VIPER – Virtual Patient Education in Radiotherapy

Design, Development, and Utility Testing of a 3D Patient Information Tool

Master Thesis

For attainment of the academic degree of
Master of Science in Engineering (MSc)

in the Master Program Digital Healthcare
at St. Pölten University of Applied Sciences

by
Alexander Raith, BSc
[1510756817]

First advisor: Andreas Jakl, MSc
Second advisor: FH-Prof. Jakob Doppler, MSc

[St. Pölten, 14.05.2017]

Declaration

I declare that I have developed and written the enclosed Master Thesis completely by myself, and have not used sources or means without declaration in the text. Any thoughts from others or literal quotations are clearly marked. This work was not used in the same or in a similar version to achieve an academic grading or is being published elsewhere.

St. Pölten, 14.05.2017 A. RAITH

....

Place, Date Signature

Preface

I would like to thank my first advisor

Andreas Jakl, MSc

and my second advisor

FH-Prof. Jakob Doppler, MSc

for the motivation and assistance provided during the writing of this thesis.

This thesis is dedicated to my wife

Babsi

my parents

Leopold & Ursula

and my sister

Julia

who have supported and endured me throughout the whole study.

Abstract

Currently, approximately 39,000 people are diagnosed with cancer every year in Austria. The current literature says that approximately 50% of the cancer patients can benefit from radiotherapy. A safe diagnosis is important, and that is why image-based methods and biopsies are usually performed to diagnose cancer. There are several methods of treatment such as surgery, chemotherapy, hormone therapy, immunotherapy, and radiotherapy. In Austria, the therapy best suited for an individual patient is decided by a tumor board comprising different specialists.

If the board decides to use radiotherapy, many patients feel nervous about the first irradiation because of the unknown process and its possible side effects. Since a radio oncologist is the most widely used and trustworthy source of information for radiotherapy patients, a novel system called VIPER has been developed to support patient education. VIPER is a virtual patient-education system, which describes the treatment process through a hologram in a Mixed Reality setting to improve understanding and to reduce patients' anxiety before the first irradiation.

A finished prototype of the program is then provided to health professionals, who are entrusted with patient education in radiotherapy. After testing the VIPER prototype, the program is evaluated with the help of a questionnaire.

Overall, VIPER received mostly positive feedback from experts. On the one hand, the participants believed patients can better understand the irradiation process and, thus, reduce their anxiety.

Kurzfassung

In Österreich erkranken ungefähr 39.000 Personen jährlich an Krebs. Laut Literatur können zirka 50% der Patienten von der Behandlung durch eine Strahlentherapie profitieren. Es ist allerdings äußerst wichtig, eine gesicherte Diagnose zu stellen. Dafür kommen radiologische, bildgebende Verfahren oder Biopsien zum Einsatz. Zur Behandlung von Krebs können Operationen durchgeführt oder Chemotherapie, Hormontherapie, Immuntherapie bzw. eine Strahlentherapie angewendet werden. Welche Behandlungsmethode am geeignetsten ist, wird in Österreich durch das Tumorboard entschieden, in dem Fachärzte jeden Fall individuell besprechen und eine geeignete Therapie festlegen.

Wenn eine Strahlentherapie durchgeführt werden soll, löst dies oft zusätzliche Ängste und Sorgen bei den PatientInnen aus. Ein Grund dafür ist der unbekannte Behandlungsablauf und die Angst vor möglichen Nebenwirkungen. Da der/die RadioonkologIn die meistgenutzte und vertrauenswürdigste Informationsquelle für StrahlentherapiepatientInnen darstellt wurde VIPER entwickelt um den Patientenaufklärungsprozess positiv zu unterstützen. VIPER ist ein virtuelles Programm, welches den Behandlungsablauf einer Bestrahlung mit Hilfe eines Hologramms in einem Mixed Reality Szenario erklärt und so das Verständnis der PatientInnen steigern sowie die Angst senken soll.

Der fertige Prototyp von VIPER wurde GesundheitsexpertInnen, welche die PatientInnenaufklärung in der Strahlentherapie durchführen, zum Testen zur Verfügung gestellt. Nach dem Test konnte das Programm durch einen Fragebogen evaluiert werden.

VIPER erhielt größtenteils sehr positives Feedback durch die Teilnehmer. Einerseits gehen sie davon aus, dass das Programm das Verständnis der PatientInnen steigert und gleichzeitig die Angst vor der ersten Bestrahlung senkt.

Table of Contents

1 Introduction

Currently, approximately 39,000 people are diagnosed with cancer every year in Austria [1]. According to calculations by the Federal Ministry of Health, the incidence of cancer in Austria will increase from 38,218 in 2009 to 41,299 in 2020 (+8%) and, by 2030, to 43,706 (+14%). In accordance with a constant variant, which measures the influence of the aging process, the long-term increase by 2030 will be 29% to 49,449 new cancer patients [2]. Current literature says that approximately 50% of the cancer patients can benefit from a curative therapy approach and another 50% from palliatives [3].

1.1 Problem

Most patients have big concerns about radiotherapy because this treatment is perceived as bad news. Despite good patient education, many cancer patients feel psychological distress and anxiety, especially before and during their very first radiotherapy session. The main reason for this anxiety before the first irradiation is mainly the concern about the side effects of the therapy and an unknown process, the loneliness in the treatment room during irradiation, the large treatment devices and an unusual noise [4]. VIPER was developed to minimize this anxiety about the first treatment during a patient education session. This is a Mixed Reality (MR) program, which visualizes the treatment process with the help of a hologram. It is intended to increase the radiotherapy patients' understanding of the treatment. Therefore, it is of interest to know whether MR or Virtual Reality (VR) devices are already used in the treatment and the education of cancer patients, and whether VIPER has a positive influence on patient education from the perspective of health professionals in radiotherapy. This leads to the following research questions.

