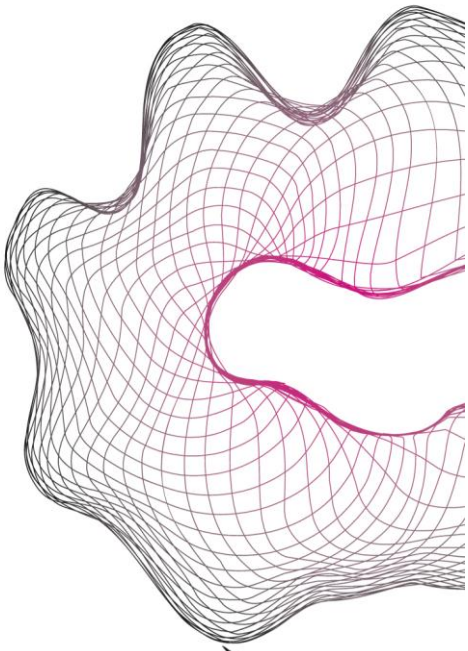

THE CORE PROCEDURES OF BRACHYTHERAPY

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Nucletron
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Foreword

This is the result of our bachelor assignment of the Bachelor programme Health Sciences at the University of Twente, which we have been working on for more than two months in a group of four students. During these two months we have seen, heard and learned a lot about brachytherapy, in particular brachytherapy in patients with prostate cancer and gynecological cancer. Because of our background and personal preferences for the medical branch, this assignment commissioned by Nucletron BV, was a great opportunity to take a look at this impressive world. With this research we hope to have contributed to the improvement of the insights in costs of brachytherapy, by identifying the core procedures of LDR BT and HDR BT in patients with prostate cancer and HDR BT in patients with gynecological cancer, time spent per staff member and resources needed in conducting these core procedures.

We would like to thank our supervisor dr. L.M.G. Vrijhoef-Steuten from the University of Twente for her enthusiasm and flexible way of guidance. Also we would like to thank H. Monteban, our external supervisor at Nucletron BV, and dr. Anne Bijlstra for their commitment to our research. Also we would like to thank the medical staff of RISO, ARTI and UMCU, who participated in the different interviews, for their time and effort. Special thanks to RISO, since we were given the opportunity to observe during several treatments of HDR and LDR brachytherapy. This has enriched our understanding of and insight in the different treatments of brachytherapy.

Enschede, July 2nd, 2012

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Summary

Introduction Rising healthcare costs and a new reimbursement system for hospital care in the Netherlands have increased the focus on healthcare costs. In order to make informed decisions regarding allocations of scares resources to cancer treatments such as brachytherapy, an important first step is the identification of the core procedures of brachytherapy and an inventory of the resources associated with this treatment. The research question of this prospective multicenter study therefore is: how much time, attendance of medical staff and resources are needed for conducting the core procedures of LDR BT and HDR BT in patients with prostate cancer (and in addition patients with gynecological cancer)? This study has focused upon the prostate as body site, because prostate cancer is the most common cancer in men and can be treated with both forms of brachytherapy. And since the opportunity has arisen and HDR BT is a standard procedure for gynecological cancer, gynecological cancer has also been included.

Methods The main research question has been addressed by performing a prospective multicenter study in which qualitative and quantitative methods have been combined. Two private radiotherapy institutes, RISO in Deventer and ARTI in Arnhem, and the University Medical Center in Utrecht participated in the study, which has been carried out in May and June 2012. The core procedures associated with LDR BT en HDR BT in patients with prostate cancer and HDR BT in patients with gynecological cancer have been identified in a first round of inventory interviews. During follow-up interviews the duration of these core procedures, the time spent per medical staff member, and the resources needed have been identified. Finally, during observations, additional data about the duration of the core procedures and the time spent by the medical staff members has been derived.

Results Three models, which present the core procedures of LDR BT in prostate cancer, HDR BT in prostate cancer and HDR BT in gynecological cancer, have been developed (Figure 2, 4 and 6). The treatment processes of LDR BT and HDR BT in prostate cancer and HDR BT in gynecological cancer consist of 15, 16 and 18 core procedures respectively. According to the follow-up interviews, the total duration of LDR BT is not very different with HDR BT for prostate cancer (a median of 558 versus 579 minutes, respectively). The results on the time spent per medical staff member and the resources needed in conducting these core procedures are shown in Table 2 to 11.

Conclusion and Discussion Regarding the core procedures of LDR BT and HDR BT, it can be concluded that despite the difference in the number of core procedures and the differences on a more detailed level, LDR BT and HDR BT also have many similarities on a more general level. Based upon the information from the follow-up interviews it can be concluded that the core procedures that take place outside the operation room are the most

time consuming in LDR BT, while the core procedures that take place inside the operation room are the most time consuming in HDR BT in prostate cancer. When comparing HDR BT in gynecological cancer to HDR BT in prostate cancer it appears that the total duration of all the core procedures in HDR BT in gynecological cancer is much higher than in HDR BT in prostate cancer. The total times of LDR BT and HDR BT in prostate cancer are quite comparable. Furthermore, the resources used for HDR BT and LDR BT appear to be mainly similar to each other. Recommendations on the favorability of any of the treatment modalities can be made based on researches that determine the costs of the several procedures and staff. The models for the core procedures and the inventory of the duration of core procedures, attendance of medical staff involved and resources needed as presented in this research can be used as a guideline for this cost estimation and also are of particular importance for compiling the content of the DTC's (Diagnosis Treatment Combinations) that are applicable for brachytherapy. The most important weakness of the current study is the fact that the results are based on interviews with medical professionals from only three different radiotherapy centers and interviews were not held with all involved staff.

Samenvatting

Inleiding De stijgende kosten van de gezondheidszorg en het nieuwe vergoedingensysteem voor ziekenhuiszorg hebben geleid tot toenemende aandacht voor de kosten van de gezondheidszorg. Om weloverwogen beslissingen te kunnen nemen over de toewijzing van schaarse hulpbronnen in de behandeling van kanker door middel van brachytherapie, is het identificeren van de kernprocedures van brachytherapie en het inventariseren van het benodigde personeel en de benodigde materialen een belangrijke eerste stap. De onderzoeksvraag van dit onderzoek is dan ook: hoeveel tijd en aanwezig van medisch personeel en materialen zijn nodig voor het uitvoeren van de kernprocedures van LDR en HDR brachytherapie bij patiënten met prostaatkanker (en gynaecologische kanker)? Dit onderzoek heeft zich gericht op prostaatkanker, aangezien prostaatkanker de meest voorkomende vorm van kanker is bij mannen en behandeld kan worden met beide vormen van brachytherapie. Aangezien de mogelijkheid zich voordeed en HDR brachytherapie een standaardbehandeling is bij gynaecologische kanker, is ook gynaecologische kanker meegenomen.

Methode De onderzoeksvraag is beantwoord door middel van een prospectief multicenter onderzoek waarin kwalitatieve en kwantitatieve onderzoeksmethodes zijn gecombineerd. Twee privéklinieken voor radiotherapie, RISO in Deventer en ARTI in Arnhem, en het Universitair Medisch Centrum in Utrecht hebben deelgenomen aan het onderzoek dat is uitgevoerd in de maanden mei en juni 2012. De kernprocedures van LDR BT en HDR BT bij patiënten met prostaatkanker en HDR BT bij patiënten met gynaecologische kanker zijn in kaart gebracht door middel van een eerste ronde inventariserende interviews. Gedurende vervolg interviews zijn de duur van deze kernprocedures, de tijdsbesteding van de verschillende medische professionals en de benodigde materialen in kaart gebracht. Tot slot is door middel van observaties aanvullende informatie verkregen over de duur van de kernprocedures en de tijdsbesteding van de medische professionals.

Resultaten Er zijn drie modellen ontwikkeld die de kernprocedures van LDR BT bij patiënten met prostaatkanker, HDR BT bij patiënten met prostaatkanker en HDR BT bij patiënten met gynaecologische kanker weergeven (Figuur 2, 4 en 6). Het behandelproces van LDR BT en HDR BT bij patiënten met prostaatkanker en HDR BT bij patiënten met gynaecologische kanker bestaat uit respectievelijk 15, 16 en 18 kernprocedures. Volgens de resultaten uit de vervolginterviews verschilt de totale duur van LDR BT niet veel van die van HDR BT bij patiënten met prostaatkanker (de mediaan is respectievelijk 558 en 579 minuten). De resultaten van de tijdsbesteding van de medische professionals en de benodigde materialen zijn weergegeven in tabel 2 t/m 11.

Conclusie en Discussie Wat betreft de kernprocedures van LDR BT en HDR BT kan geconcludeerd worden dat, ondanks het verschil in het aantal kernprocedures en de verschillen op gedetailleerd niveau, LDR BT en HDR BT in het algemeen veel overeenkomsten vertonen. Aan de hand van de interviews kan geconcludeerd worden dat bij LDR BT de kernprocedure die plaatsvinden buiten de operatie kamer de meeste tijd in beslag nemen, terwijl bij HDR BT bij prostaat kanker de kernprocedures die plaatsvinden in the operatie kamer de meest tijd in beslag nemen. Wanneer we HDR BT bij gynaecologische kanker vergelijken met HDR BT bij prostaat kanker dan blijkt dat het proces van HDR BT bij gynaecologische kanker veel langer duurt dan het proces van HDR BT bij prostaat kanker. De totale duur van LDR BT en HDR BT bij prostaat kanker is vergelijkbaar. Verder blijken de materialen die nodig zijn voor HDR BT en LDR BT ook voor het grootste gedeelte met elkaar overeen te komen. Aanbevelingen over de voorkeur voor een van beide behandelingsvormen kunnen worden gedaan op basis van onderzoek dat de kosten van de verschillende procedures en het betrokken personeel in kaart brengt. De modellen voor de kernprocedures en de inventarisaties van de duur van de kernprocedures, de betrokkenheid van medisch personeel en de benodigde materialen die gepresenteerd zijn in dit onderzoek, kunnen bij zulk onderzoek dienen als richtlijn voor het bepalen van de kosten en zijn bovendien van groot belang voor het opstellen van de inhoud van DBC’s die van toepassing zijn op brachytherapie. Het belangrijkste zwakke punt van dit onderzoek is het feit dat de resultaten gebaseerd zijn op interviews met medische professionals van slechts drie radiotherapeutische centra en dat er geen interviews gehouden zijn met al het betrokken personeel.

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1. Introduction

The incidence of cancer is rising. In the Netherlands, for example, there were more than 95,000 new cases of cancer diagnosed in 2010. This is partly due to better diagnostics and aging of the population. In elderly men (45 years or older), prostate cancer is the most prevalent form of cancer. In 2010, there were more than 10,000 newly diagnosed cases of prostate cancer in the Netherlands (IKNL, 2011).

Together with surgery and chemotherapy, radiotherapy has long been an important treatment modality for cancer. Radiotherapy alone has been proved to be effective when used in early stages of prostate cancer (Connell & Hellman, 2009). Also, it is used in combination with chemotherapy and surgery. Nevertheless, there is no recommended standard therapy for prostate cancer. In 2015, it is expected that about 50 per cent of all cancer patients will be treated with radiotherapy (NVRO, 2007).

Radiotherapy can be divided in external beam radiation therapy (*EBRT*) and brachytherapy (*BT*). Unlike EBRT, which delivers external radiation towards the tumor through healthy tissue, brachytherapy delivers the radioactive dose directly within or adjacent to the tumor. The tumor is being tackled “from the inside, out”, rather than “from the outside, in” (Nucletron, nd (a)). There are different techniques of brachytherapy in use for prostate cancer; the two most frequently used techniques are low dose rate brachytherapy (*LDR BT*) and high dose rate brachytherapy (*HDR BT*).

In LDR BT for the prostate, radioactive seeds are being permanently implanted within the prostate tumor using specially designed needles. By using imaging techniques a plan is made to determine where to place the strands with radioactive seeds, so that the tumor is best covered. LDR BT is a minimally invasive procedure that can be used as an outpatient treatment under spinal or general anesthesia (Peinemann, et al., 2011). LDR brachytherapy is being offered in several hospitals and radiotherapy institutes in the Netherlands.

On the other hand, HDR BT uses temporary implantation of a radioactive source to deliver the dose to the targeted area, using specially designed needles or catheters. The source, which has a higher dose rate than LDR BT, is being delivered via a remote afterloading system. After the treatment, the source is being transferred back into the afterloading system. The combination of a modern planning system and sophisticated imaging provides accurate source delivery (Nucletron, nd (b)). Currently, RISO in Deventer is the only institute in the Netherlands that offers HDR BT in patients with prostate cancer.

Although there is a lack of knowledge on the clinical effectiveness of brachytherapy, the studies that have been published show a comparable effectiveness with EBRT for cancer in general (Norderhaug, et al., 2003). For prostate cancer, more recent studies show generally comparable effectiveness on the different treatment options available (ICER, 2010).

1.1 Motivation for current study

Health care expenditures are rising all over the world. In the Netherlands, health care spending is expected to rise from 13.2% to 22% of the GDP from 2010 to 2040 (van der Horst, van Erp, & de Jong, 2011). Next to an aging population and the higher demands of patients, technological changes can be accountable for a large part of these rising health care expenditures (Schreyögg, Bäumer, & Busse, 2009). These developments have led to a greater emphasis on the costs of health care. Due to this greater emphasis on costs also the costs related to brachytherapy have become especially relevant.

On a more local level, hospitals have a rising interest in the costs of therapies since the introduction of performance based reimbursement in Dutch healthcare. Hospitals are being reimbursed by means of DTCs. A DTC (*Diagnosis Treatment Combination*) includes all the medical activities performed by the hospital per patient, from the first consultation until the final check-up (NZa, 2011). The reimbursement system is divided into two segments: the A-segment with fixed prices and the B-segment with free prices. Since January 2012, the part of hospital care that belongs to the segment with free prices has increased from 34% to 70% (NZa, 2011). Since then, also brachytherapy is part of the B-segment (NVZ, n.d.). The free prices in the B-segment mean that for these treatments the government no longer determines the rates, but that the rates are achieved through agreements between insurers and care providers. In order to achieve the most beneficial agreements, care providers can strengthen their negotiating position against insurers by gaining insights in the costs of a certain DTC. This also holds for the costs of DTCs related to brachytherapy.

The resources, i.e. disposables and non-disposables, related to brachytherapy are an important factor in determining the costs of brachytherapy. Another important factor in determining the costs of brachytherapy is the time required by the various professional groups involved before, during and after treatment. Although there are several recommendations on the times that professionals should spend to treat a specific number of patients with radiotherapy, none of the recommendations are based on actual measurements (Slotman, Cottier, Bentzen, Heeren, Lievens, & van den Bogaert, 2005). Thus, in order to be

able to give adequate recommendations, data is necessary about the time needed for each core procedure of the different brachytherapy techniques. For this purpose, first an identification of the core procedures is required.

In conclusion, there are two reasons that argue the need for identification of the core procedures of brachytherapy and the related attendance of medical staff and use of resources, in order to be able to gain more insight in the costs. First, there is a rising emphasis on health care resource use due to the increase in health care spending. Second, the introduction of free prices in hospital funding has led to negotiations between insurers and care providers, which leads to a rising emphasis on costs.

1.2 Objectives and research question

This study has focused upon the prostate as body site, because prostate cancer is the most common cancer in men and can be treated with both forms of brachytherapy. Since the opportunity has arisen and HDR BT is a standard procedure for gynecological cancer, gynecological cancer has also been included (Nucletron, nd (a)).

The first objective of the current study was to identify the core procedures associated with LDR BT and HDR BT in patients with prostate cancer. The second objective was to identify the duration of these core procedures, the time spent by the different medical professionals involved and the resources needed.

Therefore, the research question was as follows:
How much time, attendance of medical staff and resources are needed for conducting the core procedures of LDR BT and HDR BT in patients with prostate cancer (and in addition patients with gynecological cancer)?

In order to give an answer to this question, the following sub research questions were formulated:

1) *What are the core procedures of the treatment process for patients with prostate cancer (and in addition patients with gynecological cancer) in LDR BT and HDR BT?*
2) *How much time, attendance of medical staff and resources are needed in conducting these core procedures?*

2. Methods

The main research question has been addressed by performing a prospective multicenter study in which qualitative and quantitative methods have been combined. The first sub question requires an *exploration* and *description* of the core procedures in LDR BT and HDR BT. For this purpose qualitative methods are needed (Plochg, Juttmann, Klazinga, & Mackenbach, 2007). The second sub question requires an *inventory* of the time, attendance of medical staff and resources needed in LDR BT and HDR BT. For this purpose quantitative methods are needed (Plochg et al., 2007).

This prospective multicenter study has been performed in the months May and June (2012) at two private radiotherapy institutes, RISO[1] in Deventer and ARTI[2] in Arnhem, and the University Medical Center in Utrecht. The combination of these three radiotherapy centers ensures that the two most frequently used forms of brachytherapy, LDR BT and HDR BT, are both covered. The University Medical Center in Utrecht performs LDR BT as primary treatment in patients with prostate cancer. ARTI performs LDR BT in patients with prostate cancer and HDR BT in patients with cervical cancer, where LDR BT is given as primary treatment and HDR BT is given as a triple boost after EBRT. RISO performs both LDR BT and HDR BT in patients with prostate cancer, where HDR BT is given as a boost after EBRT and LDR BT is given either as a boost after EBRT or as primary treatment. An overview of the form of brachytherapy performed by the included radiotherapy centers is given in Table 1.

Table 1.

Forms of brachytherapy performed by the different radiotherapy centers

Radiotherapy center	Brachytherapy modality	Primary treatment / Boost	Body site
RISO	LDR BT	Primary treatment & Boost	Prostate cancer
	HDR BT	Boost	Prostate cancer
ARTI	LDR BT	Primary treatment	Prostate cancer
	HDR BT	(Triple) Boost	Gynecological cancer
University Medical Centre	LDR BT	Primary treatment	Prostate cancer

This study consisted of three rounds. First, inventory interviews have been held with medical professionals within the three radiotherapy centers, i.e. three radiotherapists, two clinical

[1] Radiotherapeutisch Instituut Stedendriehoek en Omstreken

[2] Arnhems Radiotherapeutisch Instituut

physicists, two medical laboratory technicians and a CEO, in order to identify the different core procedures of LDR BT and HDR BT and the medical staff and resources involved. Second, follow-up interviews have been held with the aforementioned medical professionals to identify the duration of the different core procedures and the time spent per medical staff member per core procedure. Finally, an observational study has been performed in order to gain more insight in the content of the core procedures and to gather more accurate data on the duration of the core procedures and the time spent per staff member per core procedure.

