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# COST-EFFECTIVENESS OF ROBOTIC SURGERY IN THE TREATMENT OF LOCALISED PROSTATE CANCER IN ESTONIA

Master's Thesis

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I have written this Master's Thesis independently. Any ideas or data taken from other authors or other sources have been fully referenced.

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**Abstract**

This thesis evaluates the cost-effectiveness of robot-assisted radical prostatectomy (RARP) compared to laparoscopic radical prostatectomy (LRP) in the treatment of localised prostate cancer in Estonia. RARP is more costly than LRP but has lower rates of urinary incontinence and erectile dysfunction complications after surgery. A 10-year Markov model was used, assuming 350 surgeries a year and an incremental cost-effectiveness ratio (ICER) of €22,120 per QALY gained was calculated. Probabilistic sensitivity analysis resulted in 63% of iterations with ICER under €40,000 and 45% under €20,000. The willingness-to-pay threshold in Estonia for non-terminal conditions is €20,000 per QALY gained, but robotic surgery has benefits that the classical health technology assessment framework cannot incorporate, such as improved surgeon ergonomics and the value of technological advancements. The results show that robotic surgery could be considered cost-effective in Estonia. If reimbursed, RARP would have an annual budget impact of 1.12 million euros. When considering other surgical procedures as well, the annual budget impact of robotic surgery could be approximately 7.33 million euros.

Keywords: cost-effectiveness analysis, prostatectomy, prostatic cancer

JEL Classification: I11, D61, I18

## Introduction

Medicine is continuously evolving and with technological innovations, there are always new treatments to consider. In smaller countries such as Estonia, public funds are limited and not all new health technologies can be reimbursed by the government. Estonia has a unified national health insurance system, under which all insured individuals have equal right to healthcare services covered by the Estonian Health Insurance Fund. The list of services eligible for reimbursement is updated annually based on both medical need and financial capabilities of health insurance. As a result, both clinical and cost-effectiveness of all treatments are considered when making decisions regarding reimbursement. (Estonian Health Insurance Fund, 2024).

One of these revolutionary advancements in medicine is robotic surgery, whose origins date back to the late 1960s. Robotic surgery offers enhanced precision compared to conventional surgery, allowing surgeons to perform intricate minimally invasive surgeries, and 3D visualisation. Due to these advantages it is applicable across many fields, such as urology, general surgery, cardiothoracic surgery, gynaecology, otolaryngology, neurosurgery, orthopaedic surgery, and surgical oncology. (Chatterjee et al., 2024)

Robotic surgery has many benefits compared to traditional surgery, including improved range of motion and reduced postoperative complications, which has made robotic surgery the preferred approach amongst many surgeons. In addition, robotic surgery causes less back and neck pain from physical strain for the surgeon due to a more ergonomic position during surgery. The most significant limitation of robotic surgery is its high cost. The cost of a robotic surgical system itself is between 1.5 and 2 million euros in addition to substantial annual service fees, making it a costly procedure. (Rivero-Moreno et al., 2023) In Estonia robotic surgery is not in use yet, however preparations are being made for implementation. (Murruste, 2025) Since it is a costly procedure, robotic surgery can only be widely spread if it gets reimbursed by the government, however it is not on the list of reimbursable health technologies yet (19. Jaanuari 2007 a Määrus Nr 9 'Tervisekassa Poolt Tasu Maksmise Kohustuse Ülevõtmise Kord' Lisa 3 [Regulation No 9 'Procedure for the Health Insurance Fund to Assume the Obligation to Pay' Appendix 3], 2026).

Prostate cancer is the most commonly diagnosed cancer in Estonian men, accounting for 29% of cancer cases in Estonian men (Zimmermann et al., 2025). Radical prostatectomy (RP), a procedure to remove the prostate gland and surrounding tissue, is used for local prostate cancer as a successful treatment. The surgery can be performed as either an open radical prostatectomy (ORP) or a laparoscopic radical prostatectomy (LRP). For LRP, small incisions are made in the wall of the abdomen through which thin tools with cameras are inserted to perform the surgery without cutting the patient open (*Prostate Cancer Treatment - NCI*, 2026). A further development is the growing trend of robot-assisted surgery (RARP), where laparoscopic surgery is performed with the surgeon sitting at a computer monitor and controlling the robotic arm. (*Radical Prostatectomy*, 2024). To show the popularity of RARP internationally, the amount of prostatectomies conducted with robots in England increased from 53.2% in 2013 to 92.6% in 2018 (Gray et al., 2022).

The aim of this thesis is to assess the cost-effectiveness of robot-assisted radical prostatectomy compared to laparoscopic radical prostatectomy in 65-year-old men with localised prostate cancer in Estonia. Laparoscopic radical prostatectomy was chosen as the comparator treatment as it is the dominating treatment in Estonia. 368 LRPs were performed in 2025 compared to only 15 ORPs (Estonian Health Insurance Fund, 2022). Sensitivity analysis, both deterministic and probabilistic, will be conducted to determine the parameters most influential to the result of the cost-effectiveness and assess overall parametric uncertainty. Discussion will follow, whether RARP would be cost-effective in Estonia and the budgetary impact it would have if the Estonian Health Insurance Fund would decide to reimburse this procedure. OpenAI's GPT-5.3 was used for proofreading this text, all additions were verified by the author.

This is the first cost-effectiveness analysis on robotic surgery from an Estonian perspective. The analysis is limited to radical prostatectomy due to the methodological requirements of cost-effectiveness analysis, where all medical conditions must be considered separately as the survival and treatment benefits of different conditions may differ. However, if adopted, the robotic surgical system would probably be used across a broad range of surgical procedures, extending the relevance of this study beyond prostatectomy alone.

# 1. Literature review

## 1.1. Health technology assessment

When a new health technology becomes available, decision makers must determine whether the new technology brings enough health gain relative to its additional cost compared with the current treatment. In other words, they must assess whether the new intervention is cost-effective. The standard method used for this purpose is health technology assessment (HTA), which systematically combines clinical and economic outcomes of a new health technology in comparison to an existing one. HTA was formally developed in the 1970s in the United States and spread to the rest of the world during the 1980s. Today, most

European Union member states have national HTA programmes to support health technology reimbursement decisions. (Banta & Jonsson, 2009)

HTA and cost-effectiveness analysis (CEA) are country-specific because both clinical practice and unit costs are specific to the country and healthcare system. The Estonian guideline for HTA methodology was published in 2024 by the Centre for Health Technology Assessment and this thesis will follow these guidelines.

As resources are limited, not all new health technologies can be reimbursed by the public payer. In Estonia, for a new health technology to be reimbursed, it must be:

a) clinically effective;
b) cost-effective;
c) relevant to society and aligned with the country's healthcare politics;
d) comply with the budgetary constraints of the Estonian Health Insurance Fund (Government of Estonia, 2025 redaction)

The effect of new health technologies is first tested on clinical trials, that assess the effects of a new health technology. However, they are usually conducted over a relatively short time horizon and do not consider long term outcomes. Additionally, clinical trials are conducted on selected patient groups, which might not reflect real life patient demographics and can bias the results (Juus et al., 2014). To combat these limitations, simulation methods are used to understand and predict the possible routes of a disease and compare a new health technology with existing medical practices. (Stahl, 2008)

The first step of HTA is defining the scope of the assessment. For this purpose, the PICO framework is commonly used, which stands for:

a) Population – the target group;
b) Intervention – the new assessed health technology;
c) Comparator – the current treatment used on the target group;
d) Outcome – the relevant health outcome measure. (Centre for Health Technology Assessment [HTA], 2024)

When the PICO has been defined, economic modelling follows. The most common models used in cost-effectiveness analysis are decision trees and Markov models (Stahl, 2008). For oncological interventions, partitioned survival models (PSMs) are also frequently used (Woods et al., 2020). A decision tree is typically used for short-term conditions as for long-term conditions the tree has too many branches and may become overly complex. In a decision tree, patients move through a sequence of health states with assigned probabilities and outcomes. An example of a decision tree is shown in Figure 1.

