CHAPTER XI

DECISION ANALYZES

A Termoz, C Buron, I Jaisson-Hot, C Colin

The rapid development of medical knowledge over the past thirty years, whether in terms of diagnostic tools or therapeutic means, is such that, in the field of health, any decision-maker, physician or manager, is confronted with increasingly difficult choices. At the same time, these technical advances are accompanied by questions from consumers about the efficacy and safety of the healthcare system.

Decision analysis makes it possible to describe, for a given clinical or public health situation, the various possible diagnostic and therapeutic strategies. It makes it possible to model medical decision-making by integrating experimental data, epidemiological data, expert opinions, and the assessment of the patient's state of health. It also allows the patient's point of view and quality of life to be taken into account. Based on these elements, decision analysis attempts to highlight a preference for an action strategy in a given clinical or public health situation.

The objective of this chapter is to present, using simple examples from clinical practice, the methodological foundations of decision analysis.

In the current daily practice of care, doctors use the most advanced technologies and the most elaborate scientific approaches. These new medical techniques, often very expensive, do not always replace previous techniques. The development of these technologies then poses the ethical problem of evaluating their effectiveness in improving the state of health of the population, and the accessibility of patients to the technique.

Our initial medical training was centered on an analytical approach to positive and differential diagnosis, that is to say the precise and exhaustive examination of all the diseases that may affect the patient. This training encouraged doctors to collect as much data as possible through laboratory and imaging tests in order to make a positive diagnosis and rule out differential diagnoses.

Once the diagnosis is made, the latest technologies and procedures are employed to cure and treat the health problem. The use of certain procedures sometimes occurs before their effectiveness has been proven, on the simple assumption that a new technology has a good probability of being more effective than an old one.

This practice of care encourages the idea that the more resources one commits to paraclinical examinations and treatments for a patient, the better the outcome. This approach, which could be called that of the maximum means, works well as long as the side effects of the medical acts are minor and as long as the source of financing is sufficient. However, the distribution of medical care changes radically according to time, place, type of practice and the availability of resources or new technologies. The increase in health expenditure in industrialized countries, as well as the lack of resources in developing countries, make an evaluative approach to the diagnostic and therapeutic strategy imperative.

I - PERFORMING A DECISION ANALYSIS

Decision analysis is a quantitative method using probabilities to inform the decision-making process in situations of uncertainty. It comes from management sciences, in which it was applied to determine the best strategies to use in a context of resource optimization.

The interest of decision analysis in the field of health is to determine, with the least possible imprecision, the strategy which maximizes the expected benefit for the patient measured for example by the life expectancy adjusted on the quality of life.

The steps of decision analysis are as follows:

- structuring of the problem;
- identification of alternatives;
- construction of the decision tree;
- the determination of the probabilities linked to the events following the decisions taken;
- determining the value of the results on the patient health outcomes;
- the calculation of the expected profit of each strategy;
- carrying out the sensitivity analysis.

A - Structure of the problem

The starting point of the analysis is a precise clinical situation for which the diagnostic and therapeutic strategy is controversial. At the time of the medical decision, all the information available and the uncertainties relating to one or the other of the strategies do not make it possible to know the strategy which maximizes the expected benefit for the patient. It is important to accurately describe the patient's condition, taking into account age, sex, history, disease presented, co-morbidities and social context.

B - Identification of alternatives

Decision analysis is based on the comparison of several strategies. The selection of these strategies is made after a critical analysis of the literature. The possible choices are thus selected by attempting to simplify as much as possible the different possible attitudes for the patient described. To limit the range of possible strategies, the choice of the starting point of the analysis, i.e. the clinical description of the patient in space and time, can authorize the selection of strategies undertaken once the result of a test is known or after the application of a therapy. It must of course be ensured that the set of identified alternatives covers all the possible alternatives.

For example, we can choose as a starting point a 40-year-old man who presented an acute coronary syndrome less than 10 days previously. To limit the number of strategies, we can also choose as a starting point a 40-year-old man who presented an acute coronary syndrome less than 10 days previously and whose risk factors are high.

C - Construction of the decision tree

The decision tree is a simplification of an often very complex reality. It is schematized by a set of nodes connected by branches *(fig. 1)*. The tree must be complete enough to represent the essential elements of the problem, but also simple enough for the understanding of the model and the facilities for calculation. *Tree nodes are of three types:*

1 – Decision nodes (shown by squares)

They represent the choices available to the decision maker at the time the decision must be made. With a decision node are associated in the tree as many branches as there are possible decisions at this level. The tree is built from left to right and the first node on the left is always a decision node.