The first contact between the medical professionals and the researchers was mediated by the Health Technology and Services Research (HTSR) department of the University of Twente and Nucletron BV.

2.1 Inventory interviews

The first round of this study consisted of semi-structured inventory interviews. This type of interviews allowed the researchers to ask specific questions, but also gave the respondents the possibility to tell about their daily practice. During the first inventory interviews a general overview of the core procedures of brachytherapy, as provided by Nucletron (Figure 1), has been presented to the medical professional. The medical professional was asked to give feedback on the core procedures of LDR BT and HDR BT separately: whether the sequence of the core procedures is correct and whether all relevant procedures are included.

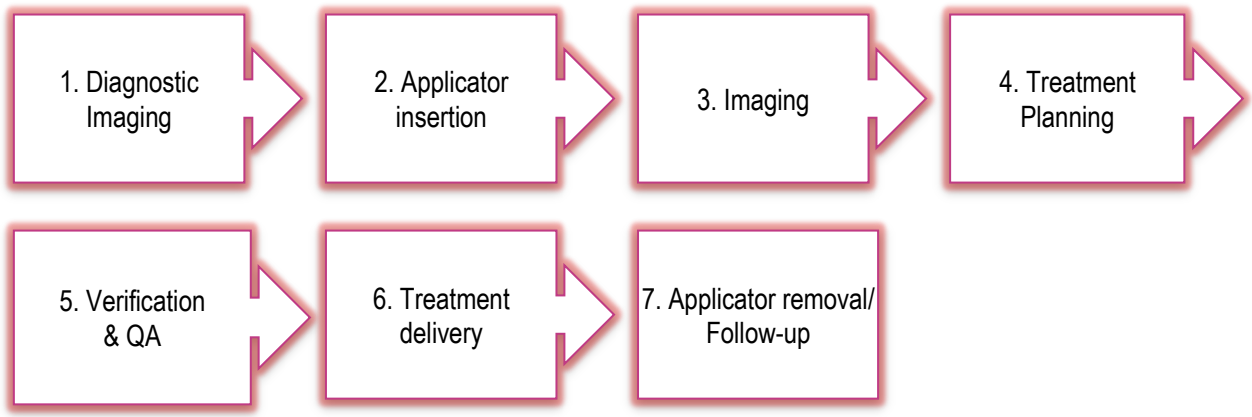


Figure 1. Core procedures of LDR BT and HDR BT as provided by Nucletron.

During the interview the feedback of the medical professional was translated into a new model, in which the core procedures of HDR BT and LDR BT are presented as they emerge in the daily practice of the professional separately. During the subsequent inventory interviews, this model was presented to the medical professional instead of the overview provided by Nucletron. The medical professional was asked to give feedback and if applicable this feedback was translated into a new model.

By using the feedback of the medical professionals from the three different radiotherapy centers, a general model was developed per type of brachytherapy and per body site: LDR BT in prostate cancer, HDR BT in prostate cancer and HDR BT in gynecological cancer. The models give an overview of all the relevant core procedures and their content.

2.2 Follow-up interviews

The second round of the study, the round of the follow-up interviews, consisted of more structured interviews. This more structured type of interviews allowed the researchers to gather quantitative data in a targeted manner. During the interviews, questions have been asked about the duration of the core procedures as presented in the models, the medical staff involved per core procedure, the time spent per medical staff member per core procedure and the resources involved in LDR BT and HDR BT. This was done by means of a sheet on which the medical staff members involved, the time spent per staff member per core procedure, the total duration of the core procedures and the disposables and non-disposables required per core procedure could be filled out (Appendix 2).

2.3 Observations

In addition to the interviews, an observational study at RISO was performed during the treatment process of four patients, who were assigned by the medical professional. Two observations were performed during the treatment process of LDR BT in prostate cancer and two observations were performed during the treatment process of HDR BT in prostate cancer. During these observations the duration of the core procedures, the involved staff and the time spent per staff member per core procedure were measured in whole minutes, from the moment the patient was being prepared for the operation room until the moment the patient left the operation room. This was done by using the developed models as a guideline for the definition, i.e. the beginning, ending and content, of the different core procedures. In addition, the observations were used to gain more insight in the content of the core procedures.

2.4 Analysis of the duration of the core procedure and the time spent per medical staff member

The data about the duration of the core procedures and the time spent per medical staff member per core procedure, as perceived from the follow-up interviews and the observations, is analyzed by using descriptive statistics. For the duration of the core procedures, both the duration of each core procedure separately as well as the total duration of all the core procedures together are presented. The medians have been calculated of the durations of the core procedures, and in addition, the ranges of the durations are determined by taking the shortest duration and the longest duration. The median values and the ranges of both the durations as obtained from the interviews, as well as the durations as measured during the observations, are presented in a table together with the amount of respondents which the values obtained from the interviews are based on. For the follow-up interviews, in case a range was given for the duration of a certain core procedure, the mean of this range was taken (i.e., a range of 15-25 gives a mean of 20) for calculating the median duration. The durations as obtained from the interviews, and the durations as measured during the observations, are thereafter being compared with each other by means of a graph.

For the time spent per staff member, both the time spent per core procedure separately as well as the total time spent on all the core procedures together, is presented. Just like for the duration of the core procedures, for the data about the time spent per staff member as obtained from the interviews, also the medians have been calculated and the ranges are determined by taking the shortest time given by the respondents and the longest time given by the respondents. In case a range was given for the time spent on a certain core procedure, the mean of this range was taken for calculating the median time. Both the median values and the ranges are presented in a table together with the amount of respondents which the values are based on. The data on the time spent per medical staff member per core procedure as measured during the observation is presented in a separate table. Again, the medians of the time spent per medical staff member are calculated, and the ranges are determined by taking the shortest time measured during the observations and the longest time measured during the observations. The data on the time spent per medical staff member as obtained from the interviews, and as measured during the observations, are compared with each other in a separate section.

The choice is made for the median, because of the small amount of data and the ability of the median to not disproportionately take into account outliers.

The analysis as described above is successively performed for LDR BT in prostate cancer, HDR BT in prostate cancer and HDR BT in gynecological cancer separately. Since no observations have been performed during the treatment process of HDR BT in gynecological cancer, for this treatment process only the data as obtained from the follow-up interviews is presented. At the end, a comparison is made between the duration of the core procedures of LDR BT and the duration of the core procedures of HDR BT in prostate cancer. This is done by comparing the duration of the core procedures before, during and after the patient is in the operation room, by means of a graph.

2.5 Analysis of the resources

The required disposables and non-disposables, the numbers of the core procedures during which they are used and the amount used per patient are presented in a table for LDR BT and HDR BT in prostate cancer separately.

3. Results: a model for brachytherapy

The results of this prospective multicenter study will be categorized according to the different sub research questions. First of all, in this chapter, the collected data about the core procedures of LDR BT in prostate cancer, HDR BT in prostate cancer and HDR BT in gynecological cancer will be presented. For each treatment modality the designed model will be presented and subsequently the different core procedures will be explained more thoroughly. The results are based upon the information provided by the different medical staff members (Appendix 1).

3.1 Core procedures of LDR BT in prostate cancer

As mentioned in the methods, LDR BT is performed in prostate cancer at all three centers. At the University Medical Center in Utrecht and ARTI in Arnhem LDR BT is given as primary treatment. At RISO in Deventer LDR BT is given either as primary treatment or as a boost after EBRT. The model below (Figure 2) presents the core procedures of LDR BT in prostate cancer as primary treatment, thus without prior EBRT. The process of LDR BT consists of fifteen core procedures, which will be described one by one below. For each procedure, first a more general description of the core procedure will be given, followed by detailed information per center.

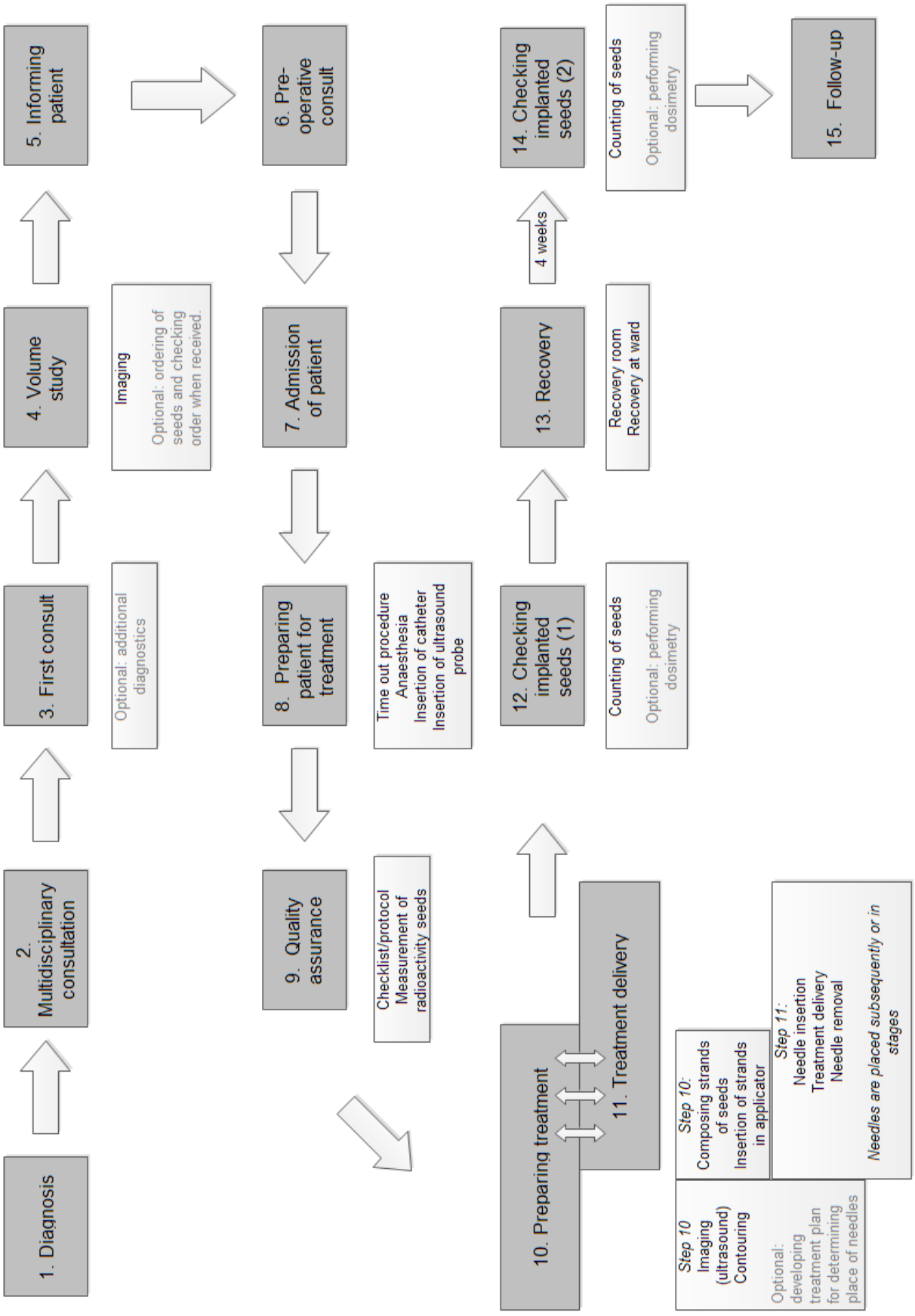


Figure 2: Core procedures of LDR brachytherapy in prostate cancer

1. Diagnosis

The first core procedure of the process of LDR BT in patients with prostate cancer is the diagnosis. The diagnosis is made by the urologist after the patient has been referred by the general practitioner. The urologist performs the pathology and uses imaging, mostly MRI, to diagnose the patient. Also the stage of the tumor is being determined.

2. Multidisciplinary consultation

After the diagnosis has taken place the patient is being discussed during the multidisciplinary consultation. Usually several urologists, an internist, a pathologist, a radiologist and a radiation oncologist are involved in the multidisciplinary consultation. During the multidisciplinary consultation the findings of the pathology and imaging are discussed and the best treatment option for the patient is deliberated. Thereafter the patient is being referred to the radiation oncologist by the urologist.

University Medical Center in Utrecht

Since the patients of the University Medical Center in Utrecht come from all over the country, the radiation oncologists of the University Medical Center often have no knowledge of the multidisciplinary consultation that has taken place in the referring hospital.

3. First consult

After the patient is referred, a first consult with the radiation oncologist takes place. During this first consult the radiation oncologist explains the treatment options to the patient. In some cases additional diagnostics take place and an appointment is scheduled for a volume study.

ARTI

Whilst an appointment is scheduled for a volume study, at ARTI also an appointment with an urologist in the adjacent hospital Rijnstate is scheduled.

RISO

In case the urologist has not performed an MRI, the radiation oncologist at RISO requests an MRI during the first consult. In addition a rectal touché and imaging take place during the first consult in order to decide which treatment the patient should get.

University Medical Center in Utrecht

At the University Medical Center in Utrecht all patients get an MRI after the first consult. The radiation oncologist only relies on this MRI; imaging performed by the urologist is not taken into account. An exception is made for MRI scans performed at the University Medical Center in Nijmegen, since the University Medical Center in

Utrecht beliefs the quality of these MRI scans is equal to the quality of the MRI scans made in Utrecht.

4. Volume study

As mentioned above, during the first consult an appointment is scheduled for a volume study. During this volume study imaging is used to determine the volume of the prostate on basis of which the radiation oncologist decides whether the patient is eligible for LDR BT or not.

ARTI

After the consult with the urologist in hospital Rijnstate, the urologist and the patient together come to ARTI. Here the urologist and a brachytherapy technician of ARTI make an ultrasound on basis of which the volume of the prostate is determined. By means of the volume study a staff member of the department of radio physics orders the radioactive seeds that are needed for the treatment. The staff member of the department of radio physics also checks the order after the seeds are delivered.

RISO

At RISO also an ultrasound is made in order to determine the volume of the prostate. Based on this ultrasound, a plan is made to determine the amount of radioactive seeds needed. Next, an order for these radioactive seeds is placed. This order is placed a week before the treatment takes place. The brachytherapy technician checks the order when received.

University Medical Center in Utrecht

At the University Medical Center in Utrecht the volume study is performed on basis of the MRI, which is made after the first consult. By means of the volume study it is only decided whether the patient is eligible for LDR BT or not. There is no order placed for the radioactive seeds, since the University Medical Center in Utrecht has seeds in stock. In case the patient is eligible for LDR BT he is invited for a tour, if not the radiation oncologist personally contacts the patient.

5. Informing patient

After it is clear that the patient will receive LDR BT the patient is being informed about the treatment in more detail by the brachytherapy technician.

ARTI

At ARTI, the informing of the patient takes place during the ultrasound, which is made by the urologist and the brachytherapy technician for the volume study.

RISO

At RISO, a separate appointment is scheduled with the brachytherapy technician after the volume study took place. During this appointment the brachytherapy technician

explains what will happen during the treatment and informs the patient on the diet with which he has to comply two days before the treatment.

University Medical Center in Utrecht

At the University Medical Center in Utrecht the patient is being informed during the tour given by the brachytherapy technician.

6. Pre-operative consult

After informing the patient, a pre-operative consult takes place with the anesthetist. During this consult the anesthetist discusses the narcosis with the patient and checks whether everything is all right. In some cases the anesthetist refers the patient to a cardiologist or internist.

ARTI

At ARTI the pre-operative consult and the admission of the patient are arranged by the urologist.

RISO

Next to the pre-operative consult with the anesthetist, at RISO usually also a consult with the urologist takes place. The informing of the patient, the pre-operative consult with the anesthetist and the consult with the urologist are often scheduled on the same day.

University Medical Center in Utrecht

At the University Medical Center in Utrecht the pre-operative consult takes place at the same day as the tour and the informing of the patient.

7. Admission of patient

Before the treatment commences, the patient is admitted to the nursing ward. Here the nurses take care of the patient and prepare him for the treatment.

ARTI

At ARTI, the patient is admitted either on outpatient or inpatient basis, depending on the moment the treatment commences and the distance the patient has to travel to get to the hospital.

RISO

At RISO, the patient is admitted on outpatient basis on the morning the treatment takes place.

University Medical Center in Utrecht

After the admission, at the University Medical Center in Utrecht the patient undergoes an enema performed by a nurse. The anesthetist prepares his tools and the patient is moved to the OR.

8. Preparing patient for treatment

Once the patient has arrived at the OR, first of all a time-out takes place. During this time-out it is checked whether all staff members are present and whether the right patient is present. After the time-out the anesthetist administers the narcosis and the catheter and ultrasound probe are being inserted by the brachytherapy technician and the radiation oncologist.

9. Quality assurance

After preparing the patient for the treatment two brachytherapy technicians perform a check based on a standard protocol and checklist. Also the radioactivity of one strand of a batch of seeds is measured to make sure that the radioactivity matches with the radioactivity of the order. Because the seeds have to stay sterile, this procedure takes place simultaneously with the preparation of the treatment (core procedure no. 10).

10. Preparing treatment

During this core procedure an ultrasound scan is made and the scan is being contoured by a brachytherapy technician. Optionally, based on the contoured ultrasound scan a treatment plan for the location of the needles can be determined. In addition the strands of seeds are being composed and inserted into the needles during this procedure.

ARTI

After the ultrasound scan is contoured a brachytherapy technician at ARTI develops a treatment plan for determining the location of the needles. Meanwhile a second brachytherapy technician composes the strands of seeds according to the treatment plan and inserts the strands in the needles.