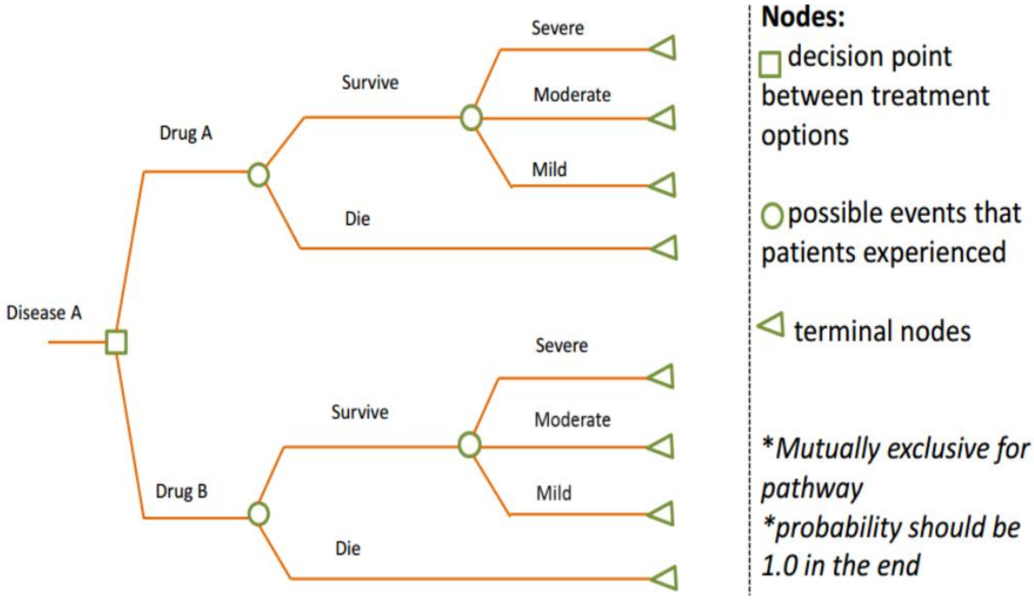


*Figure 1. Example of a decision tree (Azreena et al., 2017)*

For chronic or long-term conditions with more complicated health state transitions, a Markov model is more appropriate. The Markov model allows modelling the course of disease as cycles, with repeated transitions between health states. At each cycle, a person's health state is assessed and they can either remain in the same state, improve, deteriorate or die. (Juus et al., 2014)

In some cases, a discrete-event simulation (DES) may be used, where time-to-event is modelled instead of the risk of the event. This allows patient history and pathways to influence the outcomes. However, DES models need more complex and specific data and are therefore less commonly used. (Karnon, 2003) Another model type is the aforementioned partitioned survival model. PSMs do not use transitions between states but instead derive results from the overall survival and progression-free survival curves, making them more suitable for oncology interventions. (Woods et al., 2020)

The costs used in economic assessment can be direct or indirect. The direct costs relate to healthcare resource use while indirect costs may include productivity losses due to illness (Juus et al., 2014). The costs included into the model depend on the perspective of analysis. In Estonia, analysis is generally conducted from the perspective of the public payer, that is the Estonian Health Insurance Fund, meaning that the analysis mainly includes direct costs. A broader societal perspective may be added to the sensitivity analysis, but its use must be explained. (Centre for HTA, 2024)

The gold standard outcome measure used in CEA is the quality-adjusted life year (QALY) (Carlson et al., 2020), which enables the comparison of different health technologies by combining different health effects into a single outcome measure. A QALY considers both the quantity and quality of life. It is calculated by multiplying the time spent in a health state with the health state's utility value, which is the quality of life on a scale from 0 to1. Although full health may assumed to have utility of 1, it rather depends on age and other physical scores and is usually lower (Korfage et al., 2005).

While QALY is the most widely used outcome measure, it is not without its criticism. Sawhney et al., (2023) argue that the theoretical foundation of a QALY relies on assumptions that are unlikely to hold in place, such as:

1. A common understanding of what constitutes as perfect health.
2. Health can be measured on a linear utility scale from perfect health to death.
3. Poor health and good health are equally likely to be measured.
4. The equal absolute values of gain and loss of health have equal societal value.

There have been attempts to develop alternative approaches to QALY. Carlson et al. (2020) identified 28 QALY alternatives, of which only 3 of the measures were practically implementable. This explains why QALY remains the standard outcome measure in HTA.

In HTA health-related quality of life is typically measured using the EuroQol-5D (EQ-5D) instrument, which is one of the most common questionnaires used to measure a patient's self-rated health (Centre for HTA, 2024; EuroQol, 2025; Juus et al., 2014). While Estonian population-based utility values exist for some health states, such data is not available for the health conditions in this thesis. Therefore, this thesis uses utility values from literature.

In CEA, discounting of both costs and outcomes is used as people generally value future costs and health effects less than present ones. For surgical interventions, the biggest costs are often incurred in the first year, whereas health benefits accrue over many years. Therefore, the discount rate can substantially influence cost-effectiveness results. (Attema et al., 2018) In Estonia, a 3.5% discount rate is applied to both costs and outcomes (Centre for HTA, 2024). Previously, a rate of 5% was used. Across Europe, discount rates vary from 1.5% to 5%, with lower rates more common in richer countries and higher rates in poorer countries. Varying the discount rate in the sensitivity analysis is important as it can substantially change the results of cost-effectiveness. (Anspal et al., 2022)

The central result of a CEA is the incremental cost-effectiveness ratio (ICER), which compares two health technologies by dividing the incremental cost of the new technology by the gain in outcome, that is most commonly QALY (Juus et al., 2014).

ICER is calculated as (Centre for HTA, 2024):

$$ICER = \frac{cost_{intervention} - cost_{comparator}}{outcome_{intervention} - outcome_{comparator}} \quad (1)$$

A new intervention is dominant when it is both less costly and more effective than the comparator, and it is considered dominating when it is more costly and less effective. In these cases, the ICER is not calculated. (Centre for HTA, 2024) Many countries have explicit ICER thresholds, above which technologies are not considered cost-effective and are generally not publicly reimbursed. The willingness-to-pay threshold in Estonia is not explicitly defined, however a €20,000 threshold is used for chronic diseases and €40,000 is used for terminal illnesses (Anspal et al., 2022).

After the base-case results of a CEA model are presented, sensitivity analysis must be conducted (Centre for Health Technology Assessment, 2024). With all parameters, there is always some uncertainty, as not all patients can be measured for all possible health states. Additionally, some parameter values used in CEA models are based on subjective questionnaires, which gives another level of uncertainty. Sensitivity analysis can be deterministic, where parameters are varied one or multiple at a time, or probabilistic, where parameters are assigned certain distributions and sampled repeatedly, called Monte Carlo simulation. For utility and patient progression parameters, the beta distribution is most commonly used, while for costs, the gamma, normal or lognormal distributions are most common. (Andronis et al., 2009)

### 1.2. Robot-assisted radical prostatectomy

Radical prostatectomy is a surgical procedure to remove the prostate and surrounding tissue and it is used to treat localised prostate cancer (*Radical Prostatectomy*, 2024). Prostate cancer is the most commonly diagnosed cancer in Estonian men. While localised prostate cancer has a ten-year mortality rate of less than 1% in Estonia, distant metastatic prostate cancer has a mortality rate of 82%. (Zimmermann et al., 2025) This shows why localised cancer must be treated early, for metastasis to not occur.

In 2025, 368 laparoscopic radical prostatectomies were performed in Estonia, indicating RP to be quite a frequent procedure. As laparoscopic procedures have minimal incisions, they are preferred to open prostatectomies, of which only 15 were done in Estonia in 2025. (Estonian Health Insurance Fund, 2022) As most men live for many years after RP, minimising complications after surgery is of high importance. The main complications after RP are urinary incontinence (UI) and erectile dysfunction (ED) (Michaelson et al., 2008).

Urinary incontinence is the involuntary leakage of urine (NHS, 2017). In Estonia, according to an Estonian urologist, UI after prostatectomy is treated with a male sling procedure or pelvic floor exercises. Patients may choose an artificial urinary sphincter implantation, which can have a success rate of up to 90% (*What Is an Artificial Urinary Sphincter?*, 2024). Patients who don't undergo treatment use incontinence products such as daily absorbent pads. Approximately 24% of patients experience UI one year after laparoscopic radical prostatectomy (Xu et al., 2024). However, assessing UI is challenging, as it is often based on subjective questionnaires and definitions vary across studies, for example based on the number of daily pads used. Postoperative erectile dysfunction is also a common complication, affecting 57% of patients one year after laparoscopic radical prostatectomy (Xu et al., 2024). While oral medications are available to manage ED during intercourse, they are not permanent cures and must be used repeatedly (Johns Hopkins Medicine, 2019). Mechanical methods such as vacuum constriction devices and penile prostheses are effective treatments (Hatzimouratidis & Hatzichristou, 2005) but according to expert opinion are costly and therefore rarely used in Estonia.

Robot-assisted radical prostatectomy has become increasingly common since its introduction in 1998 and has continued to evolve ever since. The surgery is performed with robotic arms controlled by a surgeon, supported with a 3D camera that enhances depth perception. The da Vinci robotic system developed by Intuitive Surgical is the main system in use, although alternative ones are emerging. (Mian et al., 2024) Robotic surgery is already in use in all Nordic countries, as well as Lithuania and Poland, but it has not yet been used in Estonia (Eilsen, 2025).

According to the article introducing robotic surgery and its possibilities in Estonia by Eilsen (2025), robotic surgery is associated with advantages compared to traditional laparoscopic surgery such as reduced blood loss during surgery, less postoperative pain and shorter hospital stays. While potential advantages exist, no statistical differences in any of them have been proven for radical prostatectomy (Ma et al., 2023). Prostate cancer and its recurrence can be detected with an increased level of the prostate-specific antigen (PSA) in the blood (*Prostate-Specific Antigen (PSA) Test - NCI*, 2025). While some cost-effectiveness studies of RARP have assumed decreased biochemical recurrence (rise of PSA levels) after

RARP compared to LRP, randomised controlled trials have not shown there to be a statistical difference. (Ma et al., 2023; Põld et al., 2026)

What has been proven is that RARP has significantly fewer functional outcome complications compared to LRP, meaning decreased number of UI and ED problems (Xu et al., 2024). Since both affect daily life, improvements in these outcomes mean a considerable increase in quality of life.