The question of the problem should be as limited as possible. Types of decisions in the field of medicine include:

- the search for additional information, for example the prescription of a diagnostic test;
- competition between therapeutic options, for example surgery, medical treatment, or therapeutic abstention.

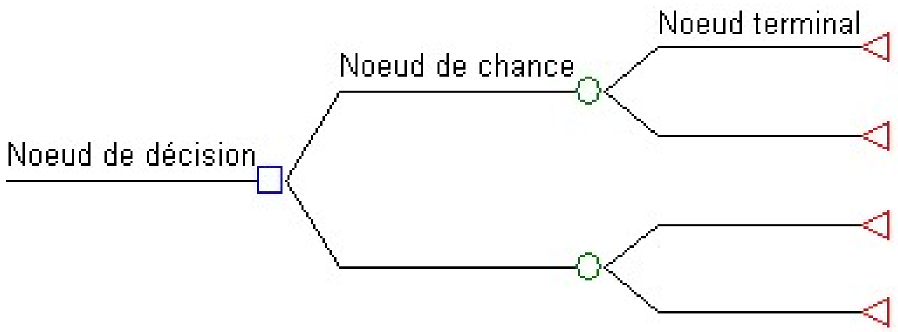

Fig. 1 - Decision tree

2 – Random nodes or lucky nodes (represented by circles)

They correspond to random phenomena that are not under the direct control of the decision maker. From each random node come as many branches as the random process admits of events. These events should be comprehensive and mutually exclusive. So, if each of the branches has a probability associated with it, the sum of the probabilities for any random node must be equal to 1.

3 - Terminal nodes (represented by triangles)

They correspond to the results of each decisional path. Each of these terminal nodes is assigned a numerical value associated with the result of the strategy and expressed from the perspective of the patient, the healthcare institution, or society. It is customary to use a homogeneous and arbitrary scale of values whose unit is defined as identical for each result of the tree (life expectancy, mortality, morbidity avoided, cost in euros, etc.). The time interval covered by the analysis is important because we must take into account the immediate results and those estimated in the future.

D - Determination of probabilities related to random nodes

The estimation of the probabilities is ideally based on objective, quantified data from the literature or from studies. But subjective data (expert opinion) can be used when objective data is not available or when the controversy between different studies is too great.

E - Determination of the value of the results on the patient's state of health

Different types of outcome scales can be used in a decision tree:

- arbitrary scale: from 0 to 1 or 0 to 100;
- survival (0 to 1 or 0 to 100%): immediate survival, at 1 year, or at 5 years;
- morbidity (time free from morbidity, or time spent in hospital);
- life expectancy (analysis on mortality table or estimate of life expectancy);

F - Calculation of the expected profit of each strategy

The calculation of the expected profit, i.e. the weighting of the result values by the probabilities of each strategy, is carried out from right to left. The expected profit of a strategy is the sum of the products of the probabilities by the values of the results of each branch. The difference observed between the expected benefits of each strategy provides decision support and shows the level of robustness of the results. However, the choice of the result scale remains the critical point for the interpretation of the results.

Let's take an example from current practice: a 70-year-old man with chronic arteriopathy of the lower limbs develops a cold ulcer on his right foot. He is hospitalized to intensify the medical treatment. After stabilization of his condition, you request a surgical opinion. For the surgeon, a below-knee amputation should be done immediately, since failure of medical treatment could force an above-knee amputation to be performed later, with a much higher operative mortality rate; the probability of ulcer progression under intensive medical therapy is 50%; the operative mortality rates for amputation below and above the knee are 1% and 2%, respectively *(fig. 2).*

The health result is assessed on an arbitrary scale of 0 and 100: a value of 0 was chosen for death, 50 above the knee, 70 for amputation below the knee and 100 for preservation of both legs .

The expected benefits of the two strategies are as follows *(fig. 2)*:

- expected benefit of amputation = 0 x 0.01 + 70 x 0.99 = 69.3
- expected benefit of waiting = 100 x 0.5 + (0 x 0.02 + 50 x 0.98)x0.5 = 74.5

The expected benefit is maximized for the “waiting for amputation” strategy.