1.2 Research Questions

1) Which medical procedures for cancer patients are being already performed using VR/MR tools?
2) What is the impression of health professionals (oncologists, radiologic technologists) in radiotherapy regarding the utility and acceptance of VIPER?

1.3 Structure and Method

To better understand the anxiety of cancer patients, the path of the patients to radiation therapy is explained at the beginning of the master thesis in the chapter, Theoretical Background. For this chapter, mainly literature in the form of specialist books is used.

Then, the scientific background is examined to evaluate the extent of anxiety dependent on a specific point in time during the radiation therapy and to identify the preferred and trustworthy information sources of cancer patients. To ensure the currency of the information, only studies published in professional journals after 2010 are used.

Subsequently, the first research question will be addressed. Since VR devices have already been available for some time, the answer to the question is based on studies from professional journals published in the last 15 years.

Afterwards, VIPER production and programming is explained and the result of a utility test with experts is presented.

The work is completed with a discussion on the test results and ends with the conclusions of the master thesis.

1.4 Goals

The aim of this work is to demonstrate the use of VR/MR tools in the treatment of cancers and to develop a prototype of the virtual patient education program for radiotherapy patients. An additional goal is to evaluate the utility and the acceptance of such modern patient education methods.

2 Theoretical Background

This chapter describes the path of a cancer patient to the first irradiation and a variety of diagnostic options for cancer diagnosis. After that, the treatment capabilities are presented and the choice of a suitable line of treatment made with the help of a tumor board is shown. Since the developed VIPER application is used in the field of radiotherapy, the course of a radiation therapy is explained right from the first patient information talk until the first irradiation.

2.1 Diagnostics

A cancer diagnosis has to be 100% certain before a patient is confronted with it. To ensure this, a lot of diagnostic procedures can be adopted. Cross-sectional imaging modalities are most frequently used for this purpose. These modalities include, for example, computed tomography or magnetic resonance imaging. But ultrasound or nuclear medicine diagnostics, too, can be used. The mentioned processes are non-invasive but an invasive biopsy is often performed for additional confirmation of the medical findings. All these important procedures for cancer diagnosis will be outlined in this chapter. It is rare that a cancer diagnosis is confirmed by just one diagnosis option. Only a combination of several methods and procedures ensures the result.

2.1.1 Ultrasound

Ultrasound is the most frequently used – and usually the first – cross-sectional imaging modality in a series of diagnostic imaging procedures. Besides radiologists, this process is also used by internists, gynecologists, urologists, dermatologists, and many more medical specialists. The advantages of ultrasound devices are that they are cheap, there is no radiation exposure, they are non-invasive, and multiplanar images are possible. On the other hand, the quality of the data and the pictures is largely dependent on the investigator's experience, the examination is susceptible to artifacts, and no gapless documentation is possible.

The sound propagates in the tissue (as in the air) as a longitudinal wave. In medical ultrasound imaging, very high frequencies are used (megahertz range). A short ultrasonic pulse is emitted by a transmitter, spreads in the tissue, hits a boundary (e.g. bones/muscles) and a part of the signal is reflected and detected by the

receiver. Since the duration of the reflection is known, a depth localization is possible (e.g. for a malignant tumor). Ultrasound has a high diagnostic validity, especially for the anatomy and pathology of parenchymal organs, e.g. heart, liver spleen, and kidneys.

An accurate cancer therapy is not possible without localization, knowledge of tumor dimensions and the accurate shape of the malignant tissue. Therefore, ultrasound is extremely important for exact cancer diagnosis because of a combination of good diagnostic significance and excellent depth localization [5].

2.1.2 Computed Tomography

The computed tomography (CT) is a process for creating cross-sectional images using x-ray. The relevant part of the body is exposed to the radiation and the absorption of the x-rays is determined. In the beam path lie different tissues with different absorption characteristics. The absorption differences will be measured and then displayed in transverse body layers.

Contrary to conventional radiographs – which are summation pictures – CT datasets are substitution pictures (non-overlapping displays of different structures with spatial delineation). That is the reason why an accurate localization and the exact volume of the individual organs and pathologies (e.g. cancer) are possible. A movable examination table is used for ideal patient positioning. This exact possibility of patient positioning is crucial for an expressive diagnosis process.

Another advantage of CT is that the density of each structure passed by the x-ray beam can be measured. The different density values are displayed in different grey scales. These scaled values, explained in Chapter 2.4, are called “Hounsfield Units” (HU) and are very important for radiotherapy treatment [6].

2.1.3 Magnetic Resonance Imaging

Magnetic Resonance Imaging (MRI) is an extremely complex area of medicine. The basis of this procedure is the resonance absorption of magnetic cores and subsequent relaxation by interaction with surrounding atoms and molecules [7]. The big advantage is the excellent contrast of soft tissues – especially in the head – and the absence of radiation use. The disadvantages are the missing Hounsfield units and the possibility of a problem occurring with metallic implants because of the magnetic field [8].

2.1.4 PET-CT

The basic principle of Positron Emission Tomography (PET) consists of determining the three-dimensional (3D) distribution of a radiopharmaceutical (fluid that is injected before the examination starts) containing a positron emitter within

the patient. In contrast to other imaging procedures in this chapter (CT, MRI), the signal emerges from within the patient's body.