In addition to patient-related benefits, robotic surgery may offer advantages to surgeons. Systematic reviews by Cooper et al. (2025) and Dalager et al. (2017) showed that surgeons report less pain after RARP than after LRP. This is vital to prolonging the longevity of surgeons' careers, as musculoskeletal disorders may lead to surgeons taking sick leaves and retiring early. However, this aspect does not fit into the classical HTA framework, which focuses on the patient's quality of life patient without allowing to incorporate the surgeon's quality of life. For example, a cost-effectiveness analysis by Lindenberg et al. (2022) translated surgeon ergonomics into the cost of sick leaves that one surgeon takes per year. However, it could be argued that this approach undervalues the actual impact of the improved surgeon ergonomics on the healthcare system, as the calculated cost was only a 16 euro difference between LRP and RARP.

### 1.3. Overview of previously published cost-effectiveness analyses

In the following section, an overview of previous cost-effectiveness analyses will be given. A systematic literature search was conducted on PubMed on 29.01.2026. Keywords related to robot-assisted radical prostatectomy and cost-effectiveness analysis were used (see Appendix A). Then, PICO was used to eliminate non-relevant results:

a) population – men with localised prostate cancer
b) intervention – robot-assisted radical prostatectomy
c) comparator – laparoscopic radical prostatectomy
d) outcome - QALYs

The first search yielded 164 articles, out of which 13 were selected based on their abstracts for further reading, out of which 4 fit the scope of the study and 2 additional were identified from systematic reviews. The methodologies of the studies are reported in Table 1. The studies are from the USA, Thailand, the Netherlands, Brazil and 2 from the UK. The earliest study is from 2012, and the 3 most recent ones are all from 2022. The Markov and decision tree models were the most common models, but a discrete-event simulation model was also used. Most of the studies used the lifetime of the robot as the timeframe, 7 to 10 years, except for 2 studies that used longer timeframes, focusing on the lifetime of the patient. For both costs and outcomes, discount rates of 3–5% were used, apart from the Netherlands, where for costs a 3.5% discount rate but for outcomes a smaller 1.5% discount rate was used. The perspective of the Health System was used in almost all the studies, except for Lindenberg et al. (2022), who used a societal perspective, being the only ones to account for surgeon comfort in their costs.

Table 2 reports the results of the studies, except for the Brazilian model by Faria et al. (2022), which was left out because of discrepancies in their data. Due to the surprisingly low ICER value reported, Marcolino et al. (2023) have written a comment, which brings out the inconsistency of the numbers reported with cited references and also within the study. For this reason, only the methods used in the study were analysed and not the results.

Table 1

*Methods of selected cost-effectiveness studies*

| Source | Country | Perspective | Time horizon | Model | Currency | Discount rate |
|---|---|---|---|---|---|---|
| Ramsay et al. (2012) | UK | Health system | 10 years | Discrete-event simulation model | GBP | 3.5% |
| Cooperberg et al. (2013) | USA | The public payer | Lifetime | Markov model | USD | 3% |
| Ratchanon et al. (2015) | Thailand | Health system | 10 years | Decision tree | THB | 3% |
| Lindenberg et al. (2022) | The Netherlands | Societal | 7 years | Decision tree | EUR | 3.5% costs<br>1.5% outcomes |
| Faria et al. (2022) | Brazil | Health system | 20 years | Markov model | BRL | 5% |
| Labban et al. (2022) | UK | Health system | 10 years | Markov model | GBP | 3.5% |

Table 2

*Results of the selected cost-effectiveness studies*

| Source | Gain in QALY | Incremental cost € (per patient) | ICER per QALY € | Willingness-to-pay threshold € | Funding source |
|---|---|---|---|---|---|
| Ramsay et al. (2012) | 0.077 | 1620 | 21,029 | 34,419 | HTA programme |
| Cooperberg et al. (2013) | | | | | Manufacturer of robot |
| Low risk | 0 | 502 | - | - | |
| Intermediate risk | 0.1 | 863 | - | - | |
| High risk | 0 | 87 | - | - | |
| Ratchanon et al. (2015) | 0.05 | 3265 | 65,304 | 4341 | University of Bangkok |
| Lindenberg et al. (2022) | 0.06 | 2029 | 34,206 | 80,000 | Manufacturer of robot |
| Labban et al. (2022) | 0.24 | −2048 | dominating | 34,419 | Manufacturer of robot |

All the costs were converted to euros with the European Central Bank (*Currency Converter | ECB Data Portal*, 2026) rate on 15.02.2026 to compare results. The gain in QALYs ranges from 0 to 0.24 in the studies and the incremental costs per surgery range from cost-saving to €3265. The differences in costs between studies is due to the varying costs of labour, hospital care, equipment etc. per country. Additionally, some studies assumed decreased surgery length and postoperative hospital stay for RARP, while others assumed these to be equal for RARP and LRP. The costs included in the studies are shown in Appendix B.

The only study to find RARP less costly than LRP was Labban et al. (2022). It is interesting to note that Labban et al. (2022) and Ramsay et al. (2012) both analysed UK data with very different results. This may be due to the 10-year difference between the two studies or due to the fact that all the studies included into the analysis used different ways to calculate the costs and health benefits. Labban et al. (2022) reported a gain in QALYs from a reduction in biochemical recurrence (BCR) while Ramsay et al. (2012) did not. The lower total cost of RARP in the study by Labban et al. (2022) comes from shorter surgery time and less distant metastasis and palliative care treatment after RARP compared to LRP.

Most of the other studies assumed that biochemical recurrence of cancer and operative outcomes are the same between LRP and RARP. Meta-analyses have not found statistically significant differences in these markers, although mean values are generally more favourable for RARP (Ma et al., 2023; Xu et al., 2024). However, decreased percentage of UI and ED after RARP have been shown to be statistically significant.

Robot-assisted radical prostatectomy was considered cost-effective in comparison to laparoscopic radical prostatectomy in 2 of the 5 studies and dominant in 1, given national thresholds. Cooperberg et al. (2013) did not calculate ICER as there were no gains in QALY and the aim of the research was mainly to compare radical prostatectomy to radiation therapy for treatment of prostate cancer not laparoscopic surgery. Ratchanon et al. (2015) did not find RARP cost-effective, but the authors note that the willingness-to-pay threshold used in the analysis was low (€4341) and fewer radical prostatectomy procedures are done annually in Thailand than in more developed countries. The authors assumed 100 surgeries per year; other studies have used 150+ per year. All the studies emphasised that increasing the volume of annual procedures brings ICER down significantly and centralisation of treatments is needed for RARP to be cost-effective.

There are no comprehensive systematic reviews of cost-effectiveness studies across specialties, the articles on robotic surgery focus on a single type of surgery. Bosscha et al.

(2025) conducted a systematic review on cost analyses of robotic surgery. They found that robotic surgery was more costly across different types of surgical procedures, except for a few individual studies, which have found robot-assisted cystectomy, hysterectomy and lobectomy cost saving or similar compared to open or laparoscopic surgery. Lai et al. (2024) conducted a systematic review on the clinical effectiveness of robotic surgery across fields. The only parameter in which robotic surgery systematically performs worse than open or laparoscopic surgery is operative time. The perioperative performance of robotic surgery is generally neutral or slightly better than other types of surgeries, with less estimated blood loss and conversion to open surgery in the case of laparoscopic surgery. For some procedures, the length of stay at the hospital after surgery also favours robotic surgery. In conclusion, robotic surgery is generally more costly but also slightly more effective. This means that cost-effectiveness analyses are needed as robotic surgery has not been proven to be a widely dominant strategy compared to open or laparoscopic surgeries.

## 2. Methods and data

A Markov model was constructed to assess the cost-effectiveness of robot-assisted radical prostatectomy compared to laparoscopic radical prostatectomy for the treatment of localised prostate cancer. The model assumed the average patient to be a 65-year-old man, which was the average age of men who underwent LRP in Estonia in 2025. The exact age distribution of patients is presented in Appendix C (Estonian Health Insurance Fund, 2022). The model was programmed in TreeAge Pro Healthcare (2026). Data for input parameters was obtained from literature search, public health information and expert opinion (urologist from Tartu University Hospital, personal communication). The study was planned from the perspective of the Estonian Health Insurance Fund, the Social Insurance Fund and the patient. The latter two have been added as they also bear significant costs.

Since Estonia does not reimburse robotic surgery yet, input parameters for functional outcomes were obtained from the literature. A meta-analysis in the Estonian HTA report by Põld et al. (2026) showed no statistically significant difference in cancer markers between LRP and RARP, which matches other cost-effectiveness studies discussed in chapter 1.3. However, statistically significant differences in functional outcomes, urinary continence and erectile function, were found, which is why the model by Lindenberg et al. (2022) was taken as inspiration and modified to a Markov model. The model used in this article is shown in Figure 2. A 10-year time horizon was used because it is the lifetime of the robot. In addition to it being the lifetime of the robot, the disutility of ED and UI might be different in older age, but there are no good studies on the utilities by age category, which is why a conservative time horizon was chosen.

