EVIDENCE BASED MEDICINE

An Introduction to Clinical Decision Analysis

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ABSTRACT

Healthcare professionals are often faced with the need to make rapid and intricate decisions in the face of competing priorities, limited resources, and an incomplete clinical picture. Decision analysis is a tool that allows users to apply evidence-based medicine to make informed decisions when confronted with difficult clinical scenarios. A Decision Tree, together with probabilities and outcome values, is used to model a given problem and help determine the best course of action. A decision-maker can thereafter accurately and expediently weigh the possibilities involved in a given decision, thus leading to an informed clinical decision. The present paper is intended to give an overview of decision analysis and its application in clinical decision-making.

INTRODUCTION

Decision-making is never easy. Even seemingly simple decisions with characteristics such as a single decision maker, clear outcomes, and non-competing interests, still have the potential to result in adverse outcomes. Healthcare professionals are often faced with the need to make intricate decisions with extremely high stakes. Additionally, their decisions are frequently made in the face of competing priorities, limited resources, and an incomplete clinical picture. Under such circumstances, an objective, rigorous analysis of outcomes and probabilities is essential to achieve the best possible clinical decision given a specific situation.

When faced with complex scenarios, studies have shown that many decision makers have a natural tendency to make overly optimistic, uninformed decisions; these choices appear to be made more on the basis of intuition than a rational weighing of outcomes and probabilities.[1,2] It has further been shown that the more complex a decision, the less likely intuition, rather than a rigorous analysis of options, will yield positive results.[1,3]

The present paper is intended to give an overview of decision analysis and its application in clinical decision-making. Using a non-clinical example, we will go through the steps involved in conducting a simple decision analysis. For more complex applications, the reader is referred to the clinical decision analysis literature.

WHAT IS DECISION ANALYSIS?

Decision analysis is a method that uses probabilities and expected values together with a Decision Model (such as a Decision Tree or more complex Monte Carlo Model) to model a problem and help determine the best course of action.[3,4] A Decision Tree is a pictorial illustration of all the plausible relationships, alternatives, and outcomes involved within a given decision. Associated with each step in the decision tree is a corresponding probability and outcome value. By using such a tree, a decision-maker can accurately and expediently weigh the possible outcomes associated with making a certain decision.[3,5] Decision trees are adaptable and all values represent a current, and non-static, benchmark on which further evolution can be critically evaluated.[3] Decision analysis can be performed with uncertain probabilities and outcome values by using tools such as sensitivity analysis.[6] Sensitivity analysis allows users to explore the uncertainty of data and to examine what the effects of variability on probabilities and outcome values in the decision tree have on expected clinical outcomes.[6] It is, in essence, the decision-makers method of statistical hypothesis testing, allowing the user to assess the degree of uncertainty associated with an analytic result.

Decision analysis is most usefully applied in clinical decisions where there is uncertainty regarding appropriate clinical strategy and when there is a meaningful tradeoff of advantages and disadvantages in the clinical problem.[4] It has been applied to a number of scenarios of health policy, including management of ventricular septal defects,[3] screening for prostate cancer,[7] and comparing different policies for cholesterol screening and treatment.[8] In the management of ventricular septal defects (VSDs), a transcatheter device was compared with surgical closure of VSDs.[3] A decision analytic model comparing probabilities of successful closure (with no residual flow), major and minor complications, probabilities of reinterventions, and relative preferences for each of the possible outcomes revealed that transcatheter device closure of suitable VSDs is preferred over surgical repair. Sensitivity analyses revealed the threshold values over which surgical closure would be preferred over device closure.

A Simple Example – To drive or not to drive

A simple non-clinical example – deciding whether one should drive or take the bus to work – can be used to demonstrate the application of decision analysis. Each option is associated with a number of advantages, disadvantages, costs, and preference values. For example, driving may be associated with greater risks of collision, greater costs, and perhaps a loss in valuable reading time. At the same time, it may come with increased comfort, convenience, and a greater probability of getting to work on time. Taking the bus, on the other hand, may lead to a safer, more productive trip; however, it may be associated with greater inconvenience (waiting for the bus, not having a seat, etc) and a greater probability of being late.