Owing to the intense detection capabilities of the signal, very small amounts of the pharmaceutics are required. The PET itself has a relatively low spatial resolution, limited possibilities to co-register, and restricted anatomical localization of lesions.

Therefore, a combination of PET and CT (PET-CT) has been formulated. Through this, it is possible to perform both studies without changing the patient position, leading to better anatomical orientation and better pathological findings. The PET shows a higher sensitivity to tumor tissue in comparison to CT or MRI and, hence, the combined PET-CT is a very helpful solution in cancer diagnostics. At the end of the procedure, a dataset with CT-images combined with the functional information provides a good basis for exact cancer detection [9].

2.1.5 Mammography

Mammography is a special imaging technique for the breast. In a mammography, the breast gets compressed and two x-ray images are taken from different angles. So far, mammography has been the only imaging mode suitable for screening in women without increased risk for breast cancer. Within the framework of national programs, mammography is used as the sole screening method. For women with increased risk, MRI is performed additionally.

Mammography has a high sensitivity and acceptable specificity, and is also inexpensive, non-invasive, reproducible, and well documentable. When pathology is detected (e.g. cancer), a classification into BI-RADS categories is done. There are categories from 1 (no result, normal mammography), over 4 (unclear finding, histological clarification necessary) to 6 (histopathologically verified cancer, appropriate actions must be taken) [10].

2.1.6 Biopsy

A lesion found in radiographic imaging does not always have to be malignant. To be safe, there is the option of a biopsy. In this examination parts of the unknown tissue will be removed. The patient's sample is sent to a pathologist for examination. All forms of cancer must be diagnosed by this procedure. Many different types of biopsies are possible and are used for exact cancer diagnosis.

Fine needle aspiration biopsy (FNA)

A very thin, hollow needle attached to a syringe is used to take out a sample of tissue or fluid from the tumor. Feeling the tumor can help the doctor to aim the needle, if it is near the body surface. If the tumor is deep inside the body, an ultrasound- or CT-guided biopsy can be done. The big advantage of this procedure

is that the skin does not have to be cut and a quick diagnosis is possible. On the other hand, the needle cannot remove enough parts of the tissue and a definite diagnosis is not possible.

Core biopsy

Needles used in this biopsy are a little bigger than those used in a fine needle aspiration biopsy (FNA). The core biopsy is done with local anesthesia and has the same advantages and disadvantages as the FNA. The chance of getting an insufficient amount of tissue is lower because of the use of bigger needles.

Excisional or incisional biopsy

The excisional biopsy is like an operation. Regional or general anesthesia is used to ensure the patient does not feel the cut through the skin. If the surgeon removes the entire tumor, the process is called an excisional biopsy. If it is not possible to remove the entire tumor mass and only small parts are extracted, then is called incisional biopsy [11].

2.2 Treatment Options

After the diagnosis of cancer by imaging procedures and biopsies, it is important to know which treatment methods are applicable to fight the disease. In the following subchapter, the treatment possibilities will be explained to better appreciate how hard a decision can be for the patient.

2.2.1 Surgery

Surgery can be used to treat, diagnose, and prevent cancer. It can also palliate problems or discomfort related to cancer. Sometimes, one surgery is enough to take care of these goals. In other cases, several different operations are necessary [12].

Curative Surgery

After a definitive cancer diagnosis, surgery is used as an attempt to destroy or remove cancerous tissues. When the aim of surgery is curative, the goal is to remove the malignant tissue completely. To ensure this, healthy tissues around the tumor is also removed. This approach should guarantee that no tumor cells remain in the operating area. There are many types of curative surgery, usually named after the area in which the physician is operating. For example, a prostatectomy is the removal of a tumor located in the prostate and the prostate itself. In addition to scalpels, lasers are also used in modern curative operations. Laser surgery uses a beam of light, which can be aimed at specific organs in the

body to damage and destroy cancer cells. Compared to scalpels, a laser is more precise and saves time.

Another possible curative surgery method is cryosurgery. A very cold liquid probe is used to kill cancer cells. It can be used for external and internal tumors.

The stage and the size of the tumor play a significant role in the choice of the operation method. Whether an operation can be called curative also depends on the tumor volume and localization, and, additionally, on age, general health conditions, and possible metastasis [13].

Palliative Surgery

Palliative treatment means to ease or relieve uncomfortable symptoms associated with advanced cancer. These symptoms can be in the form of a pain, inability to move as usual, hemorrhage, or vomiting. Palliation has no real effect on the potential survival chances but the aim is to improve the quality of life.

One type of palliation is palliative surgery. This surgery is a branch of surgical oncology, in which decision-making is very complex and requires a multi-disciplinary approach. Extra-abdominal metastases, poor general condition, poor nutritional status, advanced age, and previous radiation therapy may be a contraindication for palliative operations. In 64% of cases, a palliative surgery has been found to be beneficial (good outcome) for symptomatic patients [14].

Prophylactic surgery

This kind of surgery is done to remove tissues that are likely to become cancerous. This option is chosen even when there is no sign of cancer at the time of the operation. Pre-cancerous polyps, for example, may be removed during a colonoscopy. Sometimes, an entire organ is removed, if a patient has an inherited condition enhancing the risk of having cancer someday. These conditions can be a strong family history of breast cancer or an inherited mutation in a breast cancer gene. Owing to the elevated risk getting breast cancer, women with such a background may want to consider a preventive mastectomy (removal of both breasts) before any cancer cells are found [15].

Debulking Surgery

The term debulk means to surgically reduce the size of a tumor as much as possible. The term debulking surgery does not indicate how much of the tumor is to be removed or the type of procedure to be used. The only thing that is really known is that the tumor is not be completely removed [16].