The model starts at surgery, after which a patient can go into one of 4 health states: "incontinent and impotent", "impotent", "incontinent" or "all good". The patient can choose to undergo treatment for UI in the first year post surgery, and if the treatment successful, will be cured of the condition and move to the "all good" or "impotent" health state. Impotence cannot be cured. The patient will cycle in the same health state for the remainer of the time until they die from background mortality unrelated to prostate cancer. If a person has either UI or ED, there are annual costs of either self-managing by using urinary pads or oral medications for temporary relief of ED. The overall mortality rate was implemented each year. Each health state has a utility value corresponding to the quality of one year of life spent in that health state, with 0 representing the utility at death.

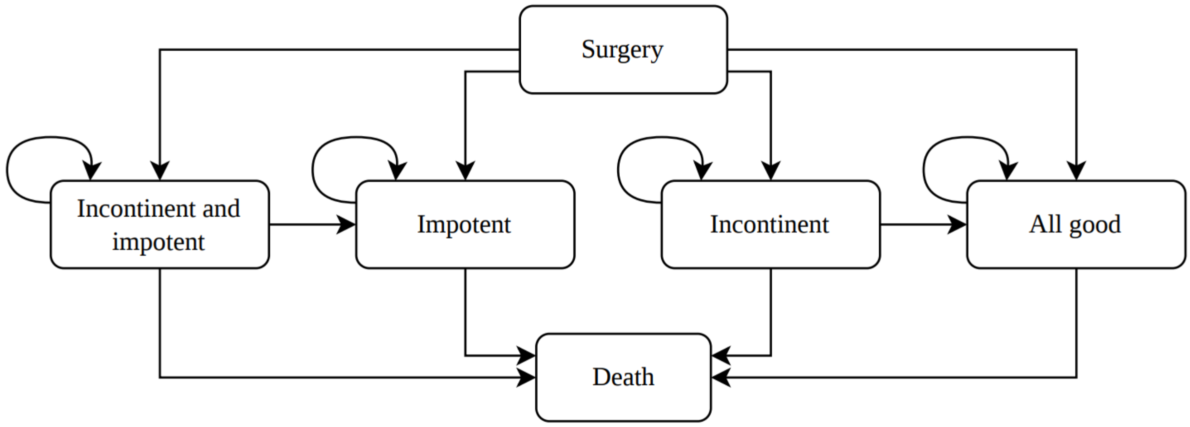


*Figure 2. Markov model.*

Table 3 presents the parameter values for the health states in the base-case analysis, deterministic sensitivity analysis (DSA) and probabilistic sensitivity analysis (PSA). The chosen utility values (0.83 for incontinence and 0.84 for impotence) have been used in multiple previous cost-effectiveness studies and are based on the study by Volk et al. (2004) that evaluated the utilities of health states after prostatectomy. If a person has both ED and UI, the utility values are multiplied to get 0.70. Probabilities for UI and ED after LRP were obtained from the literature, a 20% upper and lower value were used in the DSA and a beta distribution in the PSA. Risk ratios from the meta-analysis by Põld et al. (2026) were used to calculate similar probabilities in the case of RARP by multiplying LRP probabilities with the risk ratios. The effectiveness of interventions is usually measured with measures of associations. The risk ratio is a measure of the risk of an event happening in one group compared to the other group. (National Cancer Institute, 2011). The 95% confidence interval for risk ratios used in the DSA is given in the table and a gamma distribution was used in the PSA. According to the study by Zimmermann et al. (2025), 10-year mortality due to local prostate cancer in Estonia is under 1% (Zimmermann et al., 2025) while general population mortality rates are over 1% in the chosen population, which is why mortality rates by age and sex from Statistics Estonia (2025) were used (see Appendix D).

Table 3

*Parameter values for functional outcomes*

| Parameter | Base case | Deterministic sensitivity analysis | Probabilistic sensitivity analysis | Source |
|---|---|---|---|---|
| Utility | | | | |
| Incontinent | 0.83 | 0.664 – 0.9 | beta (139, 29) | (Volk et al., 2004) |
| Impotent | 0.84 | 0.672 – 0.9 | beta (141, 27) | (Volk et al., 2004) |
| All good | 0.9 | 0.72 – 0.95 | beta (283, 31) | (Korfage et al., 2005) |
| Probability for LRP | | | | |
| Incontinent | 23.5% | 18.8% – 28.2% | beta (869, 2828) | (Xu et al., 2024) |
| Impotent | 57.2% | 45.8% – 68.6% | beta (1770, 1324) | (Xu et al., 2024) |
| Risk ratio for RARP | | | | |
| Incontinent | 0.885 | 0.559 – 0.787 | gamma (350, 395) | (Põld et al., 2026) |
| Impotent | 0.662 | 0.806 – 0.971 | gamma (57, 86) | (Põld et al., 2026) |

Table 4 shows the data used for the treatment of functional outcomes. To determine the treatment of UI and ED in Estonia, expert opinion was included. 50% of men with UI were assumed to undergo treatment of UI and those with continued UI self-managed the leakage of urine with urinary pads. Of those 50% undergoing treatment, according to expert opinion, 70% get physiotherapy and 30% undergo a male sling surgical procedure. The artificial urinary sphincter implantation was excluded as only a few patients per year are treated with it. In Estonia, the Social Insurance Board covers 50% of the costs of incontinence pads (Social Insurance Board, 2026) but in the model, the full cost to both the patient and the public payer were added together. Incontinent patients were assumed to use 1-2 pads per day (Lindenberg et al., 2022; Ramsay et al., 2012) which is why the cost was calculated as 1.5 times the cost of 1 pad. The prices of the pads were obtained from the online store of Estonia's health-aid retailer *ITAK*. Sildenafil and tadalafil are the most common treatments for ED in Estonia (Agency of Medicines, 2025). They are not curative treatments for ED (McMurray et al., 2007) so the drugs to be taken an hour before sexual intercourse every time as curing ED by surgery is not common in Estonia. The cost of the drugs is solely on the patient as these are not reimbursed. The cost was calculated from the assumption of the average 65–75 year old male having sexual intercourse 18.2 times per year (calculated from Lõhmus et al. (2017)) and multiplying it by the average cost of one dose of medication. The male sling and physiotherapy costs were taken from the regulation by the Minister of Social Affairs, which determines the costs of each health service to the Estonian Health Fund. For physiotherapy, each man was assumed to have three 30-minute sessions.

Table 4

*The costs and treatment efficacy of functional outcomes*

| UI treatment | Percentage | Deterministic sensitivity analysis | Probabilistic sensitivity analysis | Source |
|---|---|---|---|---|
| Treatment rate | 50% | | | Expert opinion |
| of which physiotherapy | 70% | | | Expert opinion |
| of which male sling | 30% | | | Expert opinion |
| Success rate | 36.8% | 29.44 – 44.16 | beta (37, 63) | |
| of which physiotherapy | 23% | | | (Fernández et al., 2015) |
| of which male sling | 69% | | | (Constable et al., 2022) |
| UI treatment costs | Cost | | | |
| Cost of treating UI | €990.2 | | gamma (198, 25) | |
| of which 3× physiotherapy | €137.74 | | | (Minister of Social Affairs, 2026 redaction) |
| of which male sling | €2979.43 | | | (Minister of Social Affairs, 2026 redaction) |
| 1-2 pads a day annual cost | €383.25 | 142.35 – 383.25 | gamma (77, 25) | (*ITAK Terviseabivahendid [ITAK Health-aids]*, 2026) |
| ED treatment | Value | | | |
| Times used per year | 18.2 | | | (Lõhmus et al., 2017) |
| Cost per year | €79.55 | 0 – 79.55 | gamma (16, 25) | (*raviminfo.ee*, 2026) |

*Note: The prices were taken on 30.03.2026*

The cost of LRP in Estonia is €2930.94 (Minister of Social Affairs, 2026 redaction). As RARP is not reimbursed in Estonia yet, costs were calculated by taking the cost of LRP and adding the equipment cost of the robot and dividing it by 10 years (lifetime of the robot) and by 350, which according to doctors is the average needed annual amount for surgeries to be ensure treatment quality (Eilsen, 2025). The Estonian Health Insurance Fund does not discount costs when calculating average cost they reimburse to the hospitals, which is why this calculation approach was used. The exact calculations for the cost per procedure of the da Vinci robotic system are from the report by Põld et al. (2026). The cost structure is shown in Table 5.