RISO

Before the ultrasound scan is made, at RISO four gold markers are being implanted into the prostate, so that the seeds can be better positioned and the ultrasound and CT, which will be made later on, can be matched. The ultrasound scan is compared with the ultrasound scan, which was made in order to determine the volume of the prostate. Based on the new ultrasound scan a treatment plan is developed by the radiation oncologist.

Just like at ARTI the brachytherapy technician thereafter composes the strands of seeds according to the treatment plan and inserts the strands in the needles. This takes place simultaneously with the insertion of the first needles, which have already been prepared for use (core procedure no. 11).

University Medical Center in Utrecht

At the University Medical Center in Utrecht first of all two locking needles, which are later used to fix the needle template to the prostate, are implanted by the radiation

oncologist. Then an ultrasound scan is made and a brachytherapy technician contours the scan and relates it to the MRI, which is made after the first consult. Contrary to ARTI and RISO the University Medical Center does not develop a treatment plan. At the University Medical Center in Utrecht the needles are implanted in such way that a needle is located at each centimeter of the prostate, as well in the transversal plane as in the longitudinal plane.

Furthermore the University Medical Center in Utrecht has two different systems for the implantation of seeds. First there is the strand system in which strands, either composed of seeds and dummies or only composed of seeds, are sliced by the brachytherapy technician. Second there is the spot system, which composes strands of seeds in all its variation, so that the desired configuration is automatically assembled on the spot. The radioactivity of each seed that goes through the device is measured individually. In case the spot system is used, the strands of seeds do not have to be composed and inserted in the needles by the brachytherapy technician.

11. Treatment delivery

During the treatment delivery, the needles are inserted into the prostate by the radiation oncologist under guidance of ultrasound. The insertion takes place simultaneously with the composure of the strands and the insertion of the strands into the needles from the previous core procedure. Thus, as soon as the medical laboratory technician has composed a strand and has inserted the strand into a needle, the radiation oncologist inserts the needle into the prostate while the medical laboratory technician continues with the composure of the other strands. Once the needle is placed the seeds are pushed through the needle and the needle is removed. Optionally, the location of the needle can be adjusted during the treatment delivery. This is called intra-operative planning.

ARTI

At ARTI the needles are implanted according to the treatment plan in layers from the top to the bottom. During the implantation the treatment plan is adjusted online per needle by the brachytherapy technician.

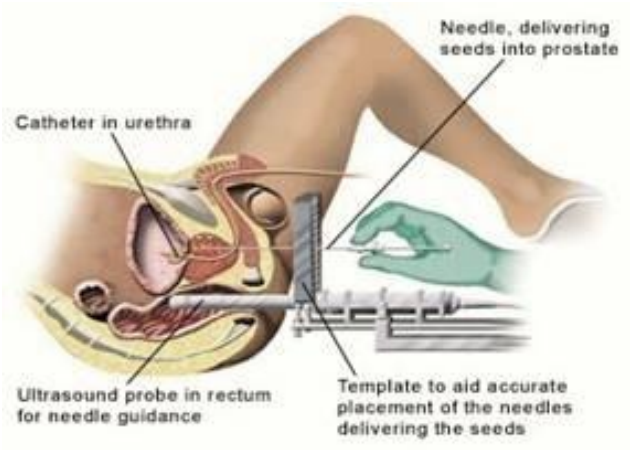


Figure 3. Treatment delivery LDR BT

RISO

At RISO the needles are implanted according the treatment plan in three rounds; first the outer edge, second the bottom and finally the inside of the prostate, under the guidance of ultrasound and X-ray. The needles placed in the outer edge are ready for use, and thus treatment delivery can commence after the treatment plan is ready. A second radiation oncologist controls the planning computer. After the insertion of each round the treatment plan can be adjusted.

University Medical Center in Utrecht

As mentioned in the description of the previous core procedure, at the University Medical Center in Utrecht the needles are implanted in such way that a needle is located at each centimeter of the prostate. Once all the needles are inserted the radiation oncologist checks the contouring of the medical laboratory technician. If they agree a second scan is made on which the needle are visible. By means of the ultrasound scan and the scanned MRI, the location and depth of the needles is picked up by the planning system needle for needle, which results in a real-time update. Then the radiation oncologist decides, together with the brachytherapy technician, where the seeds should be implanted. The computer calculates the plan and it is established whether the plan meets the criteria for the dosage. If this is the case nothing is adjusted.

12. Checking implanted seeds (1)

When the treatment delivery is finished the implanted seeds are checked. During this procedure optionally also radiation dosimetry can be performed.

ARTI

At ARTI it is checked whether all the seeds are implanted successfully by measuring the radioactivity of all the materials and equipment, the area and the floor. In case any radiation is measured this means that a radioactive seed ended up outside the body of the patient and thus the dose inside the prostate is lower than was planned.

RISO

At RISO another ultrasound and a CT scan are made after all the seeds are implanted. The ultrasound and CT are matched by means of the implanted gold markers and dosimetry is performed. Based on the distribution of the dose it is decided whether the radiation oncologist is satisfied or if a few more seeds need to be added. If this is the case also a new CT scan has to be made. Next, some urine is taken from the catheter and is checked on radioactivity to make sure that there are no seeds excreted through the urine.

University Medical Center in Utrecht

At the University Medical Center in Utrecht an X-ray is made in order to check whether all the seeds are successfully implanted and no seeds are missing.

13. Recovery

After leaving the operation room, the patient goes to the recovery room to rest. After a while the patient moves from the recovery room to the ward. Sometimes the patient directly goes to the ward.

ARTI

At the ward the catheter is removed and the patient may go home if he is able to urinate. A sample is taken form the urine and the radioactivity of the urine is measured. Before the patient leaves, the radiation oncologist further informs the patient and a new appointment is scheduled.

RISO

Just like at ARTI, at RISO the patient may also go home if he is able to urinate. After the patient has left, the nursing room is checked on radioactivity before a new patient is allowed to enter.

University Medical Center in Utrecht

At the University Medical Center in Utrecht 50% of all patients directly go to the ward. In the afternoon a CT scan is made by the brachytherapy technician, the amount of seeds is checked and if everything is all right, the catheter is removed and the patient may go home.

14. Checking implanted seeds (2)

Four weeks after the operation the implanted seeds are checked again. Also this time optionally radiation dosimetry can be performed.

ARTI

At ARTI, four weeks after the implantation, a CT scan is made and the amount of seeds is counted. Based on this the brachytherapy technicians develop a post-treatment plan, which is checked by the radiation oncologist. The counting of the seeds and the post-treatment plan serve as a quality check for ARTI itself. Next to the check of the implanted seeds the patient also has an appointment with the radiation oncologist two weeks after the implantation.

RISO

At RISO, a month after the operation a CT scan is made. This CT scan is matched with the ultrasound, which was made in the operation room before the implantation of the radioactive seeds. By means of the match of the ultrasound and CT it is checked

whether the seeds are still located as planned. If not, a few more seeds can be added. However, this only happens in about 1 in 100 patients.

University Medical Center in Utrecht

At the University Medical Center in Utrecht, a month after the operation an MRI scan is made on which each seed is identified for the dosimetry. This dosimetry is compared per radiation oncologist and per implementation system and serves as a quality check for the University Medical Center itself. The dose after a month often appears to be lower than on the day of the treatment, therefore an overdose is administered to compensate the loss.

15. Follow-up

After the second check of the implanted seeds the patient is monitored for a certain period of time. During this period the patient has several appointments with the radiation oncologist. In most cases the patient is also monitored by his urologist.

ARTI

At ARTI the patient is monitored for 5 to 10 years. The patient has an appointment with the radiation oncologist 6 week after the operation. After six months the patient has an appointment alternately with the radiation oncologist and the urologist. After two years the patient has an appointment with the radiation oncologist once a year.

RISO

At RISO the patient has an appointment with the radiation oncologist 3 months, 9 months and 21 months after the operation. After 21 months the patient is monitored by letter. Also the patient has to have his blood tested every year.

University Medical Center in Utrecht

At the University Medical Center in Utrecht the patient is monitored lifelong. The first two years the patient visits the radiation oncologist and the urologist alternately four times, thus both twice a year. After these two years the patient has an appointment one year later and after that two years later. On average the patient visits the radiation oncologist eight times during the follow-up period.

3.2 Core procedures of HDR BT in prostate cancer

HDR BT in prostate cancer is only performed at RISO in Deventer. It is given as a boost after EBRT. However, the model below (Figure 4) presents the core procedures of HDR BT in prostate cancer as primary treatment, thus without prior EBRT. The process of HDR BT consists of sixteen core procedures, which will be described below.

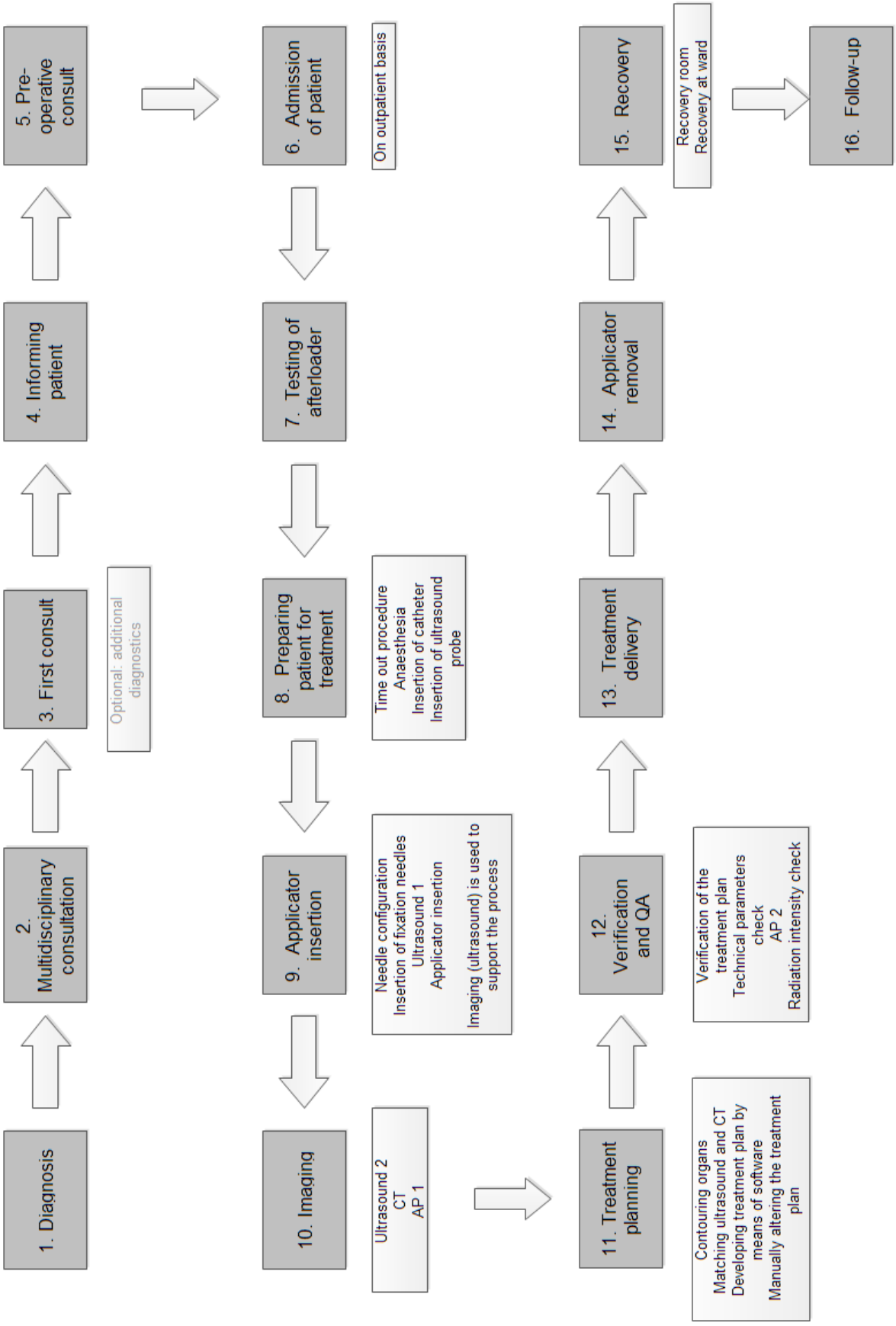


Figure 4: Core procedures of HDR brachytherapy in prostate cancer

1. Diagnosis

The first core procedure of the process of HDR BT in patients with prostate cancer also is the diagnosis. The diagnosis is made by the urologist after the patient has been referred by the general practitioner. The urologist performs the pathology and uses imaging, mostly MRI, to diagnose the patient. Also the stage of the tumor is being determined.

2. Multidisciplinary consultation

After the diagnosis has taken place the patient is being discussed during the multidisciplinary consultation. As mentioned before, usually several urologists, an internist, a pathologist, a radiologist and a radiation oncologist are involved in the multidisciplinary consultation. During the multidisciplinary consultation the findings of the pathology and imaging are discussed and the best treatment option for the patient is deliberated. Thereafter the patient is being referred to the radiation oncologist by the urologist.

3. First consult

After the patient is referred a first consult with the radiation oncologist takes place. During this first consult the radiation oncologist explains the treatment options to the patient. In some cases additional diagnostics take place in order to decide which treatment the patient should get.

4. Informing patient

After it is clear that the patient will receive HDR BT the patient is being informed about the treatment in more detail by the brachytherapy technician. A separate appointment is scheduled for this. Just as with LDR BT, during this appointment the brachytherapy technician explains what will happen during the treatment and informs the patient on the diet which he has to comply two days before the treatment.

5. Pre-operative consult

After informing the patient as usual a pre-operative consult takes place with the anesthetist. During this consult the anesthetist discusses the narcosis with the patient and checks whether everything is all right. In some cases the anesthetist refers the patient to a cardiologist or internist. Next to the pre-operative consult with the anesthetist, mostly also a consult with the urologist takes place. The informing of the patient, the pre-operative consult with the anesthetist and the consult with the urologist are often scheduled on the same day.

6. Admission of patient

Before the treatment commences the patient is admitted to the nursing ward on outpatient basis, on the morning of the treatment. Here the nurses take care of the patient and prepare him for the treatment.

7. Testing of afterloader

Before the treatment commences, the operation room is being prepared and the afterloader is tested by two brachytherapy technicians. This is done by means of a ruler with a specific scale. In this way not only the function of the afterloader, but also the position of the sources is tested. Due to the high radiation the medical staff cannot be present in the operation room during the testing of the afterloader. They can watch on camera what happens in the operation room from the inside of the planning room.

8. Preparing patient for treatment

Once the patient has arrived at the operation room first of all a time-out takes place. After the time-out the temperature of the patient is measured and the anesthetist administers the narcosis. A brachytherapy technician inserts the catheter and one of the radiotherapists inserts the ultrasound probe.

9. Applicator insertion

During this core procedure, first of all two radiation oncologists together with a clinical physicist make a sketch of the prostate and determine the location of the urethra within the prostate by using real-time ultrasound images. By using this sketch and an X-ray scan the radiation oncologists determine the needle configuration by marking the desired locations of the needles on the sketch. Thereafter a laboratory technician prepares the template. Two fixation needles, which are used to fix the template onto the prostate, are prepared and they are inserted by the radiation oncologist according to the established needle configuration. Also an extra gold marker is inserted. Then a first series of blank ultrasound images (US 1) is made and next the HDR needles are inserted by the radiation oncologist under the guidance of real-time ultrasound.

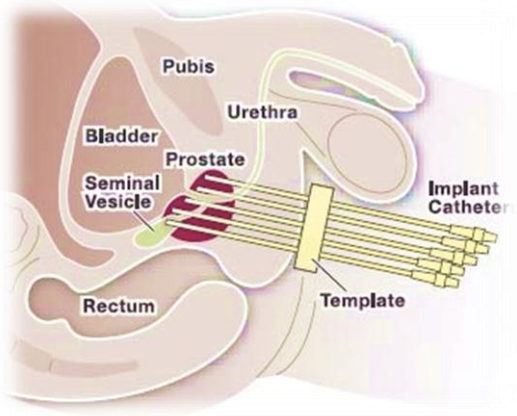


Figure 5. Applicator insertion HDR BT prostate

The needles are inserted deeper into the prostate and fixated onto the template. In the meantime an X-ray scan is made from time to time in order to check whether the needles are in the right position. The total amount of needles that is implanted depends among others on the location and volume of the tumor.

10. Imaging

During this procedure a series of ultrasound images (US 2) is made. In order to do this, first a proper position of the ultrasound probe has to be determined. The laboratory technicians connect the transfer tubes of the afterloader to the needles and a first 'anteroposterior' scan (AP1) is made. This 'anteroposterior' scan (AP1) is used later to check whether the patient, and thus the needles, have moved from their original position. Finally, in addition to the series of ultrasound images, a CT scan is made since the prostate is more apparent on the ultrasound images and the needles are more apparent on the CT scan. When this is done the brachytherapy technicians connect the transfer tubes to the afterloader.

11. Treatment planning

The series of ultrasound images and the CT scan are transferred to the planning computer. Two radiation oncologists together with the clinical physicist contour the prostate, the urethra, the rectum, the bladder base and the boost area on the series of ultrasound images with the needles (US 2) while the series of ultrasound images without the needles (US 1) is laid on top of this. Next the series of ultrasound images and the CT scan are matched by means of the extra gold marker and a number of needle points that are clearly visible. After the matching a brachytherapy technician and the clinical physicist develop a treatment plan on the planning computer. This treatment plan determines how long the radioactive source has to deliver radiation at what depth for each needle. The brachytherapy technician and the clinical physicist start with reconstructing the needles. Then points are placed on the volume of the critical organs (i.e. bladder base, urethra etc.) in order to be able to indicate the maximum quantity of radiation that is allowed on the different organs. Thereafter the system searches for a situation that meets the criteria for the maximum doses. When the computer is done the treatment plan is manually adjusted, since the results of the computer are not optimal. The manually adjustment holds that the radiation times are better distributed in order to prevent hot spots.