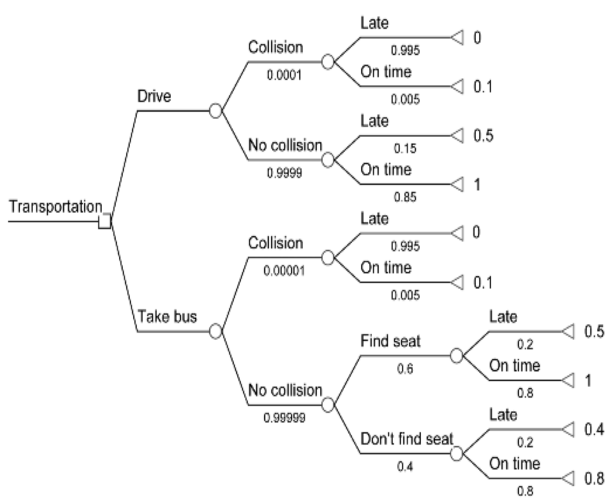

Figure 1. Hypothetical decision tree comparing driving to taking the bus. Probabilities are shown directly under the branches they represent. A square represents a choice while a circle represents a possible outcome. Overall utilities are shown at the end-nodes to the far right.

Figure 1 shows a hypothetical tree comparing driving a car to taking the bus. In this scenario, probabilities have been arbitrarily assigned and estimated. However, it is important to emphasize that the validity of a decision analysis is only as strong as the estimated probabilities and outcome values.[9] The rightmost values, or end nodes, represent the value or utility for each possible outcome. The probability at each of the respective nodes is located under the node. The tree was constructed using DATA 4.0 software (TreeAge Software, Inc., Williamstown, MA).

Probabilities: What are they and where do they come from?

Probabilities are a quantitative estimate of the chance or likelihood that a given outcome will occur.[9] In clinical decision making, reliable probabilities of clinical outcomes can be attained through a systematic and rigorous analysis of available literature, preferably randomized controlled trials or other systematic reviews. If there is a deficiency of such literature, researchers must turn to alternatives such as observational studies, expert judgment, existing databases, or unpublished work.[9] These probabilities are then incorporated into a decision tree, such as in Figure 1, to assist in the decision making process.

Probabilities, however, are always associated with uncertainty. For example, the probability of an automobile collision varies from location to location and even from driver to driver. As such, along with the average probability for each outcome attained from the literature, or baseline probability, reasonable probability ranges must also be specified.[6,9] These ranges can then be used in a sensitivity analysis to assess how different estimates can affect the final decision.[6]

Outcome values: What are they and where do they come from?

Outcome values or expected values are summary measurements of a particular outcome.[9] They can be expressed in several ways including life years, quality-adjusted life years (QALYs), costs, or utilities.[9] A utility is a measure of a decision maker's relative preference or desirability for a given outcome, and is generally expressed as a value between 0 and 1, where 0 is the worst outcome and 1 is the best. Utility values can be estimated by: 1) arbitrary assignment of values based on expert judgment; 2) published values in the literature; or 3) patient preferences.[9] As with the probabilities, the uncertainty of these values can be accounted for by including a range of reasonable values and thereafter performing a scrupulous sensitivity analysis to determine the

Expected value for choosing "Drive"

"probability of a collision" × ("probability of being late" × "utility" + "probability of being on time" × "utility") + "probability of no collision" × ("probability of being late" × "utility" + "probability of being on time" × "utility")

0.0001 × (0.995 × 0 + 0.005 × 0.1) + 0.9999 × (0.15 × 0.5 + 0.85 × 1)

0.00000005 + 0.925

0.925

Figure 2. Expected value and associated calculations for choosing "Drive" in the example decision tree.

