost-effectiveness analysis in diagnostic testing, see Hunink et al (2001).

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References


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