For a better understanding, this operation method is explained by the example “ovarian debulking”. In this case, the physician tries to remove the ovaries, the body of the uterus, the cervix, and the omentum. This is done because ovarian

cancer has the propensity to spread to these areas. The aim of this operation is to remove as much of cancer as possible. The fewer the cancer cells in the body the better the cell response to chemotherapy [17]. This treatment method is explained in the next subchapter.

2.2.2 Chemotherapy

This therapy uses drugs to reduce or kill cancer cells or slow their growth. These drugs are also called cytotoxics (cyto = cells, toxic = poisonous). These drugs can be obtained from natural sources such as plants, but they can also be developed in the laboratory. The types of drugs are varied and can be used in various combinations and strengths. Mostly, the drugs enter the bloodstream and reach the cancer cells in different organs by traveling throughout the body.

The drugs used for chemotherapy damage all cells but especially the rapidly dividing ones. The damage caused to healthy cells can evoke side effects. Malignant cells do not repair easily, regaining more slowly than healthy cells. In between the chemotherapy treatments, the damaged normal cells are able to recover, while the cancer cells cannot do so. This means that more malignant cells are destroyed with every treatment.

The reasons for giving chemotherapy are individual. The aim mostly is to cure cancer. Chemotherapy can be administered alone or in combination with other treatments. Sometimes, this type of therapy is used to control cancer. This happens when the cancer is too advanced and cannot be cured. In this case, chemotherapy can also be used to reduce cancer symptoms like pain or hampered movements of body parts. This is a palliative treatment, like palliative surgery described in subchapter 2.2.1 [18].

Chemotherapy can be given in different ways:

- orally (by mouth)
- by injection into a muscle or soft tissue
- by injection into an artery or vein
- by injection into a body space
- directly on the skin

Usually a cancer specialist – called oncologist – plans a cancer patient's treatment with chemotherapy. The drugs can be given by the doctor or a nurse. The place where chemotherapy is given also depends on specific cases. It can be in an ambulatory care center, at home or in a hospital. The length of this therapy depends on the grade and location of the cancer and can be a single chemotherapy or several sessions partitioned over multiple weeks. Since it damages healthy cells, chemotherapy can have many side effects like bone marrow depression, infections, bleeding, anemia, loss of appetite, changes in taste

and smell, sore mouth and throat, nausea and vomiting, diarrhea, constipation, fatigue, and hair loss [19].

2.2.3 Hormone therapy

Hormones produced naturally in the body can have a growth-promoting effect on the cells of certain organs. The cells of the organs influenced by hormonal effect have hormone receptors that mediate its effect in the cell, and in the cell nucleus, as a control center. Tumor cells, which occur due to changes in normal cells of the organs, also have hormone receptors. These receptors of the tumor cells are stimulated by the impact of the hormones to grow and divide. When the impulse for cell division triggered by the hormones is removed, the tumor growth may be slow down or even stop for an extended period of time. This procedure is called hormone therapy or endocrine therapy. Though it is called hormone therapy, in a way it is also anti-hormone therapy because the hormone effects are stopped [20].

In breast cancer and cancer of the uterus, the female sexual hormone estrogen fuels the growth-promoting effect. In case of prostate cancer, it is the male sex hormone testosterone. There are several ways to eliminate hormones or to neutralize their impact. The organs which produce the hormones can be surgically removed (formerly performed more frequently) or the so-called “hormone opponents” are administered. They dock on the hormone receptors of the tumor cell, blocking hormones from reaching there. As a result, the growth-promoting effect is inhibited or prevented.

Side effects of hormone therapy are usually caused by the elimination of the effect of the sexual hormones. In both genders, this lead to symptoms like those associated with menopause. Those symptoms can be a headache, heat flashes, attacks of sweating, sleep disorders, reduction of bone density, weight gain or wateriness in tissue. The advantage of hormone therapy is that, in contrast to chemotherapy, it has almost no effect on healthy cells. However, a tumor may develop resistance to hormone therapy, making chemotherapy unavoidable [21].

2.2.4 Immunotherapy

The purpose of immunotherapy is to boost the human body’s natural defenses to fight cancer. Materials, made in a laboratory or by the body, are used to boost, restore, or target a person’s immune system. The immune system has the task of protecting the body from infections and it is a network of tissues, organs, and cells working together.

The aim of immunotherapy is to slow the growth or spread of cancer. Immunotherapy can be given along with other treatments like chemotherapy, hormone therapy or radiotherapy.

New immunotherapies are monoclonal antibodies, also called checkpoint inhibitors. These inhibitors are a specific drug that tries to boost the immune system to destroy cancer cells by itself. Still uncommon are cancer vaccines. Many of them are undergoing clinical trials to study their effectiveness. Cancer vaccination exposes the immune system to an antigen. As a result, healthy cells should detect cancer cells and destroy them with these antigens.

The side effects of immunotherapy depend on the location of cancer, treatment dose, and the overall health but its common side effects are flu-like symptoms, headache, fever, rashes, low blood pressure, vomiting and weakness. Most of the side effects disappear after treatment [22].

2.2.5 Radiotherapy

Radiotherapy is the use of radiation (like gamma rays, protons, x-rays or electrons) to destroy cancer cells or to damage them to prevent their further growth. This treatment is localized, which means that only the radiated part of the body is affected. Cancer cells should begin to die within days or weeks after the treatment starts but this effect also continues for weeks or month after it has been finished.