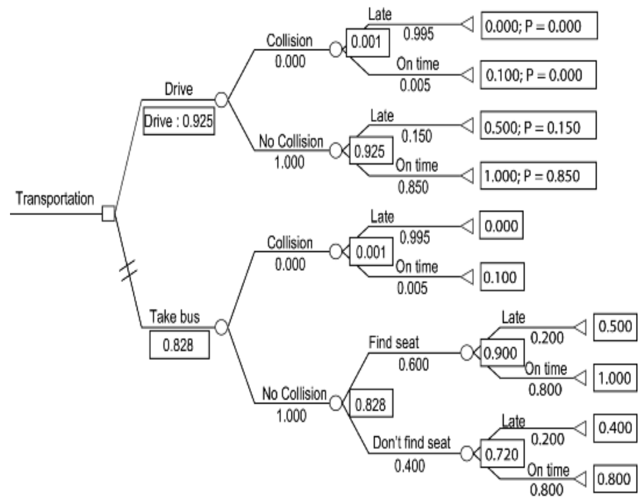

Figure 3. Rolled-back hypothetical decision tree comparing driving to taking the bus. Since the expected value of driving is slightly greater than taking the bus, the "Take bus" branch is crossed off. For each of the "drive" nodes, the probability of attaining the given outcome is also given.

range of values for which a given outcome is preferred.[6]

In the transportation example (figure 1), the best-case scenario was arriving on time, collision-free, while the worst-case scenario clearly was arriving late after an accident by car or by bus. The other scenarios fall in between these values based on measures such as convenience, costs, and preferences.

"Rolling back" the tree

Once reliable probabilities and outcome values are attained from the literature, as well as expert and patient preferences, the tree is ready to be "rolled-back," or calculated. The tree is rolled-back by multiplying the outcome values by their respective probabilities and adding across nodes within a particular decision branch. Such a calculation for the "car" node of the transportation example is shown in Figure 2. Doing this for each of the decision branches gives a final expected value for each branch, as shown in Figure 3.

ADVANTAGES, DISADVANTAGES, AND INTERPRETATION OF A DECISION ANALYSIS

The steps involved in conducting a decision analysis have been summarized in Table 1. Like any other statistical tool, decision analysis does not guarantee a correct decision; its validity and application depends entirely on the specific clinical scenario, the availability of data, and the strength and inclusion criteria of the selected literature. Additionally, the results of a decision analysis must be interpreted carefully. Clinicians must look at how closely their particular clinical situation resembles that of the analysis, the strength and reliability of the probabilities and utilities that were attained, as well as the results of the sensitivity analysis. This information is then used by the decision maker to help them make an informed, objective decision regarding the specific clinical scenario. Finally, it should be noted that constructing a decision tree, along with its corresponding probabilities and utilities, may be time-consuming and require a great deal of information and rigorous analyses. However, when it is well executed, incorporating probabilities and outcome values based on accepted data and expert opinion, decision analysis is a powerful tool that has been shown to generate highly credible and reliable results.[3,4,6,7,9]

Table 1. Five Steps to a Successful Clinical Decision Analysis

1. Clinical problem with two or more options containing some degree of uncertainty.
2. Build decision tree containing all plausible relationships, alternatives, and outcomes involved with a given decision.
3. Attain probabilities for each of the nodes through a systemic and rigorous analysis of available literature.
4. Attain outcome values for each of the decision outcomes based on expert and patinet preferences.
5. "Roll back" the tree to get a final value for each clinical decision.

In the transportation example above, the final expected value for driving was slightly higher than taking the bus (0.925 vs. 0.828). This means that in this particular situation, with the baseline probabilities and outcome values that were used, driving is preferred to taking the bus. However, it is important to remember that these values differ considerably from location to location and perhaps even from driver to driver; as such, the decision tree represents an adaptable framework on which further analysis can be conducted. A sensitivity analysis would demonstrate the range of cutoff values over which driving will be preferred to taking the bus, but was not conducted in this example for the sake of simplicity.

DECISION ANALYSIS AND EVIDENCE BASED MEDICINE

The term evidence-based medicine (EBM) refers to the incorporation of critically appraised scientific evidence into clinical practice.[3,10] EBM is arguably the most significant initiative geared towards restructuring clinical practice and reason,[11] allowing users to integrate both clinical expertise and the best available evidence in the literature.[12] Decision analysis is a tool that combines the best available evidence together with patient and expert opinion, thus allowing users to apply EBM to make informed clinical decisions. As such, decision analysis has become a powerful and effective tool with numerous applications.

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Author Biography

Ilyas Aleem received a Bachelor of Science from the University of Toronto, and is currently a second year medical student at McMaster University.