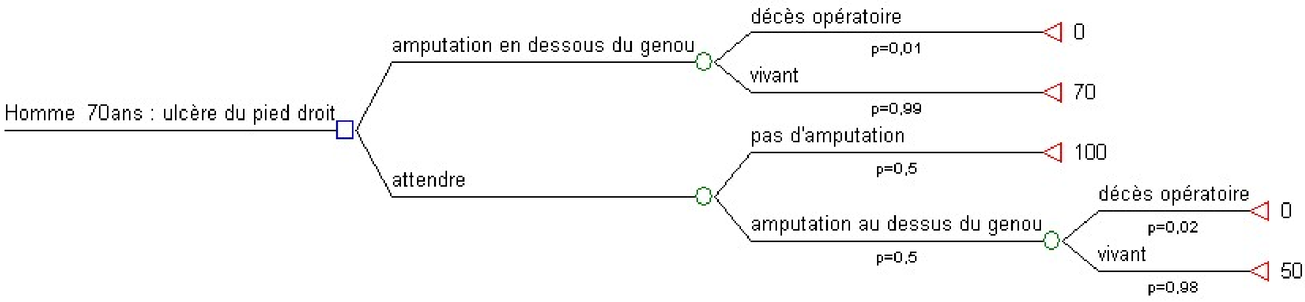

Fig. 2 - Decision tree for a cold ulcer of the foot in the context of chronic arteriopathy of the lower limbs

G - Sensitivity analysis

The interest of the sensitivity analysis is to examine the influence on the result of the variation of the parameters coming into play in the decision analysis process. All process parameters may be subject to variation, both probabilities and assigned values on the results scale.

To be able to be practiced in a realistic and reproducible way, the calculations carried out for a sensitivity analysis on one variable, two variables, or three variables require computer assistance. The software available (*Data Tree-Age, etc*.) also allows a graphic representation of the decision thresholds proposed.

II - FROM DECISION ANALYSIS TO COST-UTILITY ANALYSIS

The medico-economic evaluation makes it possible to analyze diagnostic and therapeutic strategies. It approaches the management of the patient no longer by an examination of the differential diagnoses to arrive at the "real" diagnosis, but rather by the approach to conduct, putting in competition different diagnostic and therapeutic strategies for a given clinical situation. Cost-utility analysis simply introduces this essential reality that every human decision can be placed in a context of limited resources.

Utility is defined by economists as the satisfaction or well-being associated with the consumption of a good or service. Applied to health and taking into account the new notion that the patient makes a judgment on his state of health, an indicator defining utility must take into account both life expectancy and quality of life.

For the estimation of utility, it is possible to adjust the life expectancy on the quality of life. This is what is commonly called quality-adjusted life years, QALYs (Quality Adjusted Life Years) or defined as a full year of life without functional limitation or morbid symptoms. This adjustment can be made in several ways. For long-term morbidity, a categorical scale of quality of life is used, assessed on a table integrating functional incapacity or handicap and moral state.

In our example of the cold ulcer, the subject's life expectancy after the procedure would be adjusted according to the quality of life resulting from their amputation below or above the knee. This allows the patient's opinion to be taken into account in assessing the outcome of the therapeutic strategy.

Let's take another example: an 82-year-old man has a history of posterior myocardial infarction complicated by mitral insufficiency, and atrial fibrillation. Four weeks after a first hospitalization appeared a cardio-respiratory failure requiring his admission in intensive care. On examination there is atrial fibrillation with rapid ventricular response, mitral regurgitation murmur, and moderate congestive heart failure. The digitalo-diuretic and nitrate treatment reduced the signs of heart failure. Ultrasound shows the same mitral regurgitation with an ejection fraction of 60% and moderate left ventricular hypertrophy. The question of replacement of the mitral valve is raised, cardiac catheterization shows normal left ventricular function (67% ejection fraction) and 90% stenosis of the right coronary artery. This former lawyer does not express any personal preference with regard to his medical or surgical care.

A - Selection of the different possible strategies

This is the first step of the decision tree. In this case, it is mainly about medical care and surgical care.

A cardiologist has expressed that this patient may benefit from mitral replacement with a biological prosthesis, which would not require anti-coagulant treatment.

Because mitral regurgitation is moderate, and considering an estimated 20% operative mortality risk for this patient in this center, also because the patient's functional capacity should not change even after successful surgery, another expert considered that medical treatment would be more appropriate.

The choice is then that of whether or not anticoagulant treatment is appropriate. Anti-coagulation would lead to a risk of hemorrhage requiring hospitalization in 5% of cases, and among these 5% a risk of death of 5% *(fig. 3)*. Not deagulating the patient would lead to a risk of embolic accident due to atrial fibrillation of 20%, mortality due to this systemic embolism is approximately 25%.

The life expectancy (LE) of an 82-year-old man can be determined from mortality statistics and was estimated in this case at 6.03 years.