12. Verification and QA

During this procedure the planned dose of radiation on the different organs is checked and possibly adjusted. The personal data of the patient is checked one last time and meanwhile a brachytherapy technician makes a second anteroposterior' scan (AP 2) based on which now

is checked whether the needles have moved from their original position by laying AP 2 on top of AP 1. The treatment plan is transferred to the treatment computer and the technical parameters are checked to make sure the right treatment plan is administered to the patient.

13. Treatment delivery

Before the treatment delivery starts, one brachytherapy technician goes to the patient in the operation room and informs him for the last time on the highlights of the treatment. Then the patient is left alone in the operation room and the treatment is delivered to the patient according to the developed treatment plan. First a check cable goes through the HDR needle to confirm that the passage is free, if this is the case the real source is delivered through the needle. This is done for each needle separately. From inside of the planning room the involved medical staff monitors the process by means of real-time images of a camera.

14. Applicator removal

After the treatment delivery, the radiation oncologist loosens the fixation needles and pulls the whole template with all the HDR needles out of the patient. The transfer tubes are detached and the patient is lifted from the operation table onto a hospital bed. After that the brachytherapy technicians clean up the operation room and prepare it for the next patient.

15. Recovery

After leaving the operation room, the patient goes to the recovery room to rest. After a while the patient moves from the recovery room to the ward. The catheter is removed and the patient may go home if he is able to urinate.

16. Follow-up

Just like in LDR BT, the patient is monitored for a certain period of time after the operation. The patient has an appointment with the radiation oncologist 1 month, 3 months, 9 months and 21 months after the operation. In between the patient also regularly has an appointment with his urologist. After 21 months the patient is monitored by letter and his blood is tested once a year.

3.3 Core procedures of HDR BT in gynecological cancer

HDR BT in gynecological cancer is only performed at ARTI in Arnhem. In this institute HDR BT is given only as a triple boost after EBRT, the model below (Figure 6) presents the core procedures of HDR BT in gynecological cancer as primary treatment. The process of HDR BT consists of eighteen core procedures, which will all be described below.

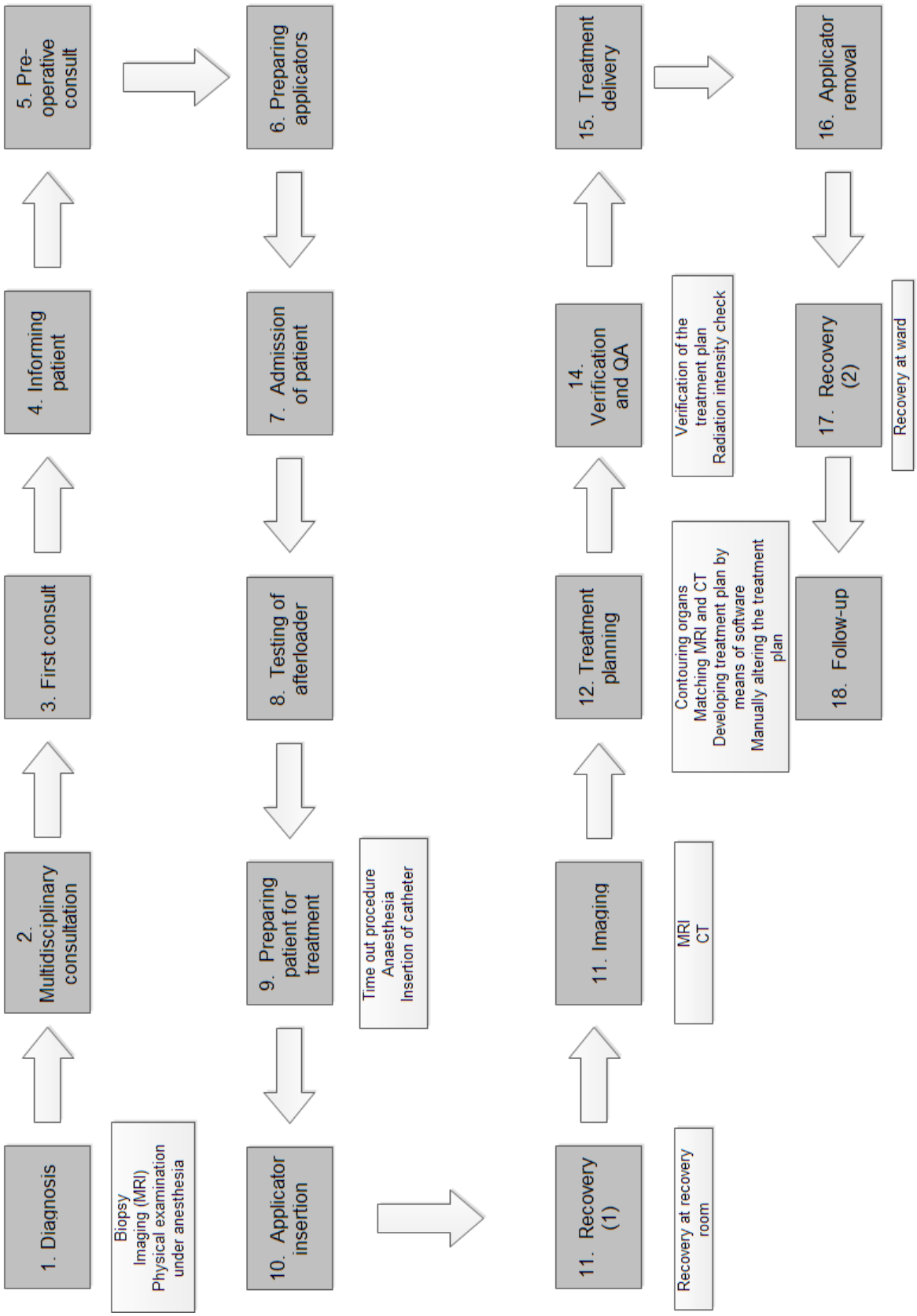


Figure 6: Core procedures of HDR brachytherapy in gynecological cancer

1. Diagnosis

The diagnosis for gynecological cancer and it severity is decisive for the possible treatment options. The diagnosis starts with the general practitioner, who refers the patient to the gynecologist because of the symptoms of the patient. Within the first consult with the gynecologist, the patient is physically examined and afterwards some biopsies are taken. Besides physical examination and biopsies, imaging is also used to diagnose the patient. This imaging consists of an MRI scan, and in one out of three patients an extra PET CT scan. In order to determine the stage of cancer, the gynecologist and the radiation oncologist examine the patient under anesthesia.

2. Multidisciplinary consultation

When the diagnosis of gynecological cancer and its stage have been determined, the possible treatment options are discussed during the multidisciplinary consultation. Five gynecologists, three radiation oncologists, an internist oncologist, a pathologist, a radiologist, a nuclear physician and several oncological nurses are involved in this consultation. In some cases, the multidisciplinary consultation does not result in a possible treatment option for the patient. For example, the removal of several glands or further diagnostic imaging may be needed to determine which options can be suggested. After the additional diagnostic imaging or the removal of such glands, the patient will be discussed within the multidisciplinary consultation for a second time.

3. First consult

The possible treatment options as discussed in the multidisciplinary consultation are proposed to the patient during the first consult with the radiation oncologist. During this consult, the radiation oncologist will inform the patient on the different treatment options in such a way that the patient is able to a make an informed decision.

4. Informing patient

More detailed information about the chosen treatment option (HDR BT) is provided by the brachytherapy technician. Since patients in ARTI first receive EBRT, and later on HDR BT as a triple boost, the brachytherapy technician provides this more detailed information during the EBRT process.

5. Pre-operative consult

After the first consult, the patient is scheduled for a pre-operative consult with the anesthesiologist in Rijnstate hospital. Involving the anesthesiologist in Rijnstate hospital is necessary, since ARTI uses the operation room of this hospital and some of its staff

(anesthesiologists, nursing staff etc.). An appointment with the gynecologist is only scheduled when the patient is not familiar with the gynecologist at Rijnstate hospital. This also applies when a patient has additional health issues; only then the patient is scheduled for an appointment with, for example, a cardiologist.

6. Preparing applicators

A week prior to the treatment, the brachytherapy technician checks whether the needed set of applicators for the treatment of the patient is present. All applicators have to be cleaned and sterilized, which is done at Rijnstate hospital.

7. Admission of patient

Patients treated with brachytherapy (LDR BT or HDR BT) in ARTI are admitted on the nursing ward of hospital Rijnstate either on the evening before or the morning the operation commences, depending on the travelling time of the patient. Contrary to other radiotherapy centers, it is highly exceptional that a patient is admitted to the nursing ward an hour before treatment. In the case of HDR BT, the patient is admitted to the nursing ward on an inpatient basis, on the evening before the treatment. At the ward the patient is monitored and prepared for the procedure by the nurses.

8. Testing of afterloader

On the morning of treatment, two brachytherapy technicians test the afterloader that is used to deliver the radioactive source to the patient. By testing the afterloader, the brachytherapy technicians ensure that the radioactive source is accurately sent to the designated point.

9. Preparing patient for treatment

The preparation of the patient for HDR BT in gynecological cancer is no different from LDR BT and HDR BT in prostate cancer. The preparation of the patient in HDR BT in gynecological cancer also consists of the time-out procedure, followed by the anesthesia and the insertion of the catheter and the ultrasound probe.

10. Applicator insertion

After the patient is prepared for the treatment, the radiation oncologist places the applicator within the cervix supported by real-time imaging, using the ultrasound probe. In contrast to HDR BT in patients with prostate cancer, the use of needles within this procedure is highly exceptional. The reason for this is because of the origin of the treated tumor. In prostate cancer, HDR BT is given within the tissue, also known as interstitial brachytherapy, which results in the use of needles. Whilst in gynecological cancer the radioactive source is placed

in the lumen, also known as contact brachytherapy, which results in the use of a fletch applicator instead of needles. After the insertion of the applicator, the ultrasound probe is removed and in some cases imaging is used to check whether the applicator is accurately placed.

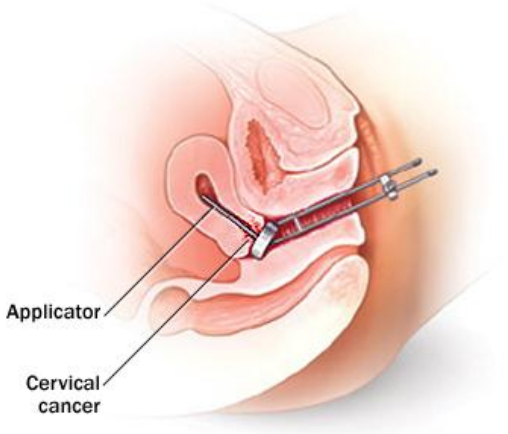


Figure 7 Applicator insertion HDR BT gynecology

11. Recovery (1)

After the applicator is inserted in the cervix, the patient is brought to the recovery room and the nursing ward. In HDR BT in gynecological cancer the anesthesia is therefore only needed for the insertion of the applicator, and in exceptional cases for the insertion of additional needles.

12. Imaging

When the patient is recovered from her anesthesia, an MRI scan is made by the brachytherapy physician assistant and the brachytherapy technician. Critical organs and the target area (the cervix) are clearly visualized on this MRI scan. However, the MRI scan does not clearly visualize the applicator. Since this applicator is visible at a CT scan, the patient is brought to ARTI where the imaging is completed with a CT scan.

13. Treatment planning

In order to design a sufficient treatment plan, the brachytherapy technicians match the CT and MRI; both images are compared to each other in order to create a full image of the critical organs, the target area and the applicator. The radiation oncologist then starts contouring critical organs and the target volume. The matched CT and MRI in combination with the contouring by the radiation oncologist are used as a basis for the design of the treatment plan. By using specially designed planning software, the brachytherapy technicians create a treatment plan for the patient. Just like in prostate cancer, this plan determines where and how long the radioactive source should deliver radiation. By adjusting the location and timespan of the placement of the radioactive source, the optimal dose of radiation can be administered to the tumor and the damage to the surrounding tissue is reduced as much as possible.

14. Verification and quality assurance

The treatment plan, as created by the software, is manually adapted and optimized by both the brachytherapy technicians and the radiation oncologist. The radiation oncologist finally determines if the plan is sufficient.

15. Treatment delivery

When the plan is approved by the radiation oncologist, the patient is brought to the treatment room. The brachytherapy technicians inform the patient about the following procedures and they subsequently connect the patient to the afterloader by using transfer tubes. Under the supervision of the radiation oncologist, the brachytherapy technicians and the clinical physicist, the treatment is administered. The afterloader sends the radioactive source into the applicator according to the designed treatment plan.

16. Applicator removal

After the completion of the treatment delivery, the applicator is removed and the follow-up procedures (aftercare) are discussed.

17. Recovery (2)

Before the patient is discharged, she is admitted at the nursing ward in order to gradually mobilize again. One must notice, that HDR BT in patients with gynecological cancer is given as three boosts. Therefore, during the first two boosts, the treatment is repeated from core procedure 6 (preparing applicators) until this core procedure, recovery (2). After the third and last boost, the full treatment is completed.

18. Follow-up

When the patient has received her last HDR BT boost, the gynecologist and radiation oncologist start with the follow-up. During the follow-up appointments side effects and the physical well being of the patient is discussed.

For patients with gynecological cancer the follow-up is as follows:

Both three and six weeks after the treatment, an appointment with the radiation oncologist is scheduled to check whether the treatment was successful.

During the appointment 12 weeks after the treatment, an examination under anesthesia is performed. Also biopsies are taken during this examination.

After the examination under anesthesia, the patient has an appointment with the radiation oncologist and the gynecologist alternately, every three months for two years.

From two to five years after treatment, the patient only has an appointment with either the radiation oncologist or the gynecologist twice a year.

Five years after treatment, the patient has an appointment only once a year. From ten years after treatment the only appointment the patient has is once a year with the radiation oncologist.

4. Results: duration of core procedures, attendance of medical staff involved and needed resources

After constructing a model for the core procedures of LDR BT for prostate cancer and HDR BT for prostate and gynecological cancer, the second sub research question can be addressed: "*How much time, attendance of medical staff and resources are needed in conducting these core procedures?,"* where 'these core procedures' stands for the core procedures described in the models from the previous chapter.
In this chapter, the results on the duration of the core procedures, the attendance of medical staff and the time spent per medical staff member will be presented.

The results of LDR BT on the follow-up interviews and the observations will be presented first (section 4.1). Thereafter, the results of HDR BT in prostate cancer (4.2) and HDR BT in gynecological cancer (4.3) will be discussed. In section 4.4, the results on HDR BT and LDR BT for prostate cancer will be compared. In the final section (4.5), the results on resources will be presented.

4.1 LDR brachytherapy in prostate cancer

The results on the core procedures of LDR BT will be discussed in this section. On LDR brachytherapy, five professionals have been interviewed, working for RISO (2), ARTI (2) and UMCU (1). Also, there have been two observations, which have both taken place at RISO. First, the results on the duration of core procedures will be presented. Then, the results on the attendance of medical staff and the times spent per medical staff member will be discussed.

4.1.1. Duration of core procedures

In Table 2, the overall duration of all core procedures of LDR BT is presented. The median of the durations per core procedure (rounded in whole minutes), as obtained from the interviews, are given. Also, if applicable, a range of times is provided. This range is determined by taking the shortest time given by the respondents and the longest time given by the respondents. In case all times obtained are the same and respondents have not given a range, no range is presented. Also, the results of the two observations, which have taken place at RISO, on the duration of core procedures, are given. It should be noted that the results of the observations are restricted to core procedure 8 up to and including 12. To be able to distinguish the duration of the core procedures that take place before, during and after entering the operation room, the total duration of core procedure 2-7, 8-12 and 13-15

together are presented too. The number of respondents and observations on each core procedure is given under the column *n*. For example, if three respondents gave a time for the duration of core procedure 5, *n* will be three. Also, the number of respondents on procedure 2-7, 8-12 and 13-15 and the total procedure is given. For the interviews, total times are obtained by adding the median times and minima and maxima of all core procedures together. For the observations, the median and range of the total time is not obtained by adding the median times and minima and maxima of all core procedures together, but based on the total times of the two observations (i.e. 72 was the total time measured for observation one, whilst 123 was the time measured in observation two, which gives a median of 98).

Table 2.
Duration of core procedures of LDR brachytherapy

Procedure	Duration in minutes			
	Interviews		Observations	
	n	median (range)	n	median (range)
1. Diagnosis	N/A	N/A		
2. Multidisciplinary consultation	2	8 (2-10)		
3. First consult	4	45 (45-60)		
4. Volume study	3	66 (65-75)		
5. Informing patient	3	38 (30-45)		
6. Preoperative consult	2	23 (15-30		
7. Admission of patient	3	30 (30-420)		
8. Preparing patient	3	23 (15-40)	2	18 (15-20)
9. Quality assurance	4	4 (2-5)	2	2
10. Preparing treatment	4	30 (20-35)	2	20 (15-25)
11. Treatment delivery	4	38 (20-90)	2	24 (20-28)
12. Checking seeds (1)	4	20 (10-20)	2	34 (20-48)
13. Recovery	3	120 (30-315)		
14. Checking seeds (2)	4	40 (20-65)		
15. Follow-up	3	75 (40-330)		
Procedure 2-7	4	209 (187-640)		
Procedure 8-12	5	114 (67-190)	2	98 (72-123)
Procedure 13-15	4	235 (90-710)		
Totals	5	558 (344-1540)		

Table 2 gives us some notable information on the data acquired from the follow-up interviews. First of all, although five respondents were included, none of the five respondents was able to give a time for all the core procedures. This is why $n < 5$ in all cases. Also, none of the respondents was able to give a time for the first core procedure, diagnosis. This is because the diagnosis takes place outside the working field of the respondents, and the respondents therefore had no information on this core procedure. The researchers have tried

to contact an urologist for more information on the diagnosis, but this appeared to be infeasible. A third striking point is that some of the core procedures have a really wide range. Core procedure 7, admission of patient, for example has a range of 30 to 420 minutes. This is due to the fact that at ARTI, patients are often admitted on the evening, the day before the procedure takes place, while at the other two centers, patients are admitted on the morning of the procedure, 30 minutes before the treatment starts. Core procedure 11, treatment delivery, has a range of 20 to 90 minutes. This is because the respondent working at ARTI gave a much higher time than the respondents working at RISO and the University Medical Centre. This also holds for core procedures 15, follow-up. The reason why the respondent at ARTI gave a much longer time, however, is not clear. Also the recovery has a really wide range, i.e. 30 to 315 minutes. The reason for this is probably that some of the respondents only gave the time of recovery in the recovery room, while others have also included the time of recovery at the nursing ward. Furthermore, the wide range of core procedure 14, checking seeds 2, is due to differences between the three centers. Finally, the somewhat wide range of core procedure 8, preparing patient, is caused by the fact that the administration of the anesthesia at the University Medical Centre takes longer than the administration of the anesthesia at RISO and ARTI.

