Chapter 7

Use of Game Theory in Decision Making in Medicine

Hülya Binokay[1]

Abstract

While diagnosing patients, doctors decide together with the patient. These decisions are made by the interaction between the patient and the doctor and the modeling of this interaction. At this stage, game theory can be used to model interaction. The use of these models provides significant convenience to doctors. The aim of this study is to show the applications of the game theory approach in medicine.

1. Decision-Making in Medicine

Decision analysis serves as a tool permitting the application of evidence-based medicine, which aids doctors in making informed decisions when faced with complex clinical choices under conditions of uncertainty (Diamond, G. A., Rozanski, A., & Steuer, M. (1986)).

Evidence-based medicine is utilized during the clinical decision-making stage, synthesizing the most appropriate evidence from literature and expert opinions (Aleem, I. S. et al. (2009)).

Decision-making is a common challenge for doctors when diagnosing patients. When doctors make a clinical decision, they blend the most suitable evidence obtained from existing literature with their own expert opinions and patient preferences (Aleem, I. S. et al. (2009)).

The clinical decision-making process comprises four stages;

In the first stage, information is gathered from the patient, and evidence presented in the literature is reviewed.

The second stage, clinical reasoning, is utilized to formulate potential therapeutic options and integrate them in terms of the patient's conditions.

1 **Arş. Gör.,** Cukurova University Faculty of Medicine, Department of Biostatistics, Adana, Turkey, hbinokay@hotmail.com Orcid:0000-0002-0162-4574

https://doi.org/10.58830/ozgur.pub124.c617

The third stage, clinical judgment, assesses the benefits and risks of the potential therapeutic options established in the second stage. It also evaluates the impacts of the treatment to be administered.

The fourth stage actualizes the clinical decision-making process. The final stage is a patient-centered process where the patient and their family arrive at a decision collectively (Duffull, S. B. et al(2019)).

The goal of decision-making is for the patient and the doctor to prefer a treatment option that offers the highest benefit.

The benefit is a measure of relative preference or desirability for a specific outcome and usually takes a value between 0 and 1. Here, "0" represents the worst outcome in a particular clinical scenario, and "1" represents the best outcome (Aleem, I. S. et al. (2009)).

Benefit values can be estimated in the following ways:

1. Values based on expert opinion,

2. Publications published in the literature,

3. Patient preferences.

When including patient preferences, it's important to note that benefit values can vary from patient to patient. For example, a young and active patient with a hip fracture may prefer internal fixation, while an older and inactive patient with a similar condition may prefer a prosthetic replacement. This difference in preferences stems from the variability in benefit values.

While an elderly patient may value pain relief and the prevention of implant failure, an athlete might place value on the range of motion (Aleem, I. S. et al. (2009)).

For the clinical outcomes to be reliable, the available literature should be obtained through an analysis of randomized controlled trials or systematic reviews. It is recommended that doctors utilize decision analysis when faced with complex clinical choices under uncertain conditions (Aleem, I. S. et al. (2009)).

2. Game Theory

Game theory, following the preliminary work of French mathematician Borel and Hungarian mathematician John von Neumann in the 1920s and 1930s, was illuminated in subsequent studies in the field by John von Neumann's 1944 book "The Theory of Games and Economic Behavior"(Tarrant, C. et al. (2004)).

Game theory is employed across various disciplines, including economics, management, political science, psychology, logic, computer science, and even biology (Mendonça, F. V. et al. (2020)).

Game theory is the mathematical modeling of competition and collaboration between two or more decision-makers, referred to as players (Madani, K. (2010)).

It also provides a framework with a set of rules for analyzing interaction among multiple players, enabling us to investigate different decision-making processes (Duffull, S. B. et al. (2019)).

Games are defined as mathematical objects comprising a set of players, a set of strategies available to them (options or moves), and the determination of payoffs for each combination of these strategies (the possible outcomes of the game) (Madani, K. (2010)).

In a typical game, decision-makers (players) aim to outsmart one another in accordance with their goals, predicting each other's decisions (Madani, K. (2010)).

Game theory is the mathematical model of competition and cooperation. One of the most famous examples of strategic games is the Prisoner's Dilemma (Pikkel, D. et al (2016)).