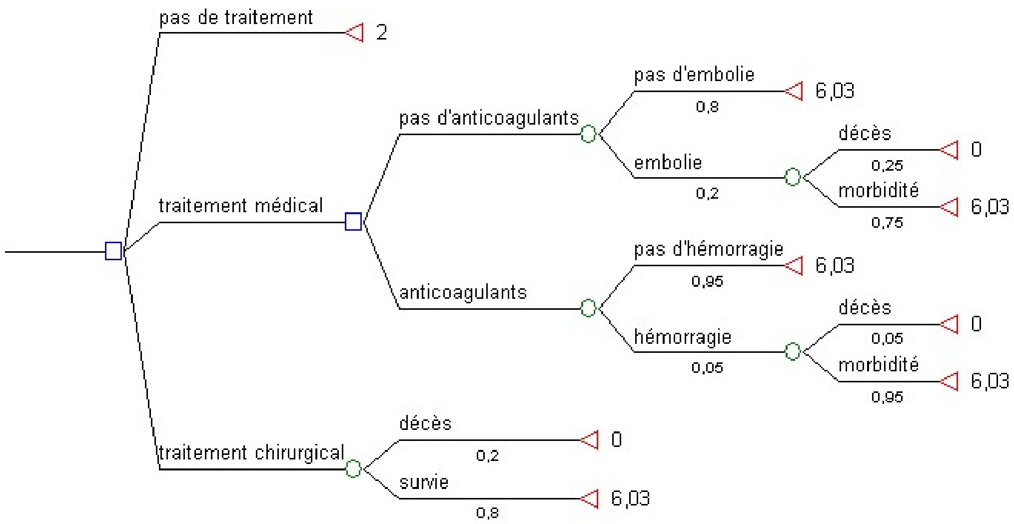

Fig. 3 - Decision tree for mitral valve replacement in the context of heart failure

B - Survival and quality-adjusted life expectancy

In most clinical studies, the usual measure of effectiveness is mortality. However, in this 82-year-old man with a disease that can significantly affect each of the strategies, it is not sufficient to consider only mortality. It is important to also consider the quality of each year of life as it may be influenced by symptoms and mobility limitations related to the primary condition and co-morbidities.

Quality of life can be measured in homogeneous units per year, which allows comparison between different strategies. These units, which are conventionally called QALYs (Quality Adjusted Life Years), correspond to the number of years of life gained adjusted by a weighting factor.

The scale used for weighting in this patient is the Quality of Well Being Index (QWBI). This index expresses the quality of life according to symptoms and activities (social activity, physical activity, mobility); it is 1 for the asymptomatic optimum and 0 for death. For each strategy, the total healthy life years (QALY) is calculated by multiplying the quality of well-being index (QWBI) by the life expectancy that the therapy is able to produce.

Other techniques make it possible to weight the life expectancy by the preferences of the patient and in particular his personal estimate of the risk of the medical or surgical intervention. We can appreciate it by the technique of the lottery or idealized game of chance: "I would rather live less well without taking the risk of an intervention, than maybe living better by taking this risk"; or by the technique of temporal arbitration: "I am ready to live less long in a better state than to live longer in a worse state".

These techniques provide more sophisticated measures than simple mortality, and are based on patient preferences.

In our example, the highest QALYs are obtained with medical therapy with anticoagulant and are slightly lower with medical therapy without anticoagulant *(Table 1)*. Clearly, medical or surgical management is in any case preferred to therapeutic abstention. Surgical management by biological prosthesis, effective for 5 to 10 years but not requiring anticoagulant treatment, provides a slightly better result adjusted for quality of life than medical treatment.

Table 1 *- Calculation of Quality Adjusted Life Years (QALYs)*

Treatment	Probability	Life expectancy	QWBI*	QALY
Abstention	1.0	2	0.560 (year 1) 0.130 (year 2)	0.69
Medical without blood thinners		6.03		3.03
No stroke	0.8	6.03	0.734	2.75
stroke-morbidity	0.15	6.03	0.394	0.28
stroke-death	0.05	0	0	0
Medical with anti-coagulants		6.03		3.14
No hemorrhage	0.95	6.03	0.673	3.00
Hemorrhage-morbidity	0.0475	6.03	0.673	0.14
Hemorrhage-death	0.0025	0	0	0
Surgical		6.03		3.17
Living	0.8	6.03	0.878	3.17
Deceased	0.2	0	0	0

*QWBI: Quality of Well Being Index

The difference in QALY between the medical strategy with anticoagulants and the surgical strategy is 0.03 *(table 1)*. When the difference is so small, it becomes interesting to integrate the costs into the analysis by applying a time discount to them. This is a cost-utility analysis based on the cost per QALY. The most efficient strategy is medical treatment with anticoagulants, both in total costs and in costs per QALY unit (Table 2). Surgery remains by far the most expensive.