When we look at the core procedures which take place before the patient is in the operation room, we can see that the core procedures that take place outside of the operation room are the most time-consuming and differ the most.

In figure 8, a graph presents the differences in the duration of the core procedures of LDR BT as obtained from the follow-up interviews and the duration of the core procedures as measured during the observations. For core procedure 8 up to and including 11 the median times from the observations were lower than the median times from the follow-up interviews. On the other hand, the median time of the observations for checking seeds (1) was much higher than the median time from the interviews. This is due to the fact that in one of the two observations a few extra seeds needed to be implanted. Although one may not be able to draw valid conclusions based on two observations, it seems that in general these core procedures for LDR BT take less time than was told during the follow-up interviews.

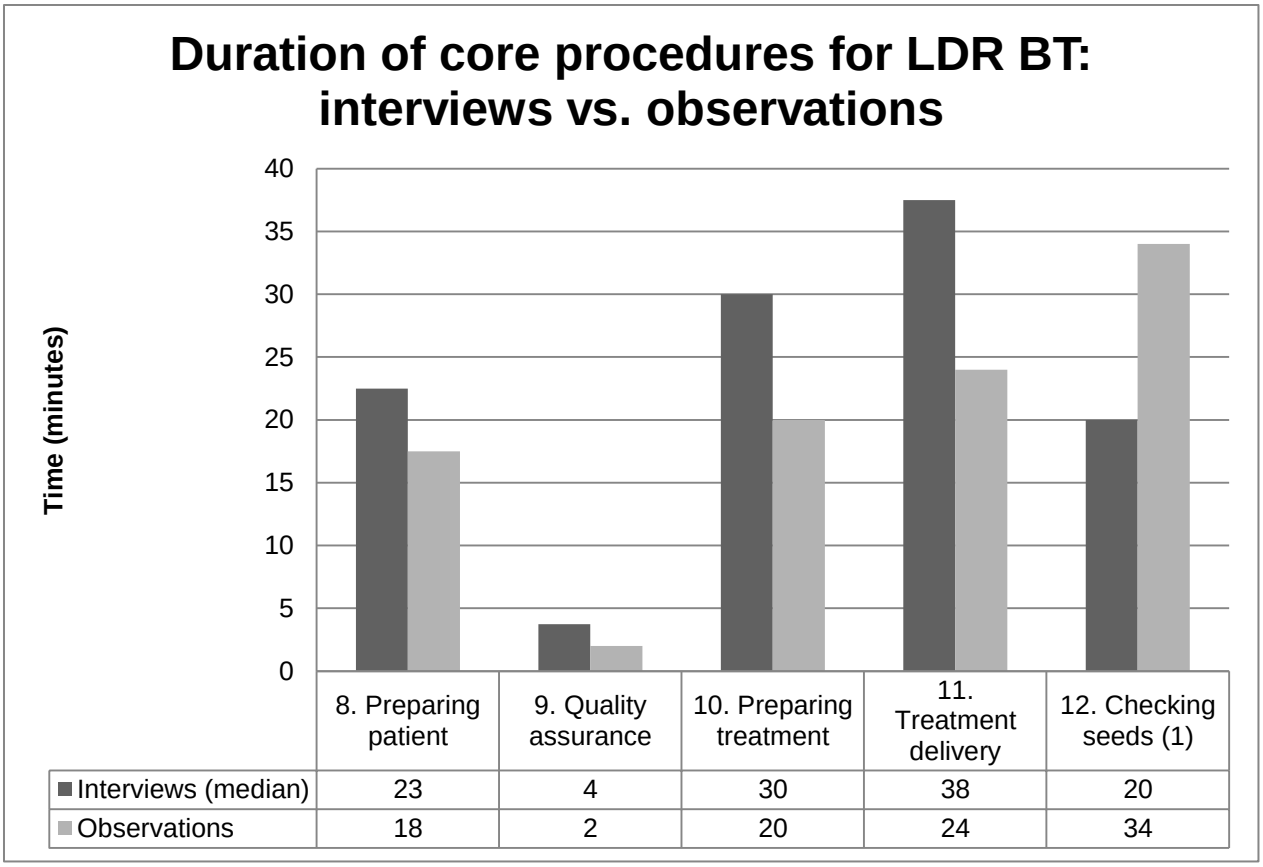


Figure 8. A comparison of the duration of core procedures 8 to 12 for LDR brachytherapy: follow-up interviews versus observations

4.1.2. Attendance of medical staff and time spent per staff member: follow-up interviews

Table 3 shows the attendance of medical staff and the time spent per medical staff member for LDR BT. The medians of the time spent per staff member per core procedure (rounded in whole minutes), as obtained from the interviews, are presented. Also, a range of times is given. However, when all times obtained are the same and respondents have not given a range, no range is presented. Total times are obtained by adding the median times and minima and maxima of all core procedures together. The number of respondents on each core procedure is given under the column *n*. For example, if three respondents estimated the time spent by a particular staff member on for example core procedure 5, *n* will be three. Also, the number of respondents on the total procedure is given.

Table 3.
Attendance of medical staff and time spent per medical staff member for LDR brachytherapy for prostate cancer

Procedure	1. Diagnosis		2. Multidisciplinary consultation[1]		3. First consult		4. Volume study		5. Informing patient		6. Preoperative consult		7. Admission of patient		8. Preparing patient	
Staff member	n	time in minutes [median (range)]	n	time in minutes [median (range)]	n	time in minutes [median (range)]	n	time in minutes [median (range)]	n	time in minutes [median (range)]	n	time in minutes [median (range)]	n	time in minutes [median (range)]	n	time in minutes [median (range)]
Rad. Oncologist #1			1	10	4	45 (45-60)							1	5	3	23 (10-30)
Rad. Oncologist #2			1	10											2	20 (15-30)
BT technician #1							3	35 (30-75)	3	38 (30-45)			1	10	3	18 (10-30)
BT technician #2							2	8 (5-10)							3	18 (10-30
Clinical physicist							1	45								
Anesthesiologist											2	15			3	23 (15-30)
Anesthesia asst.															2	20 (15-30)
Urologist			1	10			1	30			1	15				
Nursing staff													3	30 (30-420)		
OR nurse #1																
OR nurse #2																

Procedure	9. Quality assurance		10. Preparing treatment		11. Treatment delivery		12. Checking seeds (1)		13. Recovery		14. Checking seeds (2)		15. Follow-up		Totals	
Staff member	n	time in minutes [median (range)]	n	time in minutes [median (range)]	n	time in minutes [median (range)]	n	time in minutes [median (range)]	n	time in minutes [median (range)]	n	time in minutes [median (range)]	n	time in minutes [median (range)]	n	time in minutes [median (range)]
Rad. Oncologist #1	1	5	4	23 (10-30)	4	38 (20-90)	3	20 (10-20)	1	25 (20-30)	3	20 (10-50)	3	75 (40-165)	4	288 (185-495)
Rad. Oncologist #2	1	5	2	20 (10-30)	2	38 (20-45)	2	20							2	113 (90-140)
BT technician #1	4	4	3	30 (20-30)	4	38 (20-90)	4	20 (10-20)	1	25 (20-30)	4	25 (20-50)			4	241 (172-385)
BT technician #2	3	4	2	25 (20-30)	4	38 (20-90)	2	15 (10-20)			2	10 (5-15)[2]			4	116 (72-200)
Clinical physicist															1	45
Anesthesiologist															3	38 (30-45)
Anesthesia asst.	2	5	4	30 (20-35)	4	38 (20-90)	3	20 (10-20)							4	113 (70-180)
Urologist(s)					1	90	1	10					1	138 (110-165)	1	293 (265-320)
Nursing staff									3	90 (30-315)					3	120 (60-735)
OR nurse #1	1	5	1	30	1	90	1	10	1	30					1	165
OR nurse #2	1	5	1	30	1	90	1	10							1	135

[1] There is more staff involved in the multidisciplinary consult than shown in this table. The staff not shown includes three more urologists, a pathologist and an internal oncologist.
[2] In this core procedure, in fact the radiotherapy technician is involved instead of the brachytherapy technician #2

When we look at Table 3, the first thing to notice is that there is no data on core procedure 1, diagnosis. This is due to the same reason as in Table 2, namely that the diagnosis takes place outside the working field of the respondents. A second thing that needs to be noticed is the fact that the OR nurses in core procedure 9 until 13 and the urologist in core procedure 4, 11 and 12, are only mentioned by the respondent working at ARTI (n = 1), since only at ARTI OR nurses and the urologist are involved in these core procedures. Furthermore, also in this table a striking point is that some of the core procedures have a really wide range. First of all, the time spent by BT technician #1 in core procedure 4, volume study, has a range of 30 to 75 minutes, which is a result of differences between the different radiotherapy centers. At ARTI the volume study is carried out by a brachytherapy technician and a clinical physicist successively, while at RISO the whole core procedure is only carried out by a brachytherapy technician, which means that the brachytherapy technician at RISO has more work than the brachytherapy technician at ARTI. Second, the range of the time spent by the nursing staff in core procedure 7, admission of patient, can be explained by the same reason for the wide range of the duration of this core procedure. Also the wide ranges of the time spent by the different staff members in core procedures 11,13 and 15, are due to the same reason as the wide ranges of the total duration of these core procedures. The wide ranges of the time spent by radiation oncologist #1 and BT technician #1 in core procedure 14, checking seeds (2), are due to the fact that in some patients at RISO checking the seeds takes rather long, while in other patients it does not. Finally, the somewhat wide time range of BT technician #1 in core procedure 5, informing patient, is merely due to differences between patient characteristics.

4.1.3. Attendance of medical staff and time spent per staff member: observations

For the observations of LDR BT, which have taken place at RISO, the data on medical staff is presented in the table below (Table 4). The two observations both started from core procedure 8 (preparing patient for treatment) and both finished after core procedure 12 (checking implanted seeds (1)). This means that in both cases the times for all core procedures which take place in the operation room have been measured. In Table 4 the time measurement (in whole minutes) is presented for each staff member per core procedure. The medians of the time spent per staff member per core procedure are described. Also, a range of times is presented, which actually presents the measured times of both observations. In the case both observations resulted in the same time, no range is presented. In the case of total times, the median and range is not obtained by adding the median times and minima and maxima of all core procedures together, but based on the total times of the two observations (i.e. for RT technician #1, 67 was the time measured for

observation one, as 123 was the time measured in observation two. This gives a median of 95 with range 67-123). Note that in this case the median is equal to the mean, since there have only been two measurements.

Table 4
Attendance of medical staff and time spent per medical staff member for LDR brachytherapy for prostate cancer for core procedure 8 up to 12, according to observations

Procedure	8. Preparing patient	9. Quality assurance	10. Preparing treatment	11. Treatment delivery	12. Checking seeds	Totals
Staff member			time in minutes [median (range)]			
Rad. Onc. #1	18 (15-20)		20 (15-25)	24 (20-28)	34 (20-48)	96 (70-121)
Rad. Onc. #2	18 (15-20)		20 (15-25)	24 (20-28)	34 (20-48)	96 (70-121)
RT technician#1	18 (15-20)	2	18 (10-25)	24 (20-28)	34 (20-48)	95 (67-123)
RT technician#2	18 (15-20)		18 (10-25)	24 (20-28)	34 (20-48)	93 (65-121)
Anesthesiologist	14 (12-15)					14 (12-15)
Anesthesia asst	18 (15-20)		20 (15-25)	24 (20-28)	34 (20-48)	97 (70-121)

A striking difference between the two observations can be seen in the time spent for checking the implanted seeds (1). As been discussed in the previous chapter, in RISO extra seeds can be implanted if it appears that radiation is insufficient. This is the reason for the differences between measurement one and two in checking the implanted seeds (1). The differences between the two observations in the time spent for the preparation of the treatment and the treatment delivery are due to differences between patient characteristics.

4.1.4. Attendance of medical staff and time spent per staff member: follow-up interviews versus observations

When comparing the attendance of the medical staff between observations and interviews, there are some differences. Firstly, while according to the data obtained during the interviews urologists and/or OR nurses are present during core procedures 9 to 14, they were not present during the observations. This is because the observations took place at RISO, were no OR nurses or urologists are involved during these core procedures. Secondly, when carrying out the quality assurance, during the interviews the same staff members were told to be involved as in the other core procedures that take place in the operation room. During the observations however, only brachytherapy technicians appeared to be involved in the QA. This may be caused by the fact that the QA turned out to take place parallel to the preparation of the treatment, and other staff members have other tasks during the QA, which are not related to performing the QA. For the other core procedures, the attendance of medical staff was the same as was told during the interviews. Nevertheless, the anesthesiologist was only present during a part of core procedure 8, while during the

interviews some respondents told he was present during the whole procedure. During the observations, the time spent by the other staff members was in some cases, such as during the treatment delivery, different from the times spent as obtained from the interviews. This is caused by the fact that in the interviews also the University Medical Centre in Utrecht was included, from which the respondent gave a much higher time spent by the staff members for this core procedure than the other respondents.

4.2. HDR brachytherapy in prostate cancer

The results on the core procedures of HDR BT for prostate cancer will be discussed in this section. On HDR BT for prostate cancer, three professionals have been interviewed, all working for RISO. Also, two observations have taken place, both at RISO. First the results on the duration of core procedures will be presented. Then, the results on the attendance of medical staff and time spent per medical staff member will be discussed.

4.2.1. Duration of core procedures

In Table 5, the overall duration of all core procedures of HDR BT for prostate cancer is presented. The median of the durations per core procedure (rounded in whole minutes), as obtained from the interviews, are presented. Also, if applicable, a range of times is presented. This range is determined by taking the shortest time given by the respondents and the longest time given by the respondents. In case all times obtained are the same and respondents have not given a range, no range is presented. Also, the results of the two observations, which have taken place at RISO, are presented. It should be noted that the results of the observations are restricted to core procedures 8 up to and including 14. To be able to distinguish the duration of the core procedures that take place before, during and after entering the operation room, the duration of core procedures 2-7, 8-14 and 15-16 together are presented too.

The number of respondents and observations on each core procedure is given under the column *n*. For example, if three respondents gave a time for the duration of core procedure 5, *n* will be three. Also, the number of respondents on procedure 2-7, 8-14 and 15-16 and the total procedure is given. For the interviews, total times are obtained by adding the median times and minima and maxima of all core procedures together. For the observations, the median and range of the total time is not obtained by adding the median times and minima and maxima of all core procedures together, but based on the total times of the two observations (i.e. 189 was the total time measured for observation one, whilst 203 was the time measured in observation two, which gives a median of 196).

Table 5

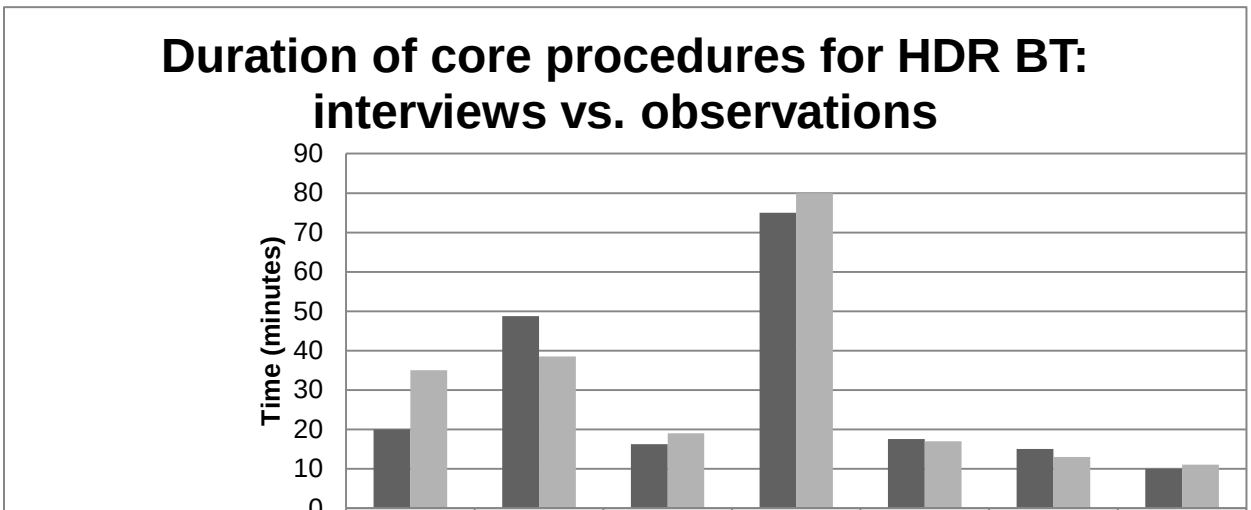
Duration of core procedures of HDR brachytherapy for prostate cancer

Procedure	Duration in minutes			
		Interviews		Observations
	n	median (range)	n	median (range)
1. Diagnosis	N/A	N/A		
2. Multidisciplinary consultation	1	10		
3. First consult	2	58 (45-60)		
4. Informing patient	2	34 (30-45)		
5. Preoperative consult	1	39		
6. Admission of patient	1	30		
7. Testing of afterloader	2	30		
8. Preparing patient	2	20 (15-25)	1	35
9. Applicator insertion	2	49 (30-60)	2	39 (30-47)
10. Imaging	2	16 (10-20)	2	19 (18-20)
11. Treatment planning	3	75 (60-120)	2	80 (65-95)
12. Verification & QA	3	18 (15-20)	2	17
13. Treatment delivery	3	15 (10-20)	2	13 (12-14)
14. Applicator removal	3	10 (10-15)	2	11 (10-12
15. Recovery	1	120 (90-150)		
16. Follow-up	2	65 (60-70)		
Procedure 2-7	2	191 (175-203)		
Procedure 8-14	3	203 (150-280)	2	196 (189-203)
Procedure 15-16	2	185 (150-220)		
Totals	3	579 (475-705)		

Table 5 gives us some notable information on the data acquired from the follow-up interviews. First of all, none of the respondents was able to give a time for the first core procedure, diagnosis. This is because of the same reason as LDR BT, namely that the diagnosis takes place outside the working field of the respondents, and the respondents therefore had no information on this core procedure. A second striking point is that some of the core procedures have a really wide range. The times for applicator insertion, treatment planning and recovery appeared to have a wider range than the other core procedures. For applicator insertion and treatment planning, this might be caused by the complex nature of these procedures (see the model for HDR BT in Figure 4), even though there has not been given any explanation for fluctuations in the duration of these core procedures by the respondents. For the recovery, the wide range can be explained by the fact that not every patient recovers at the same pace. Also, it is possible that one respondent only gives time for recovery at the recovery room, while the other also includes recovery at the nursing ward.