The disadvantage of this treatment option is that radiation can also damage healthy cells and side effects can occur. The aim of radiotherapy is to achieve remission or cure, control tumor growth, help other treatments (surgery), or can be used in a palliative setting to reduce symptoms.

Since radiation therapy as a whole, the order of events during radiotherapy, and patients' anxiety regarding of this treatment form a major topic of this master thesis, this option is discussed separately in Chapter 2.4.

2.3 Tumor board

As summarized in Chapter 2.2, there are various treatment options for cancer. To ensure optimal therapy for every cancer patient, a tumor board has been formed in all hospitals with oncologic focal points, according to the Austrian structure plan for health, 2012 [23]. A tumor board is an interdisciplinary consultation for the joint definition of therapies. The tumor board consists of the following representatives:

- internal oncology/hematology
- pathology
- radiodiagnostics
- radiooncology and
- the corresponding conservative or operative medical subject (e.g. surgery, gynecology, pneumology, urology, neurosurgery, etc.)

For the formation of tumor boards with other centers, the Austrian structure plan recommends videoconferencing, if all the disciplines are not locally available. The decision of the tumor board is a binding consent about the procedure. But it is important to know that the final decision and responsibility of the upcoming therapy is always rests with the treating physician and the individual patient. If the therapy selected by the treating physician deviates from the tumor board's decision, it must be documented and justified. The aim of the tumor board is:

- optimized care of patients with the oncological disease by regular interdisciplinary case discussions
- exchange of information between the various specialist disciplines
- optimal oncological treatment quality through early cooperation
- possible optimization of the diagnostic procedure, therapy, and aftercare of oncological patients

Each patient with a malignant disease must be recorded, presented, and discussed in the tumor board. These include patients with a confirmed malignant disease, patients with a recurrence, patients included in clinical trials, and patients requiring possible therapy changes. Cases which do not require a personal discussion in the tumor board can be handled internally by the clinic but must be documented.

The combined tasks of the tumor board are to make a therapy recommendation for individual cases based on the available documentation regarding diagnosis, therapy, and possible aftercare. Furthermore, the tumor board should obtain optional medical subjects (plastic surgery, palliative medicine) if necessary and, in case of dissent, they have to list the possible therapy options on the part of the recommended subject. Defining and listing of malignant diseases that do not require any presentation and admission of patients for clinical trials also fall within the tumor board's tasks.

The tumor board is held once a week (in exceptional cases every two weeks) and all the specialists, mentioned at the beginning of this chapter, take part. The clinic management is responsible for ensuring the active participation of the medical specialists.

In preparation for an upcoming tumor board session, the patients are registered by the specialist disciplines. The registration of a patient with the tumor board should be available to each participating physician in time so that an optimal preparation can be made. However, the invitation must be sent out at least 24 hours before the tumor board starts. The tumor board registration must contain at least the following pieces of information:

- first and last name, date of birth
- introducing physician
- diagnosis

- histology and tumor stage
- previous examinations
- previous therapies
- administrative information like name, date, and location of the tumor board

Depending on the organization of the tumor board, the registration of a patient is made available to all the participants.

A tumor board recommendation should always be on the basis of a consensus involving all the physicians. If consensus cannot be reached, all the suggested therapies should be documented as possible treatment options (while mentioning the recommended discipline) including the reasons for disagreement. The treating physician can initiate a therapy in consultation with the patient. This decision should include a justification for choosing the initiated treatment option [24].

2.4 The Way to Irradiation

Since the author of this master thesis worked five years as a radiologic technologist in a department of radiotherapy and now teaches radio-oncology at the University of Applied Sciences, the information given in this chapter comes from personal experience, obviating the need for the citation of sources.

After a patient is prescribed a radiation therapy and has agreed to this procedure, an appointment for the patient information conversation is made in a department for radiotherapy. Before this conversation is held, the oncologist creates a concept for the treatment of the patient. The therapeutic approach (curative or palliative irradiation), the irradiation technique, the determination of additional treatments (e.g. chemotherapy) as well as the fractionation scheme (dose per irradiation) are determined. To accomplish this concept, information concerning histology (from biopsy, 2.1.6), surgical report (after surgery, 2.2.1) and results from radiological imaging procedures (2.1.1–2.1.5) are required. During the conversation, the patient is told about the treatment process, both in writing and verbally. The patient signs to confirm his/her consent to the treatment process. VIPER would support this conversation and promote comprehensibility.

After completing the information dialogue, a computer tomography is performed for irradiation planning. Before the CT is done, the patient must be prepared for exercise. Depending on the area of the CT-Scan, clothes must be taken off and other preparations made (e.g. prostate – full bladder, head and neck – removal dental prosthesis and hearing aids).

In the CT room, the positioning devices are adapted for the patient. The placement of these devices is dependent on the localization of the scan and irradiation area.

Basic requirements for the positioning devices are stability (fixation of the body parts that are to be irradiated), reproducibility (written and photographic documentation), comfort (as convenient as possible), and accuracy (use of form-stable materials). There are standard positioning devices, which are adapted for each patient (e.g. breast – mammaboard, prostate – knee step) and there are customized positioning devices, which are individually molded for patients, for example, thermoplastic masks for head and neck/brain patients or vacuum cushions for irradiation in the thoracic area. After the patient positioning is over, the scan of the irradiation area is performed. Normally, the patients are already aware of the procedure of a CT because of the diagnostic CT they had undergone during the diagnosis phase (see Chapter 2.1.2).