Table 2 *- Average cost per Quality Adjusted Life Years (QALY)*

Treatment	Cost per life expectancy	QALY	Cost / QALY
Abstention	0 €	0.69	0 €
Medical without anticoagulants	22,412 €	3.03	7,397 €
Medical with anticoagulants	7,224 €	3.14	2,301 €
Surgical	€28,000	3.17	€8,833

Another way to express cost-utility analysis is to consider the marginal cost of an additional year of quality-adjusted life after surgery compared to medical treatment. This is called an incremental or differential analysis. The additional cost of surgery compared to medical treatment is six hundred and ninety-three thousand euros to obtain an increase of one QALY unit (Table 3). This does not mean that the surgical management entails an expense of such an amount (average cost). This calculates the cost of one additional unit (marginal cost) relative to the average cost.

Table 3 *- Incremental gain and marginal cost*

Treatment	QALYs gained	Incremental cost (CD)	CD per QALY gained
Abstention	----	----	----
Medical with anticoagulants	3.14 - 0.69 = 2.45	7,224 – 0 = 7,224€	7,224 / 2.45 = 2,949€
Surgical	3.17 - 3.14 = 0.03	28,000 - 7,224 = 20,776€	20,776 / 0.03 = 692,533€

This case illustrates the basic concepts of cost-utility analysis and shows how this type of thinking fits into the choice of competitive strategies taking into account therapeutic efficacy, the patient's quality of life, the preferences of the patient and resource constraint.

C - Sensitivity analysis and discounting

The sensitivity analysis makes it possible to take into account the influence that the change in value of one of the variables could produce.

In our example, if the arteriovenous difference in oxygen is lower, the QALYs for the medical treatment strategies with and without anticoagulants increase to 3.68 and 3.63 respectively (instead of 3.14 and 3.03). Another variable that could change the results is surgical mortality: if it increases to 30%, the surgical QALYs drop to 2.76 (instead of 3.17).

Thus, after sensitivity analysis, we note that medical treatment remains the preferred choice.

It is essential to take the time factor into account in the analysis. This requires choosing a time frame and setting a discount rate.

This process makes it possible to assess the present value of a service that will be performed in the future. It expresses the preference of a society between consumption or investment. The present value of the cost of a treatment performed today is not equivalent to that of the same treatment performed a decade from now. Thus with a discount rate i, an event occurring in n years has a present value of $1/(1 + i)^n$.

III- CONCLUSION

Decision analysis is not intended to model human decision-making behavior. Nor does it provide scientific truth on a given subject *(Table 4)*. It provides decision support in a context of uncertainty by taking into account epidemiological data, study results and expert opinions. It addresses as much a question limited within the framework of the doctor-patient relationship as a problem of resource allocation in public health, and represents a tool of a scientific nature in the arsenal of methods available to doctors.

Table 4 *- Advantages and disadvantages of clinical decision analysis*

ADVANTAGES	DISADVANTAGES
- Brings a simple structure - Allows you to combine multiple data sources - Allow consideration of utility (patient variable) - Allows to examine the impact of subjective data - Separates a large, complex problem into smaller, more manageable ones - Provides a representation of clinical reasoning	- Encourages reductive simplifications - Requires data - Unfamiliar - Consumes a lot of time - Provides a representation of clinical reasoning

Bibliography

Drummond M, O'Brien B, Stoddard G, Torrance GW. Methods of economic evaluation of health programs. 2nd edition. Edition Economica 1998.

Torrance GW, Blaker D, Detsky A, Kennedy W, Schubert F, Menon D et al. Canadian guidelines for economic evaluation of pharmaceuticals. Pharmaco Economics 1996;9:535-559.

Gold MR, Siegel JE, Russell LB and Weinstein MC. Cost-effectiveness in health and Medicine, Oxford University Press, New York, 1996.

Russell LB. Modeling for cost-effectiveness analysis. Statistics in Medicine 1999;18:3235-3244.

Keeler E. Decision trees and Markov models in cost-effectiveness research. In: Valving health care: costs, benefits and effectiveness of pharmaceuticals and other medical technologies. Cambridge: Cambridge University Press; 1995:185-205