Finally, it should be noted that for some core procedures, times are based on the data given by only one respondent. When we compare the wide ranges obtained from interviews with the ranges acquired from the observations, they seem to correspond to each other. Also during the observations, there was a big difference in time measured between the two observations for applicator insertion and treatment planning. This was because in one observation the patients' characteristics were favorable, while in the other observation conditions were tougher.
When one looks at the core procedures that take place before the patient is in the operation room, we can see that the core procedures that take place in the operation room are the most time-consuming and differ the most.

In figure 9, a graph presents the differences in the duration of the core procedures of HDR BT as obtained from the follow-up interviews and as measured during the observations. For core procedure 8, 10 and 11 the observed time turned out to be higher than the median times according to the interviews, although only for core procedure 8 there is a notable difference. Applicator insertion took less time than was said during the interviews, whilst for the other core procedures the data between the interviews and the observations is comparable. Although one may not be able to draw conclusions based on two observations, it seems that in general the ranges given for the duration of these core procedures told in follow-up interviews are quite accurate.



	8. Preparing patient	9. Applicator insertion	10. Imaging	11. Treatment planning	12. Verification and QA	13. Treatment delivery	14. Applicator removal
Interviews (median)	20	48,75	16,25	75	17,5	15	10
Observations	35	38,5	19	80	17	13	11

Figure 9. A comparison of the duration of core procedures 8 to 14 for HDR brachytherapy: interviews versus observations.

4.2.2. Attendance of medical staff and time spent per staff member: follow-up interviews

Table 6 shows the attendance of medical staff and the time spent per medical staff member for HDR BT in prostate cancer. The medians of the time spent per staff member per core procedure (rounded in whole minutes), as obtained from the interviews, are presented. Also, a range of times is presented. However, when all times obtained are the same and respondents have not given a range, no range is presented. Total times are obtained by adding the median times and minima and maxima of all core procedures. The number of respondents on each core procedure is given under the column *n*. For example, if three respondents estimated the time spent by a particular staff member on for example core procedure 5, *n* will be three. Also, the number of respondents on the total procedure is given.

When we look at Table 6, the first thing to notice is that there is no data on core procedure 1, diagnosis. This is again due to the same reason as in Table 2, namely that the diagnosis takes place outside the working field of the respondents. A second thing that needs to be noticed is the fact that the staff involved in core procedures 2, 5, 6 and 15 are only mentioned by one respondent (n = 1), because only one respondent was able to give information on these procedures. Furthermore, also in this table a striking point is that some of the core procedures have a really wide range, i.e. applicator insertion, treatment planning and recovery. The reason for these wide ranges, are the same as for the wide ranges in duration of these core procedures (see section 4.2.1.)

Table 6.
Attendance of medical staff and time spent per medical staff member for HDR brachytherapy for prostate cancer

Procedure	1. Diagnosis		2. Multidisciplinary consultation[1]		3. First consult		4. Informing patient		5. Preoperative consult		6. Admission of patient		7. Testing of afterloader		8. Preparing patient		9. Applicator insertion	
Staff member	n	time	n	time	n	time	n	time	n	time	n	time	n	time	n	time	n	time
Rad. Onc. #1			1	10	2	58 (45-60)									2	20 (15-25)	2	49 (30-60)
Rad. Onc. #2			1	10											2	18 (15-20)	2	49 (30-60)
BT technician#1					2	23 (15-30)	2	34 (30-45)					2	30	2	20 (15-25)	2	49 (30-60)
BT technician#2													2	30	2	20 (15-25)	2	49 (30-60)
Clin. physicist																	2	35 (15-60)
Anesthesiolog.									1	15					2	18 (15-20)		
Anesthesia asst															2	20 (15-25)	2	49 (30-60)
Urologist(s)			1	10					1	15								
Nursing staff											1	30						
OR nurse																		

Procedure	10. Imaging		11. Treatment planning		12. Verification & QA		13. Treatment delivery		14. Applicator removal		15. Recovery		16. Follow-up		Totals	
Staff member	n	time	n	time	n	time	n	time	n	time		time	n	time	n	time
Rad. Onc. #1	2	16 (10-20)	3	75 (60-120)	3	18 (15-20)	3	15 (10-20)	3	10 (10-15)			2	35 (30-40)	3	305 (235-390)
Rad. Onc. #2	2	16 (10-20)	2	75 (60-90)											2	168 (125-200)
BT technician#1	2	16 (10-20)	3	75 (60-120)	3	18 (15-20)	3	18 (15-20)	3	10 (10-15)					3	289 (225-385)
BT technician 2	2	16 (10-20)	3	75 (60-120)	3	18 (15-20)	3	18 (15-20)	3	10 (10-15)					3	233 (180-310)
Clin. physicist	2	16 (10-20)	3	75 (60-120)	3	18 (15-20)	3	18 (15-20)	1	10					3	169 (120-250)
Anesthesiolog.															2	33 (30-35)
Anesthesia asst	2	16 (10-20)	3	75 (60-120)	3	18 (15-20)	3	18 (15-20)	3	10 (10-15)					3	203 (150-280)
Urologist(s)													2	30	2	55
Nursing staff											1	90 (60-120)			1	120 (90-150
OR nurse											1	30			1	30

[1] There is more staff involved in the multidisciplinary consult than shown in this table. The staff not shown includes three more urologists, a pathologist and an internal oncologist.

4.2.3. Attendance of medical staff and time spent per staff member: observations

For the observations of HDR BT, which also have taken place at RISO, the data on medical staff is presented in the table below (Table 7). One observation started from core procedure 8 (preparing patient for treatment), while the other started from core procedure 9 (applicator insertion). Both measurements finished after core procedure 14 (applicator removal). The time measurement (in whole minutes) is presented for each staff member per core procedure. The medians of the time spent per staff member per core procedure are calculated. Also, a range of times is presented, which actually presents the measured times of both observations. In case both observations resulted in the same time, no range is presented. In the case of total times, the median and range is not obtained by adding the median times and minima and maxima of all core procedures together, but based on the total times of the two observations (i.e. for RT technician #1, 203 was the time measured for observation one, as 189 was the time measured in observation two, This gives a median of 196 with range 189-203). Note that in this case the median is equal to the mean, since there have only been two measurements.

Table 7

Attendance of medical staff and time spent per medical staff member for HDR brachytherapy for prostate cancer for core procedure 8 up to 14, according to observations

Procedure	8. Preparing patient	9. Applicator insertion	10. Imaging	11. Treatment planning	12. Verification and QA
Staff member	time in minutes [median (range)]	time in minutes [median (range)]	time in minutes [median (range)]	time in minutes [median (range)]	time in minutes [median (range)]
Rad. Onc. #1	35	39 (30-47)	19 (18-20)	80 (65-95)	17
Rad. Onc. #2	35	39 (30-47)	11 (10-12)	24 (18-30)	17
RT technician#1	35	39 (30-47)	19 (18-20)	80 (65-95)	17
RT technician#2	35	39 (30-47)	19 (18-20)	80 (65-95)	17
Anesthesiologist	5				
Anesthesia asst	35	39 (30-47)	19 (18-20)	80 (65-95)	17
Clinical physicist		25 (3-47)	12 (5-18)	80 (65-95)	17

Procedure	13. Treatment delivery	14. Applicator removal	Totals (8-14)	Totals (9-14)
Staff member	time in minutes [median (range)]	time in minutes [median (range)]	time in minutes [median (range)]	time in minutes [median (range)]
Rad. Onc. #1	13 (12-14)	11 (10-12)	196 (189-203)	179 (154-203)
Rad. Onc. #2			91 (77-105)	74 (70-77)
RT technician#1	13 (12-14)	11 (10-12)	196 (189-203)	179 (154-203)
RT technician#2	13 (12-14)	11 (10-12)	196 (189-203)	179 (154-203)
Anesthesiologist			5	0
Anesthesia asst	13 (12-14)	11 (10-12)	196 (189-203)	179 (154-203)
Clinical physicist	13 (12-14)	11 (10-12)	147 (102-191)	147 (102-191)

As can be seen in Table 7 (and Table 5 as well), the times for applicator insertion and treatment planning seemed to differ between both observations. This was for the same reasons as discussed in section 4.2.1. Especially for the involved personnel, there are also some other interesting points. First of all, for core procedure 8 the anesthesiologist was involved only 5 minutes to administer the anesthesia. Also, during core procedure 9 and 10, the clinical physicist was in only one case present for a (small) part of the duration of the core procedure, because of an emergency elsewhere. Thirdly, radiation oncologist #2 was in both cases only present during parts of core procedure 10 and 11 and left after core procedure 12. During treatment planning (core procedure 11), he only helped to contour organs and left when the treatment planning by means of software started.

4.2.4. Attendance of medical staff and time spent per staff member: follow-up interviews versus observations

When comparing the results of the follow-up interviews with the observations on medical staff for HDR BT, some interesting differences emerge. First of all, the radiation oncologist #2 was by far not as long present as one would expect based on Table 6. The biggest difference can be seen in the treatment planning (24 minutes observed vs. 75 minutes from the interviews). Also, in one case, the clinical physicist was not present during all core procedures in one observation, which does not correspondent with the results from the follow-up interviews. But, as said before, this was due to an emergency. Finally, the anesthesiologist was present for a much shorter time than one would expect based on the interviews (5 minutes in observations versus 18 minutes in interviews).

4.3 HDR brachytherapy in gynecological cancer

The results on the core procedures of HDR BT for gynecological cancer will be discussed in this section. On this subject, two professionals have been interviewed, both working for ARTI. As there have not been any observations for gynecological cancer, the results in this section are restricted to the follow-up interviews. First the results on the duration of core procedures will be presented. Then, the results on the attendance of medical staff and stand spent per medical staff member will be discussed.

4.3.1. Duration of core procedures

In Table 8, the overall duration of all core procedures of HDR BT for gynecological cancer is presented. The median of the durations per core procedure (rounded in whole minutes), as obtained from the interviews, are presented. Also, if applicable, a range of times is

presented. This range is determined by taking the shortest time given by the respondents and the longest time given by the respondents. In case all times obtained are the same and respondents have not given a range, no range is presented. The number of respondents and observations on each core procedure is given under the column *n*. For example, if three respondents gave a time for the duration of core procedure 5, *n* will be three. Total times are obtained by adding the median times and minima and maxima of all core procedures together.

Table 8

Duration of core procedures of HDR brachytherapy for gynecological cancer

Procedure	Duration in minutes	
	n	median (range)
1. Diagnosis	1	68 (60-75)
2. Multidisciplinary consultation	1	13 (10-15)
3. First consult	1	45
4. Informing patient	1	45 (30-60)
5. Preoperative consult	1	20
6. Preparing applicators	1	60
7. Admission of patient	2	360 (300-420)
8. Testing of afterloader	1	15
9. Preparing patient	2	45
10. Applicator insertion	2	41 (30-60)
11. Recovery (1)	1	45
12. Imaging	1	60
13. Treatment planning	2	103 (60-130)
14. Verification & QA	2	15 (5-20)
15. Treatment delivery	2	26 (15-35)
16. Applicator removal	2	10
17. Recovery (2)	2	98 (60-120)
18. Follow-up	1	440
Totals	2	1513 (1330-1677)

Two medical professionals working at ARTI have been interviewed on the duration of the core procedures of HDR BT in gynecological cancer. However, neither of the two respondent was able to give information on the duration of all the core procedures ($n < 2$). Contrary to LDR BT en HDR BT in prostate cancer however, for HDR BT in gynecological cancer one of the respondents was actually able to give an estimate for the duration of the diagnosis. When we look at the ranges of the duration of the core procedures, it is striking that, just as in LDR BT and HDR BT in prostate cancer, some of the ranges are rather wide. Core procedure 4 (informing patient), core procedure 7 (admission of patient) and core procedure 13 (treatment planning) for example show quite a wide range. This is due to difference between patients. Some patients for example have more questions than others, which results in a longer time needed to inform the patient. Also, the case of one patient can be more difficult than the case

of another patient, which might result in a longer duration of the treatment planning. Besides, some patients are simply admitted earlier than others for whatever reason. Furthermore, also the duration of core procedure 10 (applicator insertion) and core procedure 17 (recovery (2)) show a wide range. This is partly due to the fact that the respondents gave slightly different durations and to the fact that the case of one patient is more difficult than the case of another patient and some patients just recover faster than others. Finally, it has to be noticed that the total duration of all the core procedures is much longer that the total duration of all the core procedures of HDR BT in prostate cancer. The main reason for this is the longer duration of the admission of the patient and the follow-up. In HDR BT in prostate cancer patients are namely admitted on the evening the day before the procedure starts, while in HDR BT in prostate cancer the patient is admitted on the morning of the procedure, 30 minutes before the procedure starts. The large difference in the duration of the follow-up is most probably due to the fact that in the duration of the follow-up in HDR BT in gynecological cancer also the follow-up consults with the gynecologist are included, while in the duration of the follow-up in HDR BT in prostate cancer only the consults with the radiation oncologist (and not the consults with the urologist) are included. In addition, also the longer recovery of HDR BT in gynecological cancer compared to HDR BT in prostate cancer, and the fact that in the total duration of HDR BT in prostate cancer no time is included for the diagnosis, contribute to the large difference in the duration between HDR BT in gynecological cancer and HDR BT in prostate cancer.

4.3.2. Attendance of medical staff and time spent per staff member: follow-up interviews

Table 9 shows the attendance of medical staff and the time spent per medical staff member for HDR BT in gynecological cancer. The medians of the time spent per staff member per core procedure (rounded in whole minutes), as obtained from the interviews, are presented. Also, a range of times is presented. However, when all times obtained are the same and respondents have not given a range, no range is presented. Total times are obtained by adding the median times and minima and maxima of all core procedures. The number of respondents on each core procedure is given under the column *n*. For example, if three respondents estimated the time spent by a particular staff member on for example core procedure 5, *n* will be three. Also, the number of respondents on the total procedure is given.

Table 9.
Attendance of medical staff and time spent per medical staff member for HDR brachytherapy for gynecological cancer

Procedure	1. Diagnosis		2. Multidisciplin. consultation[1]		3. First consult		4. Informing patient		5. Preoperative consult		6. Preparing applicators		7. Admission of patient		8. Testing of afterloader		9. Preparing patient		10. Applicator insertion	
Staff member	n	time	n	time	n	time	n	time	n	time	n	time	n	time	n	time	n	time	n	time
Rad. Onc. #1	1	38 (30-45)	1	13 (10-15)	1	45											2	45	2	41 (30-60)
Rad. Onc. Asst																			2	41 (30-60)
BT technician#1							1	45 (30-60)			1	60			1	15	2	45	2	41 (30-60)
BT technician#2															1	15	2	45	2	41 (30-60)
Clin. Physicist			1	13 (10-15)																
Anesthesiolog.									1	20							2	45		
Anesthesia asst																	2	45	2	41 (30-60)
Gynecologist#1	1	68 (60-75)	1	13 (10-15)													1	45		
Gynecologist#2	1	38 (30-45)																		
Nursing staff													2	369 (300-420)						
OR nurse #1																	2	45	2	41 (30-60)
OR nurse #2																	2	45	2	41 (30-60)

Procedure	11. Recovery (1)		12. Imaging		13. Treatment planning		14. Verification and QA		15. Treatment delivery		16. Applicator removal		17. Recovery (2)		18. Follow-up		Totals	
Staff member	n	time	n	time	n	time	n	time	n	time		time	n	time	n	time	n	time
Rad. Onc. #1					2	53 (30-60)	2	15 (5-20)	2	16 (15-20)	2	10			1	220	2	500 (460-542)
Rad. Onc. Asst																	2	41 (30-60)
BT technician#1			1	60	2	73 (40-120)	2	15 (10-20)	2	26 (15-35)	2	10					2	400 (335-487)
BT technician 2			1	60[2]	2	73 (40-120)	2	15 (10-20)	2	16 (15-20)							2	275 (235-342)
Clin. physicist							1	5	1	18 (15-20)							2	40 (35-41)
Anesthesiolog.																	2	65
Anesthesia asst																	2	86 (75-105)
Gynecologist#1															1	220	1	345 (335-355)
Gynecologist#2																	1	38 (30-45)
Nursing staff	1	45											2	98 (60-120)			2	503 (405-585)
OR nurse #1																	2	86 (75-105
OR nurse #2																	2	86 (75-105)

[1] There is more staff involved in the multidisciplinary consult than shown in this table. The staff not shown includes one more radiation oncologist, three more gynecologist, two oncology nurses, a radiologist, and internist oncologist and a pathologist.
[2] The BT-technician#2 in core procedure 12 is in fact a physician's assistant.

When we look at table 9 the first thing that needs to be noticed is that, just as in the duration of the core procedure of HDR BT in gynecological cancer, one of the respondents was actually able to give the time spent per staff member for the first core procedure, i.e. the diagnosis. In addition, also in this table, a striking point is the wide ranges of the times spent by the medical staff members for some of the core procedures, i.e. informing patient, admission of the patient, applicator insertion, treatment planning and recovery (2). However, these wide ranges are caused by the same reasons as the wide ranges in the duration of these core procedures.