A CT scan is necessary for the irradiation planning procedure because of the Hounsfield Units. The basic property of the different body tissues (lungs, soft tissues, bones), which are recorded by CT, are their density and, therefore, their weakening of x-rays. In CT, the density values are considered as attenuation coefficients of the tissue, relative to water. These values are expressed in the Hounsfield scale. Since x-rays are also used in radiation therapy (with much more energy than in CT), the density and weakening of the tissues must be known before hand to guarantee reliable irradiation planning. Only because of the Hounsfield Units, available only through CT, one gets to know how the radiation would behave within the body during radiotherapy [5].

After computer tomography, a patient can go home and get a new appointment, either for a simulation or for the first irradiation. Effort is made to keep the waiting time till the next appointment as short as possible to reduce any psychological stress. The radiation treatment planning is done during this time. This procedure starts with the contouring of the CT dataset. This involves contouring of the target area of irradiation and also of the healthy organs to be kept out of the area of radiation therapy. These contours are needed to verify whether all radiation limits for the healthy organs are maintained while the target dose is sufficient. Once the target area is defined by the oncologist, radiation planning can begin. The following parameters are defined for this process:

Irradiation technique: conformal radiotherapy or high conformal radiotherapy. Both are irradiation techniques in which the irradiation volume is intended to enclose the target volume as closely as possible.

Type of radiation: Photons (no charge), electrons (negative charge) or ions (positive or negative charge)

Radiation energy: The energy amounts to the order of magnitude of megaelectronvolts (MeV). For superficial tumors treated with photons, 6–8 MeV are used and approximately 10–18 MeV for ingrained tumors.

Angles of equipment components: Different angles for the gantry, the table or the collimator of the linear accelerator.

After the planning process, the results must be checked. This is done with a dose-volume histogram. With this histogram, it is possible to see the correlation between the dose and volume of the individual organs. Different treatment plans may be compared to choose the best one. An optimal treatment plan has the desired dose utilization in the target areas with a low radiation burden on the healthy organs. These healthy organs have dose limits that must not be exceeded. These limits are defined by international directives and should be observed. Finally, the oncologist chooses a treatment plan.

The next appointment for the patient is for a simulation session. The simulation is an imitation of the irradiation procedure and is used to locate the target in the body. The aim is to set the irradiation fields according to the irradiation plan. Once the target is found, it can be marked with pencils on the skin or the mask material. These marks can be used for positioning the patient in the treatment room. For this purpose, lasers, attached to the sides and the ceiling of the room, are used.

There are three different ways to perform the simulation. The first one is a conventional simulation. In this procedure, a medical fluoroscopy system is used to find the target location in the body. The second possibility is a virtual simulation. A moveable laser system makes the marking of the body possible. The last option is a direct adjustment. In this approach, the target irradiation area is detected and recorded directly on the linear accelerator with various imaging methods.

The irradiation can be performed after the completion of the simulation. There is a dose fractionation, according to the concept of the physician and usually a daily irradiation. There are also concepts in which the irradiation is performed twice a day or every second day. Every irradiation must be thoroughly documented and a regular consultation with the oncologist should be carried out to quickly identify possible side effects.

Aftercare begins a few weeks after the last irradiation. In this procedure, the skin in the irradiation areas is examined, side effects and current results are discussed, the general health condition is assessed, and the next steps are defined.

3 Scientific Background

The following chapter provides a closer look at the scientific background with the help of studies and clinical investigations. Firstly, it deals with the topic anxiety in radiotherapy with a special emphasis on the point of time of maximum anxiety in the radiotherapy course. Afterwards, the gathering of information concerning cancer patients receiving radiotherapy is examined. The aim is to detect the source that is the most important for patients.

3.1 Anxiety in Radiotherapy

In addition to the general psychological stresses each patient suffers according to his/her diagnosis, additional specific stresses are added because of the treatment procedure of the cancerous disease. These psychological problems lead to a clear impairment of the quality of life. Unenlightened patients or patients with inadequate knowledge about their disease and treatment especially feel afraid or lonesome. That anxiety is a special fear of being exposed to a threatening disease and the upcoming unknown treatments such as radiation therapy [25].

“Anxiety and its time courses during radiotherapy for non-metastatic breast cancer: A longitudinal study” (Lewis et al., 2014) is a study dealing with anxiety in radiation therapy [26]. The main goal of this study was to investigate the fear time courses during radiation therapy in female patients with breast cancer without metastases. Anxiety was measured before and after simulation, before and after treatment in the first week, and before and after treatment in the last week of radiotherapy. To meet the inclusion criteria, patients had to be older than 17 years, undergone a primary surgical treatment, and facing the first radiotherapy in their life. It was a multicenter descriptive study with questionnaires. In the questionnaires, the study team sought socio-demographic data (e.g. age, education level, marital status) and disease-related information like month since diagnosis, disease stage, and received or scheduled treatments. The survey was carried out with a visual analog scale (VAS), which is a 10cm line with the extreme right defined as “extremely anxious” and the extreme left as “not at all anxious”. To define the time course of anxiety, the patient’s state of anxiety VAS scores was compared. Of the 340 possible patients, 47 (14%) did not meet the inclusion criteria, 47 of the 293 patients did not want to participate and 10 (3%) patients opted out before the

completion of the study. Twenty-three persons were not analyzed because of different reasons, leaving 213 patients (73%) as the final sample. The anxiety levels were highest before simulation (mean 2.9) and the first radiotherapy session (mean 3.4), and then decreased dramatically during the rest of the first treatment week (Figure 1). The anxiety after simulation and treatment sessions was, consequently, lower than before (simulation mean 1.6 and treatment session mean 2.0). The differences between post- and pre-session anxiety were significant at all treatment sessions in the first week of radiotherapy and the simulation. The absolute average maximum of anxiety was measured before the first treatment session. A limitation of this study was that the patients were only assessed during the first and the last weeks of radiotherapy and, therefore, no progress over the entire treatment time was possible. Moreover, the sample of the study only included breast cancer patients without metastases and, hence, the results were not broad enough to possibly apply to other population of patients with cancer [26].