Table 5

*The cost components of radical prostatectomy.*

| Type | Per surgery € | Source |
|---|---|---|
| LRP | 2931 | (Minister of Social Affairs, 2026) |
| RARP | 5947 | |
| of which acquisition cost of medical devices with useful life of more than 1 year | 935 | Põld et al. (2026) |
| of which annual licensing and maintenance cost | 466 | Põld et al. (2026) |
| of which single-use RP supplies cost | 2330 | Põld et al. (2026) |
| of which personnel, facility and service costs* | 2216 | (Minister of Social Affairs, 2026) |

*Note: * calculated from LRP costs*

## 3. Results and sensitivity analysis

The results of the base-case scenario are shown in Table 6. All costs and QALYs have been discounted with 3.5% rate. The incremental cost of robot-assisted radical prostatectomy compared to laparoscopic radical prostatectomy was €2825. The gain in QALY was 0.13. The ICER per QALY gained was €22,120. Since mortality due to localised prostate cancer is under 1%, from the two Estonian willingness-to-pay thresholds, a €20,000 willingness-to-pay threshold might be more appropriate and the calculated ICER was slightly above this. Meaning that with the base-case scenario, RARP is not cost-effective at a €20,000 threshold but is cost-effective by a large margin at a €40,000 threshold.

Table 6

*The results of the base-case analysis*

| Strategy | Cost | Incremental cost | QALY | Incremental QALY | ICER |
|---|---|---|---|---|---|
| LRP | €3926 | | 6.49 | | |
| RARP | €6752 | €2825 | 6.62 | 0.13 | €22,120 |

Figure 3 shows how patients progress through the health states after LRP and RARP surgeries. The percentage of patients with both UI and ED are lower after RARP. While after LRP the largest percentage of patients have ED, after RARP about half of the patients have no UI or ED complications. Due to overall mortality rates, 27% of patients will be dead in 10 years, which is why the percentage of patients in all other health states decreases annually. Table 7 presents the costs and QALYs associated with each year per patient generated by the Markov cohort simulation. The values show mean costs and outcomes for a hypothetical cohort of patients entering the model at time zero. The biggest part of the total cost is the cost of surgery in year one, in the next years higher costs are associated with self-management of incontinence and oral medications for ED. The decline in annual QALYs reflects the effect of postoperative dysfunctions and general population mortality over time.

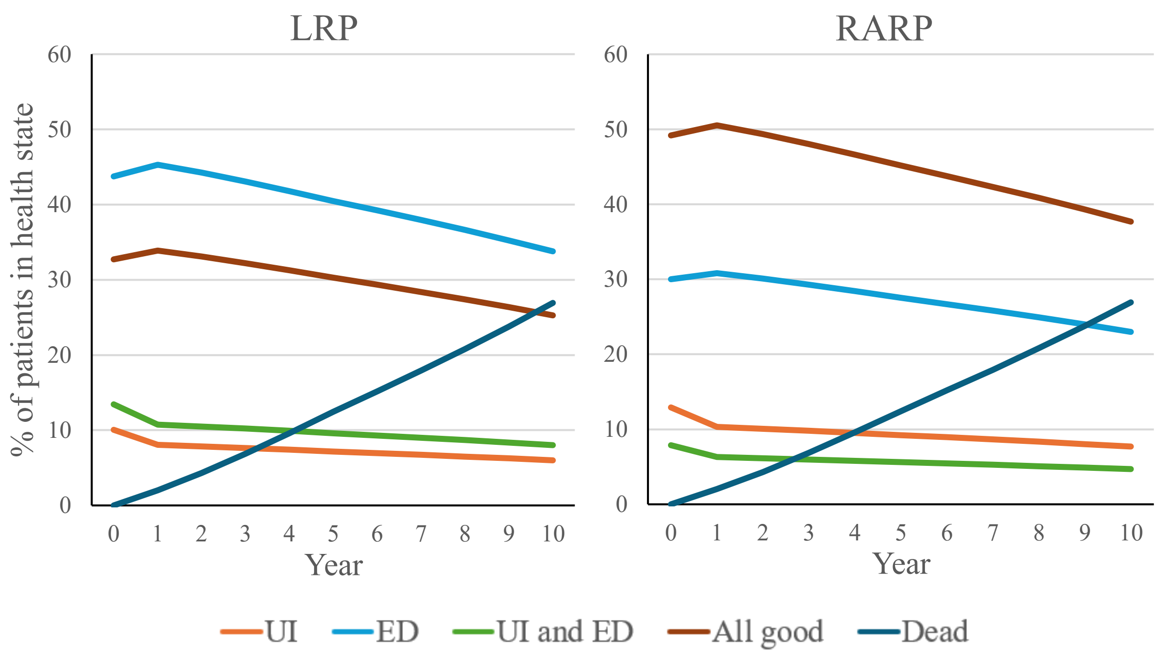


*Figure 3. Model patients moving through health states.*

Table 7

*Costs and QALYs in each year per average patient.*

| | LRP | | RARP | |
|---|---|---|---|---|
| Year | Costs | QALY | Costs | QALY |
| 0 | 3137.13 | 0.839 | 6119.50 | 0.857 |
| 1 | 111.83 | 0.799 | 89.54 | 0.815 |
| 2 | 105.42 | 0.754 | 84.42 | 0.769 |
| 3 | 99.07 | 0.709 | 79.34 | 0.723 |
| 4 | 92.84 | 0.665 | 74.36 | 0.678 |
| 5 | 86.88 | 0.622 | 69.59 | 0.635 |
| 6 | 81.28 | 0.582 | 65.10 | 0.594 |
| 7 | 75.93 | 0.545 | 60.82 | 0.555 |
| 8 | 70.74 | 0.508 | 56.67 | 0.518 |
| 9 | 65.71 | 0.472 | 52.65 | 0.481 |
| 10 | 0 | 0 | 0 | 0 |

After the base-case scenario, a deterministic sensitivity analysis was undertaken to see which parameters affect the ICER value most. For risk ratios and utilities, the lower and upper values used in the sensitivity analysis are given in Table 3. For the cost of treating ED and self-managing UI, the costs were lowered in sensitivity analysis to the amount the Estonian Health Insurance Fund would have to reimburse (as direct costs to the patient were included in the base-case scenario). For the cost of RARP surgery itself, the lower value €5527 applies to 500 surgeries a year with one robot and the higher value €9450 applies to of 100 annual surgeries (see calculation on page 23). Other parameters used were given 20% lower and higher values. The results are shown in Figure 4.

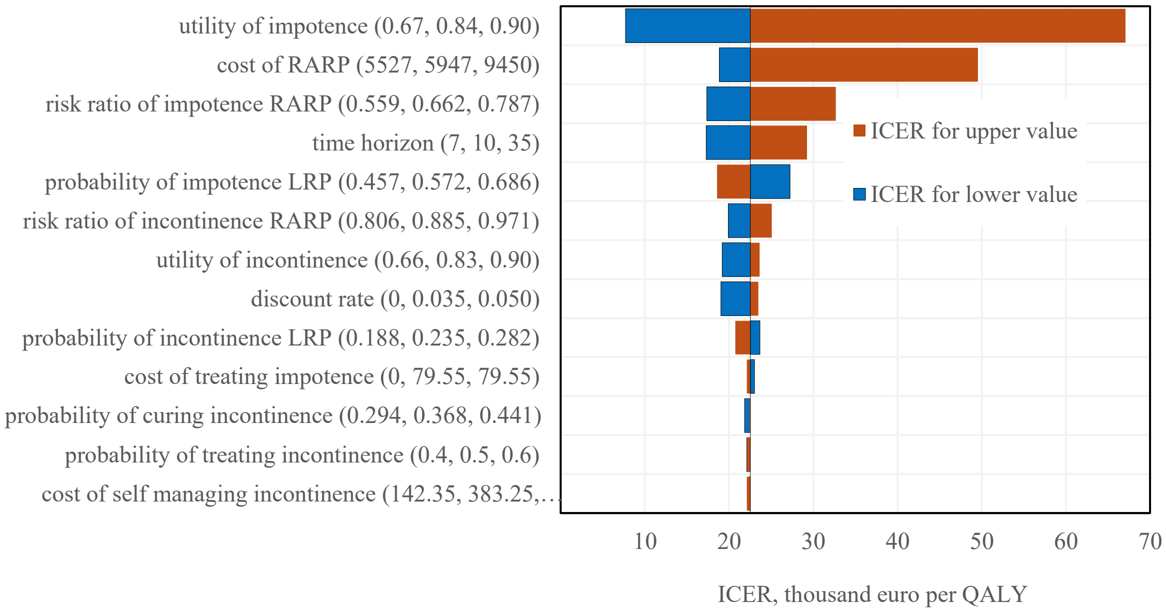


*Figure 4. ICER values in different sensitivity analysis scenarios.*

The biggest effect on the ICER value was the utility of impotence. With the lower value, ICER would be €7689 and with the upper value €67,084. The utility was calculated by Volk et al. (2004), and one limitation of the study was the mean age of men in the study being 54, while the mean age of men diagnosed with prostate cancer is higher. Additionally, a UK-based study by Guest and Das Gupta (2002) showed that while the quality of life of men with ED is significantly lower than that of those without it, the effect gets lower with age.

The second biggest impact on the ICER value was the cost of RARP surgery. If only 100 surgeries a year are performed with one robot, the ICER value would be €49,544, but with 500 annual surgeries, ICER would be €18,830.

