Aalto University

MS-E2177 - Seminar on Case Studies in Operations Research

Impact assessment of post-treatment options in nuclear medicine therapy:

Project plan

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1 Background

Isotope treatment is one way to treat cancer. In isotope treatment, the patient is given a dose of long-lasting radioactive isotope. The isotope drifts towards the cancer cells and radiates there, damaging the cancer cells. After the treatment, the patient remains radioactive and must be kept isolated for a given time. Even after the hospitalized isolation, there is some radioactivity left in the patient, and especially the secretions of the patient radiate and should be handled with caution. (Kyllönen et al., 2022)

The isotope treatment has its benefit: treating the patient and giving them more lifetime (Vaalavirta, 2021). However, it also causes harm to the patient theirself, as well as to the people around them and to the society (Lassen et al., 2023). The patient gets a dose of radioactive isotope, which, despite its curing features, exposes the patient to radiation. The side affects include skin and mucosal damages near the tumor, and increased risk of a new cancer, among others (Vaalavirta, 2021). The patient also has to be isolated in hospital and possibly in home as well. The caregivers and the family of the patient are exposed to radiation as well (Lassen et al., 2023). The isolation and the disposal of radioactive waste in the hospital have monetary costs. Radioactive waste is also generated at home from patient excreta (Kyllönen et al., 2022; Lassen et al., 2023). Ideally, this waste should end up in the water supply system, but if it ends up in the waste management system, this can cause problems: waste treatment may have to be interrupted, or radioactive ash may be generated when the waste is incinerated (Kallio et al., 2023). When the isotope treatment is considered as a treatment option, these factors have to be taken into consideration. The benefits of treatment must outweigh the harms of radiation in order to justify the treatment (Lassen et al., 2023). This can be a difficult task to accomplish, as valuing for example the harm to the patient caused by isolation is complicated.

The objective of this project is to create a mathematical model for assessing these different post-treatment options in nuclear medicine therapy after getting treated with the isotope Lu-177. The number of nuclear medicine examinations and radionuclide therapy treatments has steadily increased over the past years. In recent years, especially the use of the radionuclide Lu-177 in isotope treatments has increased significantly (Kuurne, 2023). Therefore, in this project, we focus on assessing different post-treatment scenarios in nuclear medicine therapy on treatments using Lu-177. While in hospitalized isolation, compliance with radiation safety practices is well-defined and monitored. Still, monitoring the patient's compliance with the post-treatment guidelines at home after the hospitalized isolation is more complex.

Our client for this project is STUK, the Radiation and Nuclear Safety Authority of Finland, which is responsible for protecting people, society, the environment, and future generations from the harmful effects of radiation. Generally, STUK's responsibilities in health care include for instance monitoring of occupational radiation exposure, regulatory control of radiation practices, and regulatory control of radioactive waste. The radiation practices and protective actions in health care are justified if the overall benefits of the treatment exceed the detriment caused. The benefits of the treatment may be economic, or society or health related as long as the benefits can be compared with the harm caused by the practice. (Radiation Act, 2018). For STUK, the aim of this project is to conduct an impact assessment of the post-treatment scenarios in nuclear radiation therapy by getting an insight into the most essential factors related to the justification of nuclear medicine therapy.

2 Objectives

The objective of this project is to create a model that assesses the impacts of post-treatment options in nuclear medicine therapy. The focus will be on the justification of the treatment by evaluating the overall benefits and detriments. We will focus on the treatments done in Finland and specifically, in public healthcare. In our model, we will use radionuclide Lu-177. Our focus is on post-treatment scenarios and issues, and we will not assess risks of the treatment itself. However, we will take the benefits (longer and/or better life) and the price of the treatment into consideration.

It is important that the benefits of the treatment exceed the detriments. Our tentative plan is to address the following competing considerations presented in STUK's topic description:

- The economic cost of treatment vs. the expected benefit (quality of life and life expectancy)
- Isolation vs. individual freedom
- Overall benefit of treatment vs. potential harm to the economy (e.g., downtime of a waste facility due to contaminated waste)
- Written patient guidelines vs. individuals' different attitudes towards guidelines
- Isolation increases costs and burdens the individual but protects the population

We will create the model in Excel. At this point of the project, our plan is that the model consist of an event tree that presents possible post-treatment scenarios studied in this project. One possibility is that the model's output is maximum/minimum price for human life so that the benefits of the treatment would exceed the detriments. Our goal is to assess monetary value and possibility for each scenario. We will define value functions for different variables to make them comparable: this means finding a monetary value for human life, for example. The scope of the model will be well defined. For example, we will not take potential compilations in treatment or re-visits to hospital into account. The model will assess only the most common outcomes.