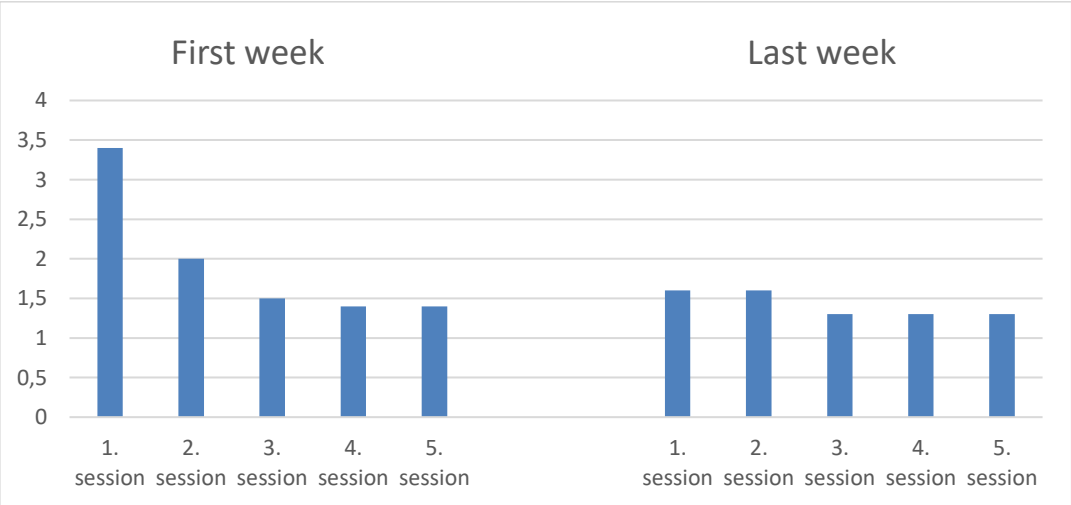


Figure 1 Time course of anxiety before radiotherapy treatment sessions (modified). [26]

The study by Maurer et al. entitled “Angst und Depressivität bei Tumorpatienten im Verlauf der radioonkologischen Behandlung” in 2012 [27] had aimed to evaluate anxiety and depression before, during, and after radiotherapeutic therapy. The study included 60 patients (36 women, 24 men) patients, who received radiation therapy in a curative or palliative setting between June 2005 and April 2006. Many of the patients (95%) were irradiated for the first time and the other 5% received a repeated radiotherapeutic treatment. In 44 cases (74%) the irradiation had an adjuvant (supportive) character and five were neoadjuvant (therapy to reduce tumor mass before surgery). For the rest of the patients, it was a primary therapy. In 72% of the cases, it was a curative approach and in 28% palliative.

To evaluate anxiety and depression, the “Hospital Anxiety and Depression Scale” (HADS) was used. This questionnaire is used to assess anxiety (HADS-A) and

depression (HADS-D) in adults with physical complaints or diseases. For each question, a 4-step item-specific answer option (0–3) with changing answer keys is specified. With seven questions for anxiety and seven questions for depression a value range of 0–21 is obtained for each of these two subscales, while 0–7 points is ordinary, 8–10 is the border area, and, above 10, anxiety or depression is detected.

Data collection in this study took place before the start of the radiotherapy (date A), after radiotherapy (date B) and at the aftercare appointment six weeks after the last treatment session (date C). The median total sum score of the HADS scale, consisting of the sum of the anxiety and depression values, fell from 12.5 to 11.5 during the time from A to B. Further along the course, up to the point of time C, the same score of 9 points was recorded. Overall, there was a significant reduction in the total score for anxiety and depression between points of time A and C. The number of patients with positive anxiety score (>10) decreased from 16% at A to 9% at B and ends at 6% at point C. Many patients thought that the treatment would be much worse because they could not have a fair idea of the treatment. They experienced the therapy rather positively because of the non-invasive process. The conclusion of this study was that anxiety played an important role in the treatment of cancer patients, a fact well represented by the increased values before the start of the therapy (25 patients in the border area and 16 patients with detected anxiety, Figure 2) [27].

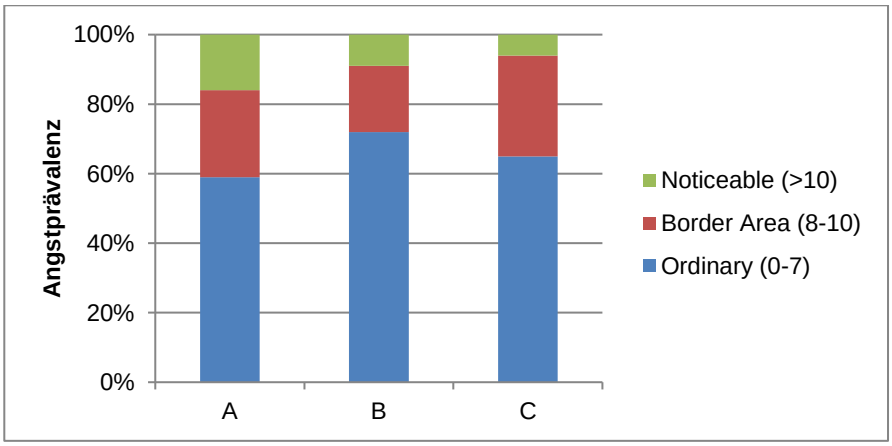


Figure 2 Anxiety prevalence (modified).[27]