ICER was not over €40,000 in any other scenario. It was lower than €20,000 for 5% discount rate, lower utility of incontinence, higher probability of impotence and lower risk ratio of impotence, but not under €17,350 for any of these parameters. For the time horizon, 7 years was used as the lower value in the sensitivity analysis since it is the lifetime of the robot used in some cost-effectiveness studies and 35 years was used as the upper value for a person's lifetime perspective. As impotence might not have a high effect for older men, the utility of impotence was set equal to the utility of a healthy person after 10 years. Even with that, the effect of the time horizon was the third largest, with a €17,297 ICER for the lifetime perspective and €29,251 for 7 years.

In the base-case analysis, for the utilities of both UI and ED, the utilities of the separate states were multiplied as there is no separate utility value from literature for both occurring together. As a worst-case dependency assumption, an additional sensitivity analysis was conducted so that the utility of both dysfunctions occurring was the lowest of the two, meaning the utility of incontinence. In that case, the ICER was €35350 per QALY gained. This shows that the choice of utility measures has a significant effect on the results.

All previous calculations have been done with the assumption of 350 surgeries per year with one robot. However, since the price of the robot depends on the volume of annual surgeries, additional analysis of the relationship between robot's price and annual surgery count is shown in Figure 5. As can be seen on the graph, the cost curve becomes smoother with more annual surgeries, suggesting that for robotic surgery to be efficient, a base volume of annual surgeries should be met.

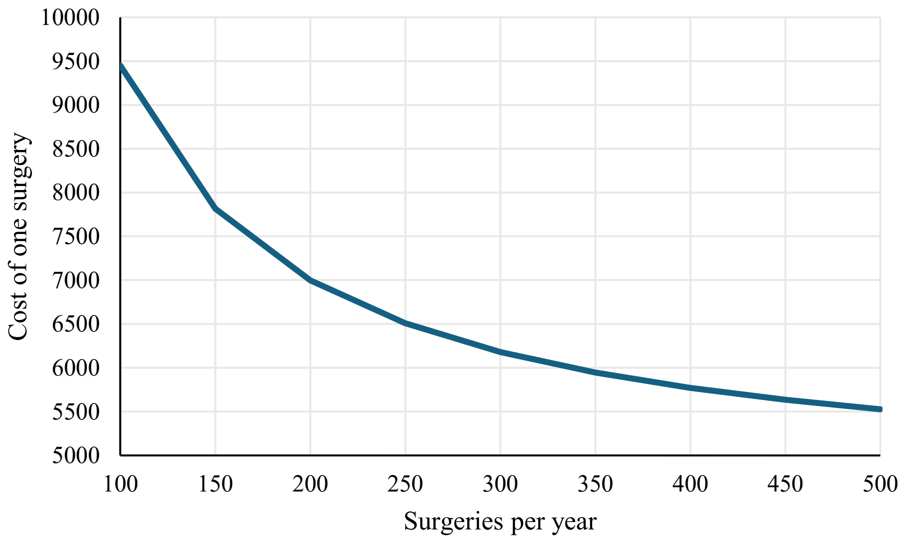


*Figure 5. The cost of one RARP surgery depending on the amount of surgeries per year.*

Figure 6 shows how ICER changes with different prices for robot-assisted radical prostatectomy. With the €20,000 threshold, RARP becomes cost-effective when its cost is less than €5676. This means at least 434 surgeries a year with one robot would have to be performed. ICER exceeds €40,000 when price of RARP is over €8231, which is the price in the case of less than 133 annual surgeries. Adding together the information on Figures 5 and 6, if at least 150 surgeries a year are performed, then the ICER is under €40,000 per QALY gained.

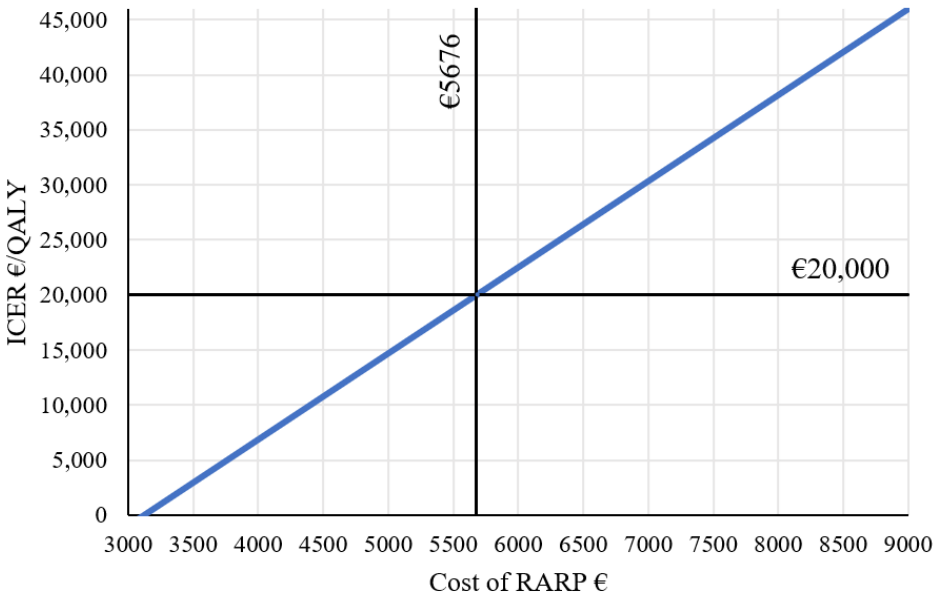


*Figure 6. ICER values with different RARP costs.*

In addition to deterministic sensitivity analysis, a probabilistic one was conducted. Each parameter was assumed to have a probability distribution (see Tables 2 and 3), and Monte Carlo simulation was used to sample 10,000 values for all parameters. Figure 7 shows the results on the cost-effectiveness plane. The green points represent all values where ICER was below €20,000, the yellow points represent values between €20,000 and €40,000 and red points above €40,000. 45.2% of the iterations are under €20,000, and 63.3% are under €40,000. There were 2 dominated iterations and 4 dominating iterations. Additionally, the cost-effectiveness acceptability curve can be seen in Figure 8. Once the willingness-to-pay was over €22,500, RARP became more cost-effective than LRP. The probability of RARP being cost-effective compared to LRP at a €20,000 willingness-to-pay threshold was 43% and at a €40,000 threshold it was 82%.