4.4 Duration of core procedures: HDR BT versus LDR BT for prostate cancer

In this final section a comparison of the duration of HDR BT and LDR BT for prostate cancer will be presented. To gain comparable data, the durations of all core procedures taking place before entering the operation room, in the operation room, and after leaving the operation room are compared. This data is only based on the median times given during the follow-up interviews. In Figure 10, a comparison of the duration of core procedures between HDR and LDR BT according to follow-up interviews is given

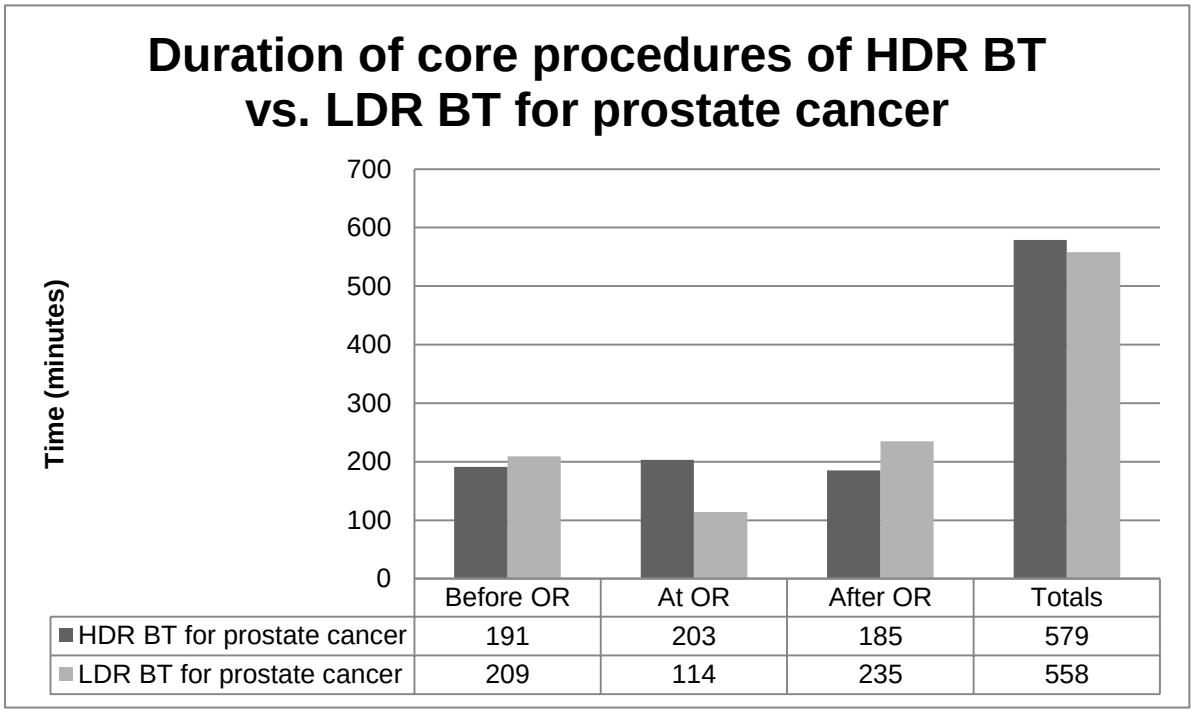


Figure 10. A comparison of the duration of core procedures according to follow-up interviews before, during and after OR for HDR and LDR BT for prostate cancer.

The first thing one will notice is that, although the OR-time for LDR BT is much lower than for HDR BT, the total times of both therapies seem to be quite comparable. The results show that for LDR BT the core procedures before and after the OR take more time than is the case

in HDR BT. This can partly be explained by the fact that for LDR BT the seeds have to be checked a certain period of time after treatment, and that a volume study is carried out. The treatment planning and applicator insertion cause a longer OR-time in HDR BT in comparison to LDR BT. Finally, some differences may be explained by the fact that for both therapies the group of respondents differed.

4.5 Resources needed for HDR and LDR BT for prostate cancer

Beside the time and attendance of medical staff involved, the second sub question also mentioned the resources needed in conducting the core procedures. This section will address the different disposable and non-disposable materials that are used during LDR BT and HDR BT in prostate cancer. Tables 10 and 11 will provide an overview of the needed resources for HDR and LDR BT for prostate cancer, respectively. An explanation of what the materials are used for can be found in appendix 3.

The inventory of materials needed is based upon the data as collected during the follow-up interviews at RISO in Deventer.

Table 10.
Resources needed for HDR BT in prostate cancer

Material	Used in core procedure	# used per patient	(non)-disposable
Ultrasound device	3, 9, 10	1	non-disposable
Condom	3, 9	1	disposable
Ultrasound gel	3, 9	1	disposable
Ultrasound probe	3, 8	1	non-disposable
Stepper	3, 9, 10	1	non-disposable
Table with leg supports	3, 9	1	non-disposable
Planning software Variseed	9	1	non-disposable
Computer with educational material	4	1	non-disposable
ECG device	5	1	non-disposable
Catheter	8	1	disposable
Infusion	8	1	disposable
Anesthetics	8	1	disposable
Gold marker	9	1	disposable
Needle	9	1	disposable
C-arm (Cone beam)	10,12	1	non-disposable
Carbon blade	10,12	1	non-disposable
Fixation needles	9	2	non-disposable
Needles	9	20	non-disposable
Lock-inserts	9	20	disposable
Template	9	1	non-disposable
Planning software Flexiplan	9, 11, 12	1	non-disposable
Afterloader	7, 13	1	non-disposable
Ruler	7	1	non-disposable
Source	7	1	non-disposable

Table 11.
Resources needed for LDR BT in prostate cancer

Material	Used in core procedure	# used per patient	(non)-disposable
Ultrasound device	3, 10,11,12	1	non-disposable
Condom	3, 10	1	disposable
Ultrasound gel	3, 10	1	disposable
Ultrasound probe	3, 8,	1	non-disposable
Stepper	3, 10,11	1	non-disposable
Table with leg supports	3, 10,11	1	non-disposable
Variseed	3, 10,11,12	1	non-disposable
Computer with educational material	5	1	non-disposable
ECG device	6	1	non-disposable
Ruler	7	1	non-disposable
Needles	7,9,10,11	23 - 28	disposable
Catheter	8	1	disposable
Infusion	8	1	disposable
Anesthetics	8	1	disposable
Gold marker	10	4	disposable
C-arm (Cone beam)	11,12	1	non-disposable
Carbon blade	12	1	non-disposable
Seeds	9, 11	70 - 80	disposable
Multidos-meter	9	1	non-disposable
Quickload loader	11	1	non-disposable
Links	11	35	disposable
Template	11	1	disposable

5. Conclusion & Discussion

The objective of this study was to develop a model, containing all the core procedures for each of the aforementioned treatment modalities and to provide an overview of the duration of the different core procedures, the medical staff involved, the time spent by the medical staff, and the resources needed in conducting these core procedures. Within this chapter, the results regarding the objective of the research will be summarized and interpreted, followed by the discussion of the strengths and weaknesses of this research.

5.1 Core procedures of brachytherapy

It can be concluded that the treatment process of LDR BT in prostate cancer consists of fifteen core procedures (Figure 2), the treatment process of HDR BT in prostate cancer consists of sixteen core procedures (Figure 4) and the treatment process of HDR BT in gynecological cancer consists of eighteen core procedures (Figure 6). In order to address the similarities, differences and their implications between the different treatment modalities, the core procedures are divided in three categories: preparatory, executive and checking phase.

Preparatory phase

Before the actual treatment takes place, several preparatory core procedures can be identified. All three treatment processes begin with the same preparatory core procedures; *diagnosis* by the urologist or gynecologist followed by a *multidisciplinary consultation*, a *first consult* with the radiation oncologist, *informing of the patient* by a brachytherapy technician, a *pre-operative consult* with the anesthetist and *admission of the patient* on the nursing ward. This is not remarkable, since these core procedures are more general procedures that are required for all treatments in which an operation room and anesthesia are involved.

However, in LDR BT an additional core procedure, *volume study*, takes place between the first consult and the informing of the patient. For two out of three institutes, this volume study is needed in order to place an order for the needed seeds during the treatment and therefore takes place during these preparatory core procedures. In HDR BT in gynecological cancer, the required applicators are being prepared between the pre-operative consult and the admission of the patient.

Executive phase

The executive phase starts from the moment that the preparatory core procedures are completed, thus from the moment that the patient is admitted to the nursing ward. Within this phase, the core procedures of the three treatment processes differ from each other. In

HDR BT (both in prostate cancer and gynecological cancer), first the *afterloader is tested* and thereafter the *patient is being prepared for treatment*. Subsequently, the HDR *applicator(s) are inserted*, *imaging* takes place and based upon this imaging a *treatment plan* is developed. Since the anesthesia in HDR BT in gynecological cancer is only needed for the applicator insertion, the additional core procedure of *recovery (1)* in this treatment process takes place between the applicator insertion and the imaging. Thereafter, *the treatment plan is verified* (including a quality assurance), the *treatment is delivered* and the *applicator(s) are removed*. On the other hand, in LDR BT, the *patient is prepared for treatment* right away. After preparing the patient, first a *quality assurance* takes place and then *the treatment is prepared* and *delivered*.
Although the differences, mainly in the number of core procedures, are obvious, LDR BT and HDR BT also have their similarities. Table 12 provides an overview of the main similarities between HDR BT and LDR BT.

Table 12.

A comparison of core procedures for HDR BT vs. LDR BT

Core procedure HDR	**Comparable core procedure LDR**
Testing of afterloader	No comparable core procedure (N.A)
Preparing patient for treatment	Preparing patient for treatment
Applicator insertion	Needle insertion as component of treatment delivery
Imaging	Imaging as component of preparing treatment
Treatment plan	Optional as component of preparing treatment
Verification	During treatment delivery and afterwards during the control phase (checking implanted seeds).
and QA	QA
Treatment delivery	Treatment delivery
Applicator removal	Needle removal as component of treatment delivery

Although on a more detailed level there are many differences between HDR BT and LDR BT, there are many similarities on a more general level. For example, in both treatment modalities needles/applicators are inserted before the treatment delivery and the QA is used for the determination of the level of radiation of the source. The differences on a more detailed level have their origin in the used source. In HDR BT, the source is temporarily placed within the patient by the afterloader that uses the treatment plan as guideline. Because there is no possibility for direct adjustment during the treatment delivery, the emphasis is more on the design and optimization of the treatment plan. In contrast to HDR

BT, in LDR BT the sources are permanently placed within the patient by the medical staff itself. The treatment plan, if there is any, in LDR BT is merely used as guideline for the placement of the needles and seeds. Due to the manual treatment delivery (and therefore the possibility for live adjustment), the emphasis in LDR BT is more on the placement of needles and checking the implanted seeds afterwards.

Checking phase

After the executive phase is finished, the patient goes to the recovery room and/or nursing ward to rest and after a while the patient is dismissed. Due to the emphasis on the implanted seeds in LDR BT, the seeds are checked right after the treatment delivery and again at four weeks after the procedure. In all treatment modalities the patient is being monitored (follow-up) by the radiation oncologist for a certain period of time.

5.2 Time, medical staff and resources

Within this section, the results regarding the duration of the core procedures and attendance of medical staff will be discussed for each of the three treatment processes: HDR BT and LDR BT in prostate cancer and HDR BT in gynecological cancer. The results regarding the resources needed in HDR BT and LDR BT in prostate cancer will be discussed afterwards.

5.2.1. LDR BT in prostate cancer

Based upon the information from the follow-up interviews, it can be concluded that the total duration of all core procedures (with the exception of *diagnosis*) is 558 minutes (9 hours and 18 minutes). Furthermore, it can be concluded that the core procedures that take place outside the operation room are the most time consuming in LDR BT; total durations of 209 minutes and 235 minutes for the procedures outside the operation room against 114 minutes for the procedures within the operation room. As mentioned before, this has to do with the origin of the therapy; the radioactive sources are permanently and manually placed within the patient. Therefore, the treatment delivery can be rather quick but the follow-up, in which the permanently radioactive resources are checked, is rather extensive.

These estimations about the duration of core procedures, however, are based upon data that was incomplete. For example, none of the respondents was able to give data about the duration and medical staff involved in the first core procedure, diagnosis, and besides that, respondents could not give a time for all the core procedures of LDR brachytherapy.

When the data regarding the duration of the core procedures from the follow-up interviews is compared to the data obtained from the observations, it seems that in general the core procedures as measured for LDR BT (98 minutes) take less time than was told during the follow-up interviews (114 minutes). This remarkability can be caused by the characteristics of the patients during whose treatment the researchers have observed. For example; one of the observations included a patient with a prostate that was rather easy to access and treat. Another remarkability is seen at the differences between the attendance of medical staff at the three centers. For example, ARTI is the only center that mentioned the attendance of OR nurses and the urologist. It is not clear why these differences exist between the three centers, since ARTI does not have much influence on the OR nurses and urologists as they are part of the medical staff of the Rijnstate hospital.

5.2.2. HDR BT in prostate cancer

Based upon the information from the follow-up interviews, for HDR BT in prostate cancer it can be concluded that the total duration of all core procedures (with the exception of *diagnosis*) is 579 minutes (9 hours and 39 minutes). Furthermore, it can be concluded that the core procedures that take place inside the operation room are the most time consuming in HDR BT with a total duration of 203 minutes for the procedures inside the operation room against 191 minutes and 185 minutes for the procedures outside the operation room. Just like in LDR BT, this has to do with the origin of the therapy; the radioactive sources are temporarily and non-manually placed within the patient. Therefore, the follow-up can be rather quick, but the phase in which the treatment plan for the delivery is developed is rather extensive.

As is also the case in LDR BT, these estimations about the duration of core procedures are based upon incomplete data. Again, none of the respondents was able to give data about the duration and medical staff involved for the first core procedure, diagnosis, and besides that, respondents could not give a time for all the core procedures of LDR brachytherapy.

When the data regarding the duration of the core procedures from the follow-up interviews is compared to the data obtained from the observations, it seems that in general the duration of core procedures as estimated during the follow-up interviews (203 minutes) is quite comparable to the times as measured for HDR BT (196 minutes). This comparable data can be caused by representative observations in which a rather “easy patient” was observed and a rather “difficult patient”.

5.2.3. HDR BT in gynecological cancer

According to the data from the follow-up interviews, the total duration of the core procedures as performed during HDR BT in gynecological cancer is 1513 minutes (25 hours and13 minutes). One must notice, that this total duration includes the duration of the core procedure *diagnosis*.

Also in this case, none of the respondents was able to give information on the duration of all the core procedures, however one of the respondents was able to give an estimation about the duration of the core procedure *diagnosis*.

In comparison to HDR BT in prostate cancer (579 minutes), the total duration of all the core procedures in HDR BT in gynecological cancer is much higher (1513 minutes). This difference is caused by the fact that the core procedure *diagnosis* (68 minutes) was included for HDR BT in gynecological cancer in contrast to HDR BT in prostate cancer. On the other hand, the duration of admission of the patient (360 minutes versus 30 minutes) and follow-up (440 minutes versus 65 minutes) was much longer for HDR BT in gynecological cancer than it was for HDR BT in prostate cancer. As mentioned before, the results of HDR BT in gynecological cancer were only based upon ARTI, where patients are admitted one day in advance and follow-up time includes both appointments with the radiation oncologist and the gynecologist. Data regarding HDR BT in prostate cancer was, on the other hand, only based upon RISO, where patients are admitted 30 minutes in advance and follow-up is less extensive.

5.2.4. LDR BT versus HDR BT in prostate cancer

Since the major part of data is collected regarding HDR BT and LDR BT in prostate cancer, the main differences between both therapies will be pointed out in this section. Based upon these differences, recommendations can be drawn for the daily practice in which brachytherapy is performed.

Although the OR-time for LDR BT is much lower than for HDR BT (114 minutes versus 203 minutes, respectively), the total times of both therapies seem to be quite comparable (558 minutes versus 579 minutes). This is because the duration of the core procedures before entering and after leaving the operation room is much higher for LDR BT than for HDR BT in prostate cancer; 209 minutes before and 235 minutes after leaving the operating room for LDR BT versus 191 minutes before and 185 minutes after leaving the operating room for

HDR BT. These differences can be explained by the therapies origins as mentioned before. LDR BT involves manually and permanently implantation of radioactive sources, resulting in a more extensive duration of two core procedures, namely preparation before entering the operating room (volume study) and more extensive check-up and follow-up after leaving the operating room (checking of the seeds). HDR BT involves the temporarily implantation of radioactive sources by means of the afterloader, which results in a more extensive duration of applicator insertion and treatment planning performed at the operating room.

5.2.5. Resources needed for HDR BT and LDR BT in prostate cancer

The resources used for HDR BT and LDR BT are mainly similar to each other, as can be seen in Tables 10 and 11. For example, in both HDR BT and LDR BT needles, templates, a CT and ultrasound are used. The main difference is that for HDR an afterloader (and its accessories) is used, and for LDR seeds (and their accessories) are used. Because it can be assumed that the afterloader is more expensive than the seeds, one might draw the conclusion that HDR BT is a more expensive therapy than LDR BT. However, it has to be taken into account that the afterloader is a non-disposable and can be used for a long period of time, while the number of seeds in LDR BT are disposable and have to be purchased for each patient (resulting in higher long-term costs). Therefore, costs might be approximately the same for both treatment modalities.

5.3 Recommendations for radiotherapy centers performing brachytherapy

Throughout this discussion of all the results as presented in this research, recommendations for the daily practice of brachytherapy can be made. First of all, some recommendations will be made that could save time during some of the core procedures or could improve the treatment process in other ways. After that, the differences between LDR BT and HDR BT are the basis for the recommendations made.

The first recommendation that can be made, based on the interviews, is that diagnostic imaging, in most cases by means of an MRI, has to be performed sufficiently by urologists during the first core procedure. Nowadays it is already supposed to be made by urologists, but in some cases the diagnostic images are not useful enough for some reason. Therefore, it is not exceptional that additional diagnostic images have to be made later on in the treatment process, for example after the multidisciplinary consultation or the first consult. Time could be saved when the urologist is encouraged to improve the diagnostic imaging he performs.