STUK wished that the model could be adapted to other radionuclides, and the different assumptions would be adjusted easily. Thus, we will try to make our model as generalizable as possible. We plan to construct the model so that each parameter are given as a range between two values, and the user can change the values by themselves. We will provide initial ranges.

3 Tasks

The content of the following main tasks may vary as the project progresses and more information is gathered but outlining the different tasks will aid in generating a structured approach to successfully meet the goals of the project members and the client. The tasks are divided into five parts, each of which contains several subtasks.

3.1 Initial research and scoping of the problem

The scoping of the project will start by discussing with the client to gather more information about the objectives of the project. In addition, through meetings with the client, additional information about the problem can be gathered, such as the contact information of other parties involved in the problem as well as relevant data and articles about the topic. As the initial scope of the problem is broad and not clearly defined, these discussions are important in understanding the client's main interests and objectives, so that the problem can be structured adequately to meet the course's schedule and the client's objectives. Additionally, as the healthcare sector and radiation treatments are not familiar to most team members, initial research on the topic is needed before the team can move on to gathering data and developing the model. This initial research will be done through extensive literature research on the topic, which will contain information about radiation treatments and their post-treatment impact on individuals and society. In addition, the literature review will focus on the justification of the treatments, and how this can be modeled through risk and decision analysis tools. To conclude, these tasks are centered around educating the team members on the project topic as well as understanding the client and their objective better.

3.2 Data collection and validation

To construct the model, data about radiation amounts in different post-treatment scenarios and costs of different post-treatment activities are needed. This data is collected from various parties, in more detail from the client, hospitals, waste management companies, and other relevant parties. In addition, data about decreasing and/or increasing the quality of life, increasing life expectancy, and the risk of exposing other people to radiation are needed. As there are no agreed monetary values for these factors, the team must construct monetary value ranges for each of these factors. These ranges are constructed by reading publications and reports about the topic as well as discussing with experts to get their subjective view on these factors, in order to have an idea of how these factors are typically valued monetarily. Then, these commonly used values will be discussed and sparred within the team and finally, initial ranges will be constructed. After this, the initial ranges will be validated and possibly modified with the client through data validation meetings. As these values are subjective, the use of ranges will ensure that the model will consider the uncertainty related to these values. Finally, the probabilities of different scenarios are needed, and to calculate them, data from the different parties (the client, hospitals, and waste management companies) as well as public data and research on the post-treatment behavior of patients are used. Also, these values will be iterated and validated through discussion within the team and with the different parties.

3.3 Constructing the model

The model construction can begin when the problem setting is understood after completing the initial research and scoping of the problem, and thus not all data need to be collected and validated before starting this task. After the literature review, the most suitable decision analysis model is identified for modeling the justification of radiation treatments, which we hypothesize to be an event tree. This model will be constructed in Excel so that the use of the model is easy and possible for the client. In Excel, it is also easy to change the value and probabilities of the different scenarios, which makes further development and modification of the model easier for the client. The model constructed in this project will focus on post-treatment scenarios of LU-177 treatment, but the model will be constructed so that it can be used to evaluate the impact of different treatments as well. Different modifications of the model can be constructed, for example, to have additional scenarios and parties beyond the already specified ones.

3.4 Validation of the model

The model will be validated with the client to ensure that it meets the client's requirements and has all the required scenarios and values needed to model the post-treatment impacts realistically. This will be done through validation meetings with the client. If needed, the model is modified and developed further. In addition, the different scenarios can be validated with the hospitals and waste management companies, to ensure that the model is adequate throughout.

3.5 Reporting

In addition to the additional meetings with the client, the progress and results of the project are reported and presented to the client, the course staff, and other students with three different reports. This project plan introduces the background of the problem, objectives, tasks, schedule, resources as well as risks of the project. The interim report will present the progress of the project as well as possible changes to the initial project plan. The final report will include the key results and findings of the project as well as the final model and instructions on modifying it for further use.

4 Schedule

The schedule of the project is illustrated in Figure 1, with all the tasks discussed in Section 3 as well as tentative meetings with different parties. Note that the project has already started, and thus the schedule starts from week 3 (from 15.1.2024).