2.0.1. Game theory related concepts

2.0.2. Game and Players: In the context of action choices, games are reciprocal models where multiple players express the consequences of these options. Players against each other strive to achieve their own beneficial objectives and try to limit the movements of the other party. The parties of the game are referred to as players. Any decision-makers who compete with each other and apply strategies in their own interests are called players. These players could be anyone or anything in a planned game, such as humans, patients, and doctors. Players are required to choose between possible situations or strategies.

2.0.3. Strategy: One of the most important concepts in game theory is "strategy". The first person to use the word "Strategy" in the literature was Von Neumann. Strategy represents the attitudes and trial options that opponents can create against any possible contingency.

2.0.4. Zero-Sum Game: Games where one player's gain equals the other player's loss are called zero-sum games. In these games,

one of the players always wins while the other loses. In non-zero-sum games, all players win or lose the game together.

2.0.5. Game Theory: Game Theory is a method for determining the most accurate strategy against conflicting probabilities. This definition illustrates that Game Theory plays an important role in decision-making.

2.1. Prisoner's Dilemma

In a non-zero-sum game, a gain for one player does not necessarily reflect a loss for another (Riggs, J. E. (2004)).

The Prisoner's Dilemma, one of the best-known models of a non-zero-sum game for two players, was proposed by Merrill Flood and Melvin Dresher and developed by Albert Tucker in 1950 (Blake, A., & Carroll, B. T. (2016)).

Two individuals (prisoner A and prisoner B) are arrested for a crime they committed together. They are interrogated separately and the same deal is offered to both (Riggs, J. E. (2004)).

If one confesses to the crime while the other does not, the confessor will receive a suspended sentence, while the other will receive a 10-year prison sentence.

If both prisoners confess, they will each receive a 3-year prison sentence.

If both prisoners do not confess, they will each receive a 1-year prison sentence.

So, what decision will the prisoners make? The best way to answer this question is to construct a decision table.

Table 1 Prison sentences (in years) of two prisoners (A, B) as a result of confessing or not confessing

	Prisoner B	
Prisoner A	Confess	Not confess
Confess	3,3	10,0
Not confess	0,10	1,1

Prisoner A will determine the most suitable scenario based on the possible decisions of Prisoner B. For example, if Prisoner B decides to confess to the crime, the most logical decision for Prisoner A would be to confess as well. (According to Table 1, if Prisoner A confesses, they will receive a 3-year

sentence, whereas if they choose not to confess, they will receive a 10-year sentence.)

If Prisoner B decides not to confess to the crime, the most logical decision for Prisoner A would still be to confess. (According to Table 1, if Prisoner A confesses, they will receive a 0-year sentence, while if they choose not to confess, they will receive a 1-year sentence.) In this case, no matter what decision Prisoner B makes, Prisoner A logically concludes that the best decision is to confess. Similarly, regardless of what decision Prisoner A makes, the most logical decision for Prisoner B would also be to confess.

One of the most important aspects of the Prisoner's Dilemma is that when both "players" play their best strategies together, they end up in a worse situation together (Riggs, J. E. (2004)).

3. Use of Game Theory in the Clinical Decision-Making Process

Hockstra and Miller were among the first to recognize the value of game theory in modeling the patient-doctor interaction in medical consultations, which is based on modeled decision-making (Tarrant, C., et al. (2004)).

In a consultation, the doctor collects information from the patient, then presents a diagnosis or opinion and may also suggest a treatment. The patient evaluates the views about their disease obtained from the doctor and can ask questions about these views. The patient can also choose how to respond to the diagnosis or treatment offered by the doctor. The outcome of this consultation is influenced by the choices of both participants. This consultation forms the interactive decision-making between the doctor and the patient (Tarrant, C., et al. (2004)).

For instance; an adult patient, who has been suffering from a sore throat for a few days, consults a doctor during a busy Friday afternoon surgery in a hospital.

Assume that the examination findings of the patient indicate redness in the throat, slight fever, and slightly swollen cervical lymph nodes. In such a situation, the Doctor could write a prescription for an antibiotic and deal with the patient in less than 5 minutes, or the Doctor could ask the patient a series of lifestyle-related questions and write a personalized antibiotic prescription. This would take more than 10 minutes to consult with the patient.