Another recommendation, based on the interviews, is the realization of better planning software, to reduce the time of one of the longest core procedure, treatment planning, in

HDR BT for prostate cancer. At the moment, the treatment plan as designed by software is lacking in quality and much time is needed to manually optimize the treatment plan. In addition to the improvement of the planning software, a system that automatically transfers the images made in the operation room to the planning computer should be developed. Nowadays, time is lost because images have to be transferred manually (by means of a USB-stick) from one computer to the other, and the transferred images have to be checked afterwards.

Although these recommendations intent to decrease the duration of the core procedures, decreasing time does not always result in better quality of the treatment process. For example, the long duration of the admission of the patient on the nursing ward in Rijnstate hospital could be seen as “time-consuming” or “inefficient”. However, for the patient this approach might be more desirable especially when travelling times are long. Focusing upon decreasing times of more technical procedures, such as treatment planning and diagnostic imaging could improve quality of care. But one should be careful with decreasing times such as patient admission and informing the patient, since these steps might not only decrease time but also the quality of care for the patient.

Although some recommendations have been made to improve quality of care and decrease inefficiency, an important remarkability has not been thoroughly addressed yet, namely the similarities between HDR BT and LDR BT in prostate cancer. Throughout literature and the interviews with different medical staff members, it became clear that the clinical effectiveness of both LDR BT and HDR BT in prostate cancer is as equal. On the other hand, the results from this research indicated that the total durations of both treatments are comparable to each other. With almost equal clinical effectiveness and duration, recommendations on the favorability of any of these treatment modalities can be made based on researches that determine the costs of the several procedures and staff. The models for the core procedures and the inventory of the duration of core procedures, attendance of medical staff involved en resources needed as presented in this research can be used as a guideline for this cost estimation.

5.4 Strengths and weaknesses

As mentioned before, the importance of radiotherapy in the treatment of cancer is increasing. At the moment, two main forms of radiotherapy are available for the patient; external beam radiation therapy and brachytherapy (internal radiation therapy). Although the clinical effectiveness of brachytherapy is comparable to the clinical effectiveness of external beam radiation therapy, the current literature has its main focus upon researches regarding

external beam radiation therapy. There is a lack of consistent and clear information regarding the content of the treatment process of brachytherapy, which has led to little understanding of this treatment process for one who is not directly involved in this process. The models, containing all the core procedures of brachytherapy, and especially the comprehensive description of these core procedures as presented in this research contributes to enlarging the understanding of the process of brachytherapy. It is of particular importance for compiling the content of the DTC's (Diagnosis Treatment Combinations) that are applicable for brachytherapy. Based upon a comprehensive description as provided in this study, one could determine which activities are included in a certain DTC. Based on the costs of these included activities, more appropriate tariffs for the several brachytherapy modalities can be determined. The quantitative data presented in this study, regarding the duration of the different core procedures, the medical staff involved and the resources needed for each treatment process allows one to make first rough estimates about the costs (of the core procedures) of brachytherapy.
On the other hand, both the qualitative data regarding the core procedures as well as the quantitative data regarding the duration of the core procedures can be used for health care providers in order to identify bottlenecks within the brachytherapy process and subsequently improve efficiency.

Although this research has its strengths, especially concerning the relevance of the study, several marks have to be made regarding to the results.
The first remark that can be made is the fact that the results are based on interviews with medical professionals from only three different radiotherapy centers. The influence of this low number of included radiotherapy centers is especially apparent in the results regarding HDR BT in prostate cancer and HDR BT in gynecological cancer. These results were merely based on data collected from just one center, since HDR BT in prostate cancer is only performed at RISO and data about HDR BT in gynecological cancer was only collected at ARTI, due to the studies' main focus upon prostate cancer. Besides the inclusion of only three radiotherapy centers, a remark can be made regarding the included respondents. Interviews were not held with all involved staff, but only with staff members who play a main role in the treatment process. Therefore, there is, for example, a lack of insight in administrative procedures within this study. Both the inclusion of only three radiotherapy centers and the inclusion of not all involved staff is due to full agendas of professionals in healthcare and the limited time to perform this study.

The qualitative data derived from the interviews and observations has resulted in the design of three models with a certain level of detail. However, the desired level of detail was not always obvious during the interviews and therefore not all details were discussed with all respondents. During the design of the models, efforts were made to equalize the level of detail but there is still a possibility that there are differences between the models. For example, the core procedure 'preparing applicators' has been included in the model of HDR BT in gynecological cancer, but not in the model of HDR BT, even though this most probably also takes place in HDR BT in prostate cancer.

This difference in level of detail is not the only remark that can be made regarding the design of the models. The models and description of all three treatment processes are based on LDR BT and HDR BT as primary treatment, even though in any case HDR BT, and at some centers also LDR BT, is given as a boost after EBRT. This might have led to the inclusion or exclusion of core procedures that actually are not performed in the three radiotherapy centers. For example, the diagnosis as core procedure is not performed when brachytherapy, either LDR or HDR, is given as boost.

Another remark can be made about the quantitative data regarding time, medical staff and resources**.** While for almost all identified core procedures information about the attendance of medical staff and time spent per core procedure is obtained, this is not the case for the whole process, i.e. all core procedures together. Instead, total times were derived by means of summation of times of separate core procedures.

Concerning the resources inventory, the results were based on only one interview within one institute. In case there would have been interviews on this matter with respondents within the other two centers as well, results could have been slightly different. For example, these institutes might use other imaging techniques and the use of gold markers might be institute-specific. However, no major differences within the current inventory based upon one institute are expected. All institutes do need, for example, needles in LDR brachytherapy. The remark regarding the incompleteness of the inventory however is of higher importance. Not all materials are included, since composing a complete list of resources has turned out to be not feasible during this short period of time. The incompleteness is mostly visible on the area of disposables, but non-disposables such as monitoring equipment have not been included as well.

In conclusion, it can be said that although there are several remarks regarding the results of this research, the objective to design a model which presents the core procedures for each

included treatment modality along with the objective to determine the time spent per medical staff member per core procedure and the resources needed in conducting these core procedures has been achieved. However, the question remains whether and to what extent these results are externally valid and thus can be generalized. Due to the low number of respondents, resulting from the low number of included radiotherapy centers, the results of this research cannot be nationally or internationally generalized. However, this did not implicate that the designed models and the inventory of time spent per medical staff member and resources needed per core procedure are useless. The methods as developed for this study can be used nationally or internationally within a larger follow-up study with the inclusion of more radiotherapy centers and respondents. Furthermore, the models and the inventory studies can be used in order to compile the content of DTC's regarding brachytherapy, make rough estimations about the related costs and appropriate DTC-tariffs and identify bottlenecks within the brachytherapy process.

5.5 Conflict of interest

As mentioned in the colophon, this research was commissioned by the University of Twente and Nucletron BV, an Elekta company. There is not, nor will be, any financial, material or other compensation or reward granted or agreed between the University of Twente and/or the students personally, and Nucletron BV.
Dr. Lotte Steuten is, in addition to her employment as associate professor at the University of Twente, in the capacity of Director of Health Economics and Market Access of PANAXEA BV, a paid consultant for Nucletron BV. Supervising the research, however, falls entirely within her academic employment and responsibility.

The relationship between the researchers and Nucletron BV might have influenced the respondents. Views expressed in this thesis are solely the authors.

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7. Appendix

Appendix 1. Respondents

The results within this thesis were based upon several interviews with different medical professionals. In order to thank them all for their participation, this appendix enumerates all the respondents.

Radiotherapeutisch Instituut Stedendriehoek en Omstreken (RISO)

Dr. T.T. Nuver (Clinical physicist)
Dr. C.J.M. Hoekstra (Radiation oncologist)
Mw. A. van der Molen (Brachytherapy technician)
Ir. H. Westendorp (Clinical physicist)

Arnhems Radiotherapeutisch Instituut (ARTI)

Drs. R.B. Keus (CEO and radiation oncologist)
Drs. M.A.D. Haverkort (Radiation oncologist)
Dhr. T. Janssen (Brachytherapy technician)

University Medical Center Utrecht (UMCU)

Dr. J.L. Noteboom (Radiation oncologist)

Appendix 2. Sheet attendance of medical staff and resources

LDR BT for prostate cancer

1. DIAGNOSTICS		
Staff member	#	Time spend
Materials	#	

2. MULTIDISCIPLINARY CONSULTATION		
Staff member	#	Time spend
Materials	#	

3. FIRST CONSULT		
Staff member	#	Time spend
Materials	#	

4. VOLUME STUDY		
Staff member	#	Time spend
Materials	#	

5. INFORMING PATIENT		
Staff member	#	Time spend
Materials	#	

6. PRE-OPERATIVE CONSULT		
Staff member	#	Time spend
Materials	#	

7. ADMISSION PATIENT		
Staff member	#	Time spend
Materials	#	

8. PREPARING PATIENT FOR TREATMENT		
Staff member	#	Time spend
Materials	#	

9. QUALITY ASSURANCE		
Staff member	#	Time spend
Materials	#	

10. PREPARING TREATMENT		
Staff member	#	Time spend
Materials	#	

11. TREATMENT DELIVERY		
Staff member	#	Time spend
Materials	#	

12. CHECKING IMPLANTED SEEDS I		
Staff member	#	Time spend
Materials	#	

13. RECOVERY		
Staff member	#	Time spend
Materials	#	

14. CHECKING IMPLATED SEEDS II		
Staff member	#	Time spend
Materials	#	

15. FOLLOW-UP		
Staff member	#	Time spend
Materials	#	

HDR BT for prostate cancer

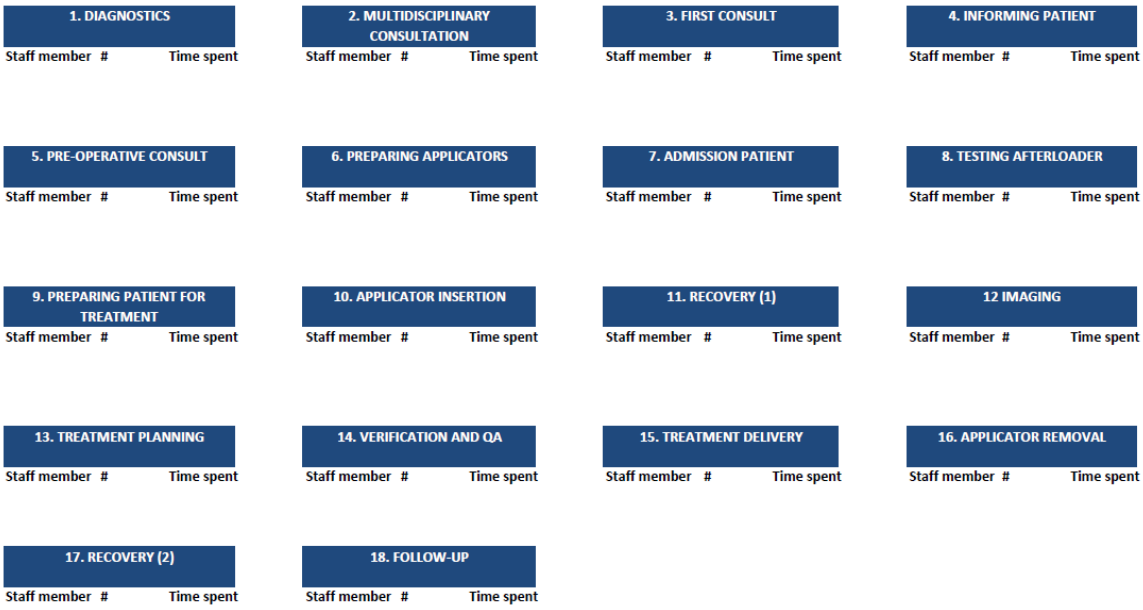
1. DIAGNOSTICS		2. MULTIDISCIPLINARY CONSULTATION		3. FIRST CONSULT		4. INFORMING PATIENT	
Staff member #	Time spent	Staff member #	Time spent	Staff member #	Time spent	Staff member #	Time spent
Materials #		Materials #		Materials #		Materials #	

5. PRE-OPERATIVE CONSULT		6. ADMISSION PATIENT		7. TESTING OF AFTERLOADER		8. PREPARING PATIENT FOR TREATMENT	
Staff member #	Time spent	Staff member #	Time spent	Staff member #	Time spent	Staff member #	Time spent
Materials #		Materials #		Materials #		Materials #	

9. APPLICATOR INSERTION		10. IMAGING		11. TREATMENT PLANNING		12. VERIFICATION AND QA	
Staff member #	Time spent	Staff member #	Time spent	Staff member #	Time spent	Staff member #	Time spent
Materials #		Materials #		Materials #		Materials #	

13. TREATMENT DELIVERY		14. APPLICATOR REMOVAL		15. RECOVERY		16. FOLLOW-UP	
Staff member #	Time spent	Staff member #	Time spent	Staff member #	Time spent	Staff member #	Time spent
Materials #		Materials #		Materials #		Materials #	

HDR BT for gynecological cancer



NB: Materials for HDR Gynecology were not included in this research

Appendix 3. Description of materials used for brachytherapy

Resources used for both HDR and LDR brachytherapy in prostate cancer

- **Ultrasound device (Flexfocus)** makes an ultrasound (real time or an image), which is a radiological examination with ultrasound waves. It is used to make body parts and internal organs more apparent, like the prostate. By means of an ultrasound the radiotherapist is able to decide which treatment the patient should get. Also it is used during the whole treatment as real time view and several images of it are taken. In LDR brachytherapy, the ultrasound is used for volume studies as well.
- **Ultrasound probe** is a tool that makes it possible to get the ultrasound in the rectum and is used for positioning the ultrasound transducer in a fixed and predetermined position in a patient.
- **Condom** is used on the ultrasound probe to provide hygienic protection for patient (and doctor) during ultrasonic examinations.
- **Ultrasound gel** is used to facilitate the insertion of the ultrasound probe in the patient.
- By attaching the ultrasound probe to the **stepper**, ultrasound images can be made from different depths in the prostate.
- **Table with leg supports** is used for a well positioning of the patient for the operation. It makes the operation area better visible and accessible for the radiotherapists.
- **Computer with educational material** is used to explain what will happen during the treatment by means of digital images and to inform the patient on the diet which he has to comply.
- **ECG device** makes an electrocardiogram during the pre-operative consult. By this test issues with the electrical activity of the heart are checked to rule out any risks.
- **Ruler** is a tool that is used to measure the accuracy of the positioning of afterloader system. The source is sent by the afterloader to a specific point at the rulers scale. Deviation from this specific point means that the afterloader cannot accurately position the source during the treatment.
- **Catheter** is a tube, which is inserted into a patients bladder via the urethra. Catheterization allows the patient to urinate freely during the treatment.
- **Infusion** is used to give continuous necessary liquids during the whole treatment.
- **Anesthetics** are given whereby spraying anesthetic in the spinal fluid numbs the lower body. The spinal anesthesia is administered by an anesthesiologist.

- **Gold marker** is clearly visible on CT and ultrasound scans. Therefor it is used for CT-US fusion for improved delineation of the prostatic gland. Gold markers do not migrate within the prostate.
- **C-arm (Cone beam)** is an X-ray machine that looks like a C. Because the C-arm rotates around the patient, all areas are easily and quickly visualized. The images which are made for brachytherapy by means of the ‘’C-arm” are CT scans, AP photos and X-ray scans.
- **Carbon blade** is a radiation table made of carbon. This material is very light, strong and radiation permeable. When the ‘’C-arm” is used for imaging the carbon blade is laid down under the patient.
- **Planning software (VariSeed)** is a seed planning system for LDR brachytherapy, which provides clear visibility of the positions of individual seeds during permanent seed implantation. Also it is used for contouring organs, planning dose rate, checking the amount of seeds etc. In HDR brachytherapy it is only used for imaging during several procedures of the treatment.
- **Template** is used to insert the needles through, to control their spacing. In LDR brachytherapy this template is used for just one patient in contrast to HDR brachytherapy, in which it is used a couple of years for several patients.

Resources used for HDR brachytherapy in prostate cancer

- **Afterloader (Flexitron)** is an HDR machine, which contains the radioactive sources in a shielded safe. Once the applicators are correctly positioned in the patient, they are connected to this afterloader system through a series of connecting transfer tubes. The treatment plan is sent to the afterloader, which controls the delivery of the sources along the transfer tubes into specified positions within the applicator (in the prostate). The sources remain in place for a specified length of time, again following the treatment plan, subsequently they return along the tubes into the afterloader.
- **Planning software (Flexiplan)** is a planning system that is used for determining the needed radiation and the intended positions of the radiation sources during the treatment planning in HDR brachytherapy.
- **Fixation needles** are used in HDR BT to attach the template to the prostate.
- **Lock-inserts** are used to ensure fixed position of each needle when adjusting another needle.
- The **source** used in HDR brachytherapy is a single high-intensity radiation source on the end of a thin cable that is inserted temporarily. The usage duration of this radiation source is just three months, because the intensity of the radiation declines 50%.
- The amount of **needles** (also called applicators) that are used in HDR brachytherapy is about 20. The needles are used to deliver the high intensity radiation source into the prostate. These needles are non-disposable, because they are used for five different patients.

Resources used for LDR brachytherapy in prostate cancer

- In LDR brachytherapy a large number of uniform strength **seeds** are inserted into the prostate permanently, as individual free seeds or connected by strands. Half of the seeds are already prepared before treatment.
- **Links** are used in composing the seeds in strands.
- **Multidos-meter** is a tool, which enables the brachytherapy technician to compose strands of seeds with the desired level of radiation.
- **Quickloader** is a device that is used to compose seeds and links in a desired strand.
- In LDR brachytherapy **needles** are used to position seeds (individual or connected by strands) into the prostate. For treatment delivery about 20-25 needles are used. For inserting the gold markers 2 needles are used and for QA (measurement of seeds) also 1 needle. These needles are disposable, because they are used just for one treatment.