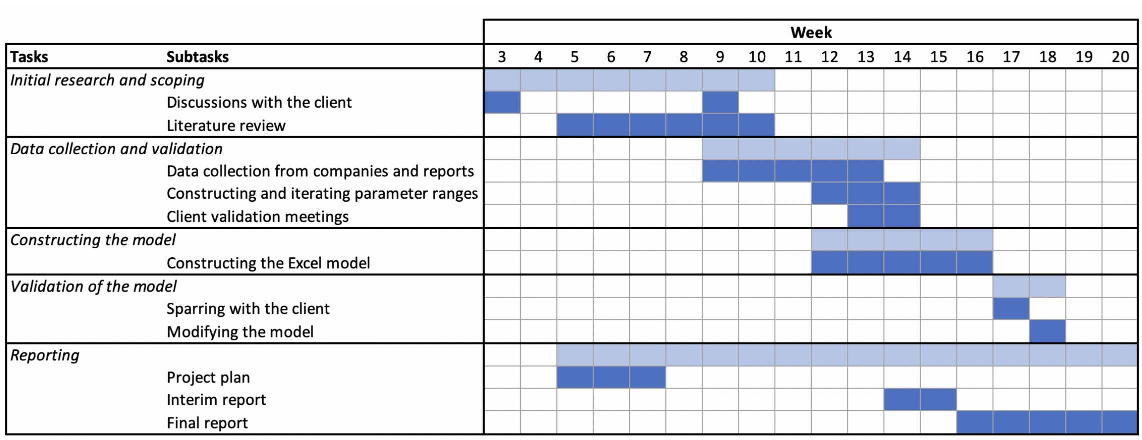

Figure 1: Initial schedule of the project

5 Resources

The team consists of five master level students majoring in Systems and Operations research. Our team has a solid background in mathematics and problem solving that are required skills for completing the project. Our team also has knowledge in other domains including industrial engineering and management, environmental science and computer science. In addition, two students of our team have a bachelor in bioinformation technology which enables suitable foundation for solving a problem related to medical technology. This bachelor namely gives tools for understanding how cells and tissues work and the basic theory related to biological systems. Due to the varying background of our team, we can cover different aspects for our topic.

Our team has regular meetings in which we divide the workload equally between the team members. In these meetings, team members discuss about the possible problems and the next steps that are needed to take for completing the project on time. Our project manager Olivia Antikainen also makes sure that all team members are committed to complete their part of the project and that the workload is equally divided.

We also have regular meetings with our client STUK so that we have the possibility to share our thoughts and get clarifications about the topic. Our main contacts at STUK are Jukka Liukkonen and Sampsa Kaijaluoto. STUK has already shared us open data related to the numbers of nuclear medicine examinations and radionuclide therapy treatments, the radiation exposure of adults from the treatments and the ages and numbers of nuclear medicine imaging devices and activity meters.

To complete the project successfully, we contact appropriate parties related to health and waste management problems. STUK has already given the contact information of the appropriate institutions. This way we can take the aspects of waste management and health care into account when building the mathematical model.

Other necessary information is sought from the scientific literature for example about the use of Lu-177 in the treatment of prostate cancer and gastroenteropancreatic neuroendocrine tumours, radioactivity of residues from waste incineration facilities and patient instruction about Lu-177 treatment. In addition, it is important to familiarize with laws about radiation protection and safety. The course professor Ahti Salo also will supervise and help us with possible problems related to the course.

The mathematical model is implemented using Excel so that the client has an opportunity to change the parameters if needed. This way the client is able to utilize the model for example for comparing Lu-177 with I-131 that is used for diagnosing and treating thyroid cancer.

6 Risks

There are several risks that can occur during the development of the model. Most risks are related to the data, the scope of the model and communication between the team members as well as between the client. The main risks are presented in table 1 below. For each risk, its likelihood, impact, effect and prevention mechanism have been identified. The scale of likelihood and impact estimate is low, medium and high. Identifying the risks at early stage, helps us eliminate them and as a result, complete the project on time.

Table 1: *Main risks that can occur in the project*

Risk	**Effect**	**Likelyhood**	**Impact**	**Mitigation**
Communication problems with the client	Not getting appropriate feedback for the model. The final model does not meet the client's requirements.	Low	High	Initiating communication with the client.
Inactive group members	Project is not completed on time due to increased workload	Low	High	Having meetings regularly. Good communication between team members. Following the schedule.
Inaccurate data	The quality of final model has decreased.	Medium	High	Trying to contact different parties related to health care and waste management in order to get more data. Getting the data as early as possible so that it can be discussed with the client.
Unrealistic assumptions	The final model is not accurate.	High	High	Consulting the client about the assumptions. Constructing ranges for the parameters based on publications and reports about the topic.
Poorly defined objective	The final model does not capture the problem and therefore, does not meet the requirements.	Low	High	Discussing about the objective with the client at an early stage. Also getting familiar with the data and literature at an early stage.
Overly complex mathematical model with too many variables	The model is not completed because the problem is too wide for the time we have reserved.	Medium	High	Formulating the objective clearly. Having a clear plan.
Lack of time	The model is not completed on time or the problem is simplified significantly in order to complete the model.	Low	High	Having a clear plan and schedule.

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