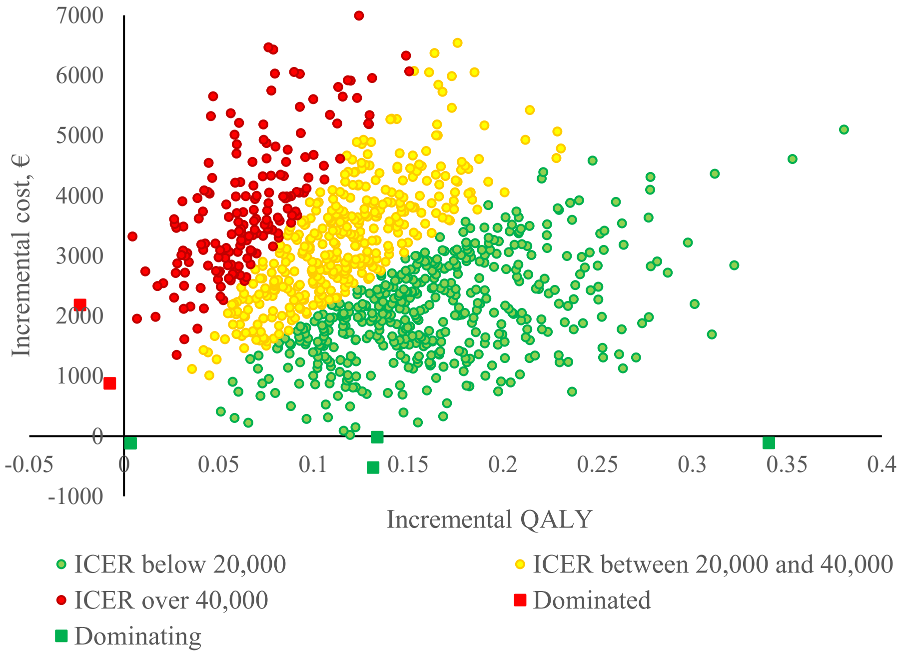


*Figure 7. Cost-effectiveness plane.*

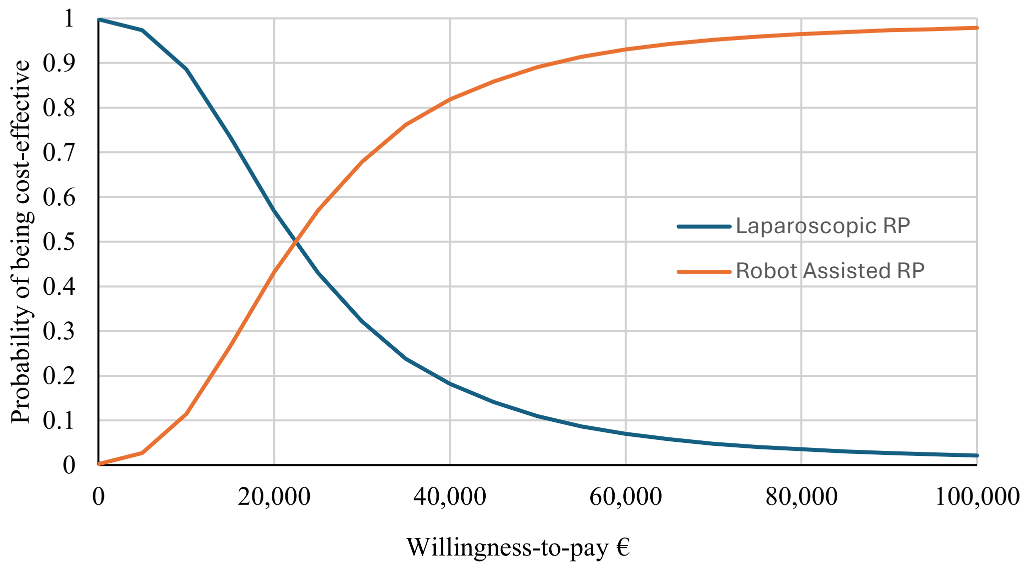


*Figure 8. Cost-effectiveness acceptability curve.*

In the next section, a budget impact analysis for the Estonian Health Insurance Fund will be done to determine whether robotic surgery should be reimbursed. The analysis will be done with the assumption of robotic surgery being in full optimal use. After removing direct costs to the patient and the Social Insurance Board, the incremental cost per surgery for RARP was €3056. In 2025, 368 laparoscopic radical prostatectomies were done in Estonia. If all of these were to be replaced by robot-assisted radical prostatectomies, the budget impact would be 1.12 million euros to the Estonian Health Insurance Fund.

If robotic surgery is reimbursed, not only prostatectomy but other surgeries would be done with it as well. In 2025, 2017 surgeries were done in total, which could theoretically be replaced with the da Vinci robot (see Appendix E). Since all these surgeries have their own specific equipment, whose cost is not the same as for prostatectomy, the exact budget impact cannot be determined with full certainty. However, assuming similar additional costs as with prostatectomy, if all 2400 were to be replaced by a robot, the budget impact would be 7.33 million euros a year.

Not all surgeries will realistically be replaced by a robot. When looking by hospital, there are 4 hospitals over Estonia which could achieve a volume of 350 surgeries per year (Estonian Health Insurance Fund, 2022). With the conservative approach of 1 machine per hospital, the additional budget impact is shown in Table 8. The calculations have been done using the different costs in Figure 5, with the cost per surgery decreasing with the number of annual surgeries. With the base case of 350 surgeries per year, the budget impact would be 4.22 million euros a year for 4 robots in all of Estonia.

Table 8

*Budget impact with the assumption of 4 robots total in Estonia.*

| Nr of annual surgeries with one robot | 100 | 150 | 200 | 250 | 300 | 350 | 400 | 450 | 500 |
|---|---|---|---|---|---|---|---|---|---|
| Budget impact (million €) | 2.61 | 2.93 | 3.25 | 3.58 | 3.90 | 4.22 | 4.55 | 4.87 | 5.19 |

## 4. Discussion

In the next section, discussion will follow on aspects of robotic surgery that could not be incorporated into the model. When considering the appropriate ICER threshold or whether robotic surgery should be reimbursed in Estonia, it is important to recognise that robotic surgery is not only an intervention for prostate cancer treatment. This thesis only considers radical prostatectomy. However, if robotic surgery is reimbursed in Estonia, it would be used more widely in other surgeries as well. Otherwise, the volume of surgeries needed to be cost-efficient will not be achieved. At the same time, the health benefits and specific costs vary between surgeries which is why the real value of robotic surgery to the health system as a whole is difficult to estimate.

The exact number of radical prostatectomies that would be performed with a robot each year is difficult to predict. Not all surgeries performed today will completely be replaced with robotic surgery. For example, smaller hospitals will not achieve the necessary annual number of surgeries to be efficient. With robotic surgery becoming available, it might influence patient treatment choices. According to the clinical expert consulted, patients with prostate cancer have the option to choose whether they want to have radical prostatectomy or undergo radiation therapy. With RARP showing better functional outcomes, some patients may opt for it instead of radiation. As radiation therapy is more expensive than RARP, robotic surgery could even have the impact of reducing healthcare expenses.

With all new technologies, implementation takes time. If the reimbursement decision is made, the Estonian Health Insurance Fund will set a reimbursement cost it will pay to the hospital for one surgery. In the first few years, the optimal volume of 350 surgeries a year will probably not be met as surgeons need time to learn the new technology and optimal usage of the robot will develop over time. Appendix F demonstrates the calculations of how failing to achieve 350 annual surgeries may leave the hospital operating a deficit. For example, if a hospital performs 100 surgeries annually, the Estonian Health Insurance Fund will reimburse the hospital the price of €5947 per surgery based on optimal usage. The actual cost for the hospital is €9449 per surgery, resulting in a deficit of €350,250 for the year for the hospital.

One of the main reported benefits of robotic surgery is surgeon comfort. Since traditional HTA methods only allow incorporating the health benefits of the patient, this analysis does not account for the improved health of the surgeon. Lindenberg et al. (2022) in their cost-effectiveness analysis incorporated ergonomic differences between RP methods by using costs per surgeon having sick leave in the model. According to expert opinion this approach would not be applicable from the Estonian perspective as surgeons generally do not take sick leaves for back pain. However, they do end their careers early due to physical strain. This factor could not be added to the cost-effectiveness analysis, but it is an important benefit of robotic surgery.

While this thesis focused on the current state of robotic surgery, Chatterjee et al. (2024) discuss its greater future potential with technological advancements. Artificial intelligence and machine learning today are rapidly developing, and robots are being trained to recognise complications and assist decision making during surgery. Additionally, robotic surgery has the potential to be performed remotely, a method known as teleoperation technology. This could reduce geographical limitations and give access to specialised healthcare for less common surgical procedures.

In addition to considering its potential cost-effectiveness, robotic surgery also has the value of technological innovation. Keeping up with technical advancements is important so that Estonia can provide patients with modern treatments and high-quality care. Robotic surgery is already widely available in many other European countries and according to expert opinion, some surgeons may refuse to work if there isn't a robot available at the hospital.

## Conclusion

This study found that RARP in Estonia would have an ICER of €22,120, which falls between the two thresholds used: €20,000 and €40,000 per QALY gained. Although the ICER value was slightly over the lower threshold, the discussion highlights that robotic surgery has benefits that cannot be incorporated into traditional health technology assessment methods. Taking these extra aspects into account, robot-assisted radical prostatectomy could be considered cost-effective in Estonia.

This analysis was conducted with the assumption of at least 350 surgeries per year, and the results depend strongly on surgical volume, which determines price per surgery. This means that robotic surgery can be cost-effective only at hospitals that can guarantee a certain volume of surgeries. If a hospital can achieve over 434 annual surgeries, the ICER value will fall below €20 000, making it cost-effective. The findings are consistent with previous literature, which has shown that while RARP is expensive, it is in accordance with the health benefits and should be considered.

The analysis was conducted assuming the optimal usage of robotic surgery. It does not consider the learning curve associated with the adoption of new technologies. In the discussion section, the hospitals were shown to potentially run a short-term financial deficit at first due to the Estonian Health Insurance Fund reimbursing the cost of the surgery based on calculations done on optimal use of the robot. Additionally, the hospital will have to train surgeons for these new surgeries, which will take time and financing at early stages of implementation. The surgeries might not be most efficient at first, taking more time and surgeons not being as skilful. This means that the benefits of robotic surgery might not be seen in the first few years. As literature does show a slight decrease in perioperative and postoperative complications, the benefits might emerge in the long perspective.

The study does have some aspects that were not added into the model but might impact the results. First, while the utility of impotence was in line with previous studies, the effect of it may be overestimated, as on average prostate cancer patients are men over 65. On the other hand, the time frame of 10 years might underestimate the burden of urinary incontinence that will persist for the remainder of the patient's life. This was supported with the longer time perspective used in sensitivity analysis, which lowered the ICER to €17,297 per QALY gained. Overall, clinical data is always at risk of bias and uncertainty due to subjective measurements and selection bias.

Second, while not statistically significant, robotic surgery has been shown to somewhat reduce postoperative complications and biochemical recurrence of cancer. If true, this would lower ICER even more. Due to no statistically significant evidence, these effects were not considered in the model. This means the results are from a conservative approach and the true ICER would likely be even lower than in this analysis. The average age of prostatectomy patients in Estonia is 65, which is retirement age. This means that for the average patient, inability to work due to cancer does not reduce their income. Nevertheless, as shown in Appendix C, there are 150 patients under 65, including approximately 70 patients under 60. While UI and ED may not have a big effect on ability to work, the possibility of reduction in recurrence of cancer might carry socioeconomic benefits.