The patient can choose to accept or decline this treatment process. In this case, there are 4 possible outcomes.

(C, C): The doctor spends time giving advice, and the patient chooses to follow it.

(C, D): The doctor spends time giving advice, and the patient chooses not to follow it.

(D, C): The doctor gives a prescription, and the patient accepts the treatment process.

(D, D): The doctor gives a prescription, and the patient does not accept the treatment process.

In this example, the (C, C) outcome is the most suitable decision because the doctor would have given the best advice for the patient, and the patient follows this advice. If the doctor chooses to write a prescription instead of spending time here, then the best outcome for the patient may be to refuse the treatment and wish to consult another doctor (Tarrant, C., et al. (2004)).

As in the example, a medical consultation best explains the interaction between the doctor and the patient (Tarrant, C., et al. (2004)).

When there is an interaction between common and conflicting interests between two players - a doctor and a patient - the situation can be explained using game theory (Djulbegovic, B., et al. (2015)).

It is not surprising that game theory is used in these contexts, as it is designed to study the interaction between patient and doctor (Yeung, H. M., & Makkapati, S. (2023)).

For instance, medical decisions about how a diagnosis will be made or whether a placebo drug will be prescribed are suitable for game theory analysis.

Game theory models are considered in the context of optimizing medical decision-making under uncertain conditions that doctors face daily and maximizing the expected benefit (Diamond, G. A., Rozanski, A., & Steuer, M. (1986)).

Game theory is widely used in various decision-making studies, but there are very few applications to health issues, namely the doctor-patient relationship (Mendonça, F. V. et al. (2020)).

Game theory offers a new perspective for the investigation and modeling of decision-making between the patient and the doctor (Yeung, H. M., & Makkapati, S. (2023)).

REFERENCES

Albert, D. A. (1978). Decision theory in medicine: a review and critique. *The Milbank Memorial Fund Quarterly. Health and Society*, 362-401.

Aleem, I. S., Jalal, H., Aleem, I. S., Sheikh, A. A., & Bhandari, M. (2009). Clinical decision analysis: incorporating the evidence with patient preferences. *Patient preference and adherence*, 21-24.

Blake, A., & Carroll, B. T. (2016). Game theory and strategy in medical training. *Medical education*, *50*(11), 1094-1106.

Dhawale, T., Steuten, L. M., & Deeg, H. J. (2017). Uncertainty of physicians and patients in medical decision-making. *Biology of blood and marrow transplantation*, *23*(6), 865-869.

Diamond, G. A., Rozanski, A., & Steuer, M. (1986). Playing Doctor: application of game theory to medical decision-making. *Journal of chronic diseases*, *39*(9), 669-677.

Djulbegovic, B., Hozo, I., & Ioannidis, J. P. (2015). Modern health care as a game theory problem. *European Journal of clinical investigation*, *45*(1), 1-12.

Duffull, S. B., Anakin, M. G., & Wright, D. F. (2019). Understanding the process of clinical judgment for pharmacists when making clinical decisions. *Research in Social and Administrative Pharmacy*, *15*(5), 607-614.

Madani, K. (2010). Game theory and water resources. *Journal of Hydrology*, *381*(3-4), 225-238.

Mendonça, F. V., Catalao-Lopes, M., Marinho, R. T., & Figueira, J. R. (2020). Improving medical decision-making with a management science game theory approach to liver transplantation. *Omega*, *94*, 102050.

Pikkel, D., Pikkel Igal, Y. S., Sharabi-Nov, A., & Pikkel, J. (2016). Are doctors risk-takers? *Risk management and healthcare policy*, 129-133.

Riggs, J. E. (2004). Medical ethics, logic traps, and game theory: an illustrative tale of brain death. *Journal of medical ethics*, *30*(4), 359-361.

Tarrant, C., Stokes, T., & Colman, A. M. (2004). Models of the medical consultation: opportunities and limitations of a game theory perspective. *BMJ Quality & Safety*, *13*(6), 461-466.

Yeung, H. M., & Makkapati, S. (2023). Applying Game Theory Models to Inpatient Medicine: Opportunities to Improve Care. *Journal of Community Hospital Internal Medicine Perspectives*, *13*(1), 20.