Overall, this thesis contributes to the existing literature by providing further evidence regarding the potential of robotic surgery to be cost-effective. As previous literature has shown differing results, policymakers need to approach the results with caution and consider wider implications. Simply looking at the ICER value is not enough to make a decision on adopting and reimbursing robotic surgery, additional benefits of improved surgeon ergonomics and the value of technological innovation must be considered.

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# Appendix A
## Systematic literature search keywords

The following keywords with Boolean operators were used on PubMed on 29.01.2026:

("Robotic Surgical Procedures"[MeSH Terms]) AND ("Prostatectomy"[MeSH Terms] OR "robot-assisted radical prostatectomy"[Title/Abstract] OR "robotic prostatectomy"[Title/Abstract]))) AND (((cost AND effectiveness) OR cost-effectiveness OR (cost AND utility) OR cost-utility OR (economic AND evaluation) OR (economic AND burden) OR (cost AND benefit) OR cost-benefit OR (cost AND efficiency) OR "Cost-Benefit Analysis"[MeSH Terms]))

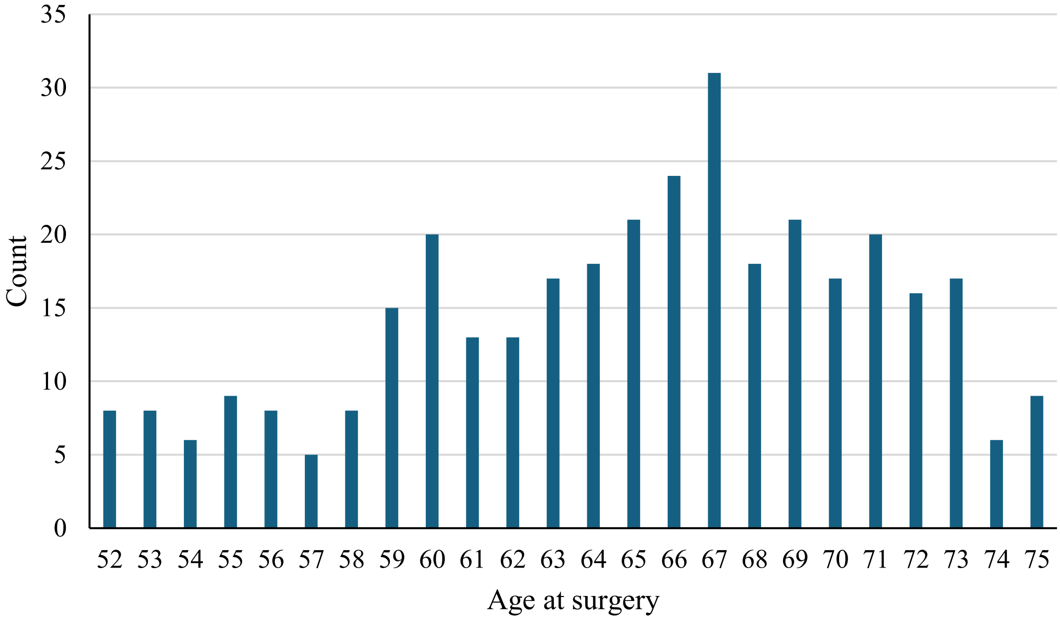
## Appendix B

## Types of costs included in previous cost-effectiveness analyses

| Authors | Ramsay et al. | Cooperberg et al. | Ratchanon et al. | Lindenberg et al. | Faria et al. | Labban et al. |
|---|---|---|---|---|---|---|
| Year | 2012 | 2013 | 2015 | 2022 | 2022 | 2022 |
| Country | the UK | USA | Thailand | the Netherlands | Brazil | the UK |
| Surgery costs | + | | + | + | + | + |
| Surgical complications | + | + | | + | | + |
| ED treatment | + | + | | + | | + |
| Incontinence treatment | + | + | | + | | + |
| Surveillance | + | + | | | + | + |
| Biochemical recurrence | | + | + | | + | + |
| Metastasis treatment | | + | | | + | + |
| Urinary pad use | + | | + | + | | |
| ED medicine use | + | | + | + | | |
| Surgeons sick leave due to neck/back pain | | | | + | | |

**Appendix C**

**Prostatectomies by age in 2025 in Estonia**




Source: (Estonian Health Insurance Fund, 2022)

## Appendix D

## Mortality rates by age for men in Estonia

| Age | Mortality rate |
|---|---|
| 65 | 0.02032 |
| 66 | 0.0233 |
| 67 | 0.02653 |
| 68 | 0.02942 |
| 69 | 0.0314 |
| 70 | 0.0315 |
| 71 | 0.03237 |
| 72 | 0.03505 |
| 73 | 0.03733 |
| 74 | 0.04144 |
| 75 | 0.05094 |
| 76 | 0.04480 |
| 77 | 0.06294 |
| 78 | 0.05378 |
| 79 | 0.06688 |
| 80 | 0.07262 |
| 81 | 0.06613 |
| 82 | 0.08161 |
| 83 | 0.08581 |
| 84 | 0.09849 |
| 85 | 0.09952 |
| 86 | 0.11866 |
| 87 | 0.11886 |
| 88 | 0.14323 |
| 89 | 0.17386 |
| 90 | 0.16115 |
| 91 | 0.17444 |
| 92 | 0.20063 |
| 93 | 0.22842 |
| 94 | 0.26939 |
| 95 | 0.27893 |
| 96 | 0.34259 |
| 97 | 0.32117 |
| 98 | 0.25000 |
| 99 | 0.40909 |
| 100 | 0.43077 |

Source: (Statistics Estonia, 2025)

## Appendix E

## Estonian codes of surgeries that can be replaced by a robot

Urology: 1K2210, 1K2222, 1K2223, 1K2227, 1K2209, 1K2220 ,1K2236, 1K2214

General surgery: 0J2214, 0J2215, 0J2201, 0J2202, 0J2203, 0J2210, 0J2218, 0J2206, 0J2207, 0J2208

Thoracic surgery: 80401, 80402, 80404, 100403, 90404, 1G2103, 80403, 90402, 40402, 30401, 40403

Gynaecology: 1L2214, 1L2210, 1L2208, 1L2215, 1L2133.

Otorhinolaryngology: 1E2172

Source: (Eesti Kirurgide Assotsiatsioon [Estonian Association of Surgeons], 2025)

## Appendix F

**Cost of 100 annual surgeries from the hospital's perspective**

| | Cost of one RARP surgery | Amount covered by the EHIF* | Total cost to hospital | Deficit to hospital |
|---|---|---|---|---|
| Cost calculated from assuming 100 annual surgeries | 9449.53 | 594,703 | 944,953 | -350,250 |
| Cost calculated from assuming 350 annual surgeries | 5947.03 | 594,703 | 594,703 | 0 |

*Note: * EHIF – Estonian Health Insurance Fund.*

**Resümee**

ROBOTKIRURGIA KULUTÕHUSUS LOKAALSE EESNÄÄRME VÄHIS EESTIS

Paula Timmi

Magistritöös hinnati robot-assisteeritud radikaalse prostatektoomia (RARP) kulutõhusust võrreldes laparoskoopilise radikaalse prostatektoomiaga (LRP) lokaalse eesnäärmevähi ravis Eestis. RARP on kallim protseduur kui LRP, kuid sellega kaasneb väiksem tõenäosus operatsioonijärgse uriinipidamatuse ja/või erektsioonihäirete tekkeks. Analüüsis loodi 10-aastase ajaperspektiiviga Markovi mudel, eeldades 350 operatsiooni aastas ühe robotiga. Tulemuseks arvutati täiendkulu tõhususe määr (ICER, ingl k *incremental cost-effectiveness* ratio) 22 120 eurot lisanduva kvaliteetse eluaasta (QALY, ingl k *quality-adjusted life year*) kohta. Eestis on kasutusel kulutõhususe piirmäär 20 000 € kergemate haiguste ja 40 000 € elulõpuhaiguste korral, seega tulemus jääb nende kahe piiri vahele. Järgnes tundlikkuse analüüs, mille tulemused näitasid, et 63% Monte Carlo simulatsiooni iteratsioonidest jäi alla 40 000 € piiri ja 45% iteratsioonidest alla 20 000 € piiri. Kulutõhususe piirmäära tõustes üle 22 500 € muutub RARP kulutõhusaks võrreldes LRP-ga.

Aastal 2025 tehti Eestis 368 LRP operatsiooni. Kui kõik need robotiga asendada, oleks eelarvemõju ligikaudu 1,12 miljonit eurot. Kui robotkirurgia oleks Tervisekassa poolt kompenseeritav, ei piirduks robotiga tehtavad operatsioonid vaid prostatektoomiaga. Kokku tehti 2025. aastal 2400 operatsiooni, mida oleks võimalik asendada robotiga. Sellisel juhul oleks eelarve mõju ligikaudu 7,33 miljonit eurot aastas.

Töö käsitles kulutõhusust klassikalise tervisetehnoloogiate hindamise metoodika alusel. Seega ei olnud võimalik arvestada mõningate robotkirurgia eelistega nagu väiksem füüsiline koormus kirurgidele ning tehnoloogilise innovatsiooni laiem väärtus.

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