Kaur et al. examined in the study “Effect of an orientation program on anxiety level of patients undergoing radiotherapy for first time: A randomized trial” in 2014 [28] if the additional information helped to reduce anxiety. The study included 100 patients – 50 subjects were in the intervention group (additional information before the first treatment) and 50 were in the control group (no additional information). The inclusion criteria were that the patients had to be above 18 years of age and had their first radiotherapy. In addition, they had to be assessable during the data

collection and had to speak English, Punjabi or Hindi since the study was conducted in India. The additional information for the intervention group was given in an orientation program before the first treatment. During this program, the function of the radiotherapy department, general planning of radiation therapy, procedure of radiotherapy, common side effects, and the ways to manage them were explained. At the end of the program, a visual explanation in the form of a 12-page booklet was given to each patient. The measurement of the anxiety values was done with the anxiety assessment scale. The scale had 17 positive statements and for each statement 0 (“not at all”) to 3 (“severely it bothers me a lot”) points could be given so that the maximum score was 51. A score of 0 was no anxiety, 1–17 was mild anxiety, 18–34 moderate anxiety, and > 34 severe anxiety. As indicated already in the other presented studies, anxiety significantly decreased between the first and the last treatment sessions. The reduction of anxiety was more marked with shifts of subjects from severe and moderate anxiety levels toward mild anxiety (Figure 3). An additional conclusion was that anxiety was a common psychological problem, especially among patients undergoing radiation therapy for the first time, and certain interventions and good patient education was necessary to reduce anxiety [28].

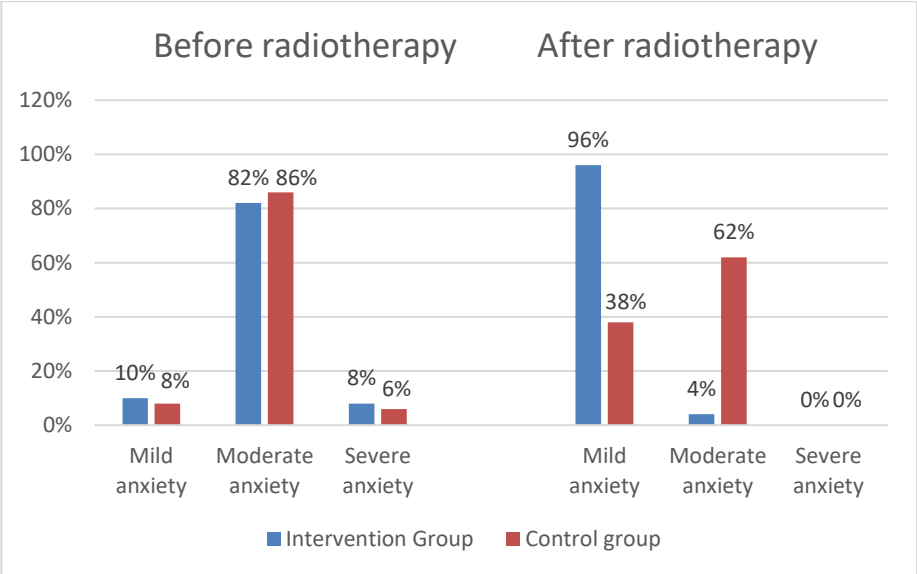


Figure 3 Level of anxiety before and after intervention in both groups. [28]

The aim of the study, “Estimation of anxiety and depression in patients with early stage breast cancer before and after radiation therapy”, by Kawase et al. [29] was to obtain data on the types and grades of anxiety in early breast cancer patients. Like in the other studies, the measurement was carried out before and after radiotherapy. A total of 172 females participated in this study, which was conducted at the Juntendo University Hospital in Japan from April 2006 to December 2007. The scales used for the anxiety scores were the already described HADS (HADS-A and HADS-D) and the Radiotherapy Categorical Anxiety Scale. This scale

consisted of three subscales and 17 items. The subscales consisted of the following:

- anxiety of radiotherapy effects (including side effects),
- anxiety about radiotherapy environment (e.g. left alone in the room) and
- anxiety about treatment effects (effectiveness of therapy)

The score of HADS-A, HADS-D and the total scores of Radiotherapy Categorical Anxiety scale were lower after the treatment than before (Table 1). Besides, the anxiety values of all the subscales of the Radiotherapy Categorical Anxiety scale also decreased. The authors of this study noted that the anxiety or depression score could already be high before the treatment option radiotherapy was chosen. So, the reason why the scores were reduced after the last therapy session could also be due to the relief brought about by the realization that radiotherapy was over. Nevertheless, the need for a good patient education was indicated [29].

Table 1 Differences between means of values after and before treatment (modified).[29]

	Pre	Post
HADS-total	19.2	17.4
HADS-A	*11.0*	*9.9*
HADS-D	*8.0*	*7.5*
Anxiety about radiation	25.3	21.5
Adverse effects	*10.8*	*9.0*
Environment	*6.4*	*5.0*
Treatment effects	*8.1*	*7.5*

The objective of a study by Hernandéz Blázquez et al. in 2016 [30] was to determine the evolution end prevalence of depression, anxiety, and adjustment disorders. It was a longitudinal study involving cancer patients, who had to be at least 18 years old, capable of speaking and understanding Spanish, and had a Karnofsky Performance Score (KPS) > 80. This score is a scale that can be used to assess the symptom-related limitations of activity, self-care, and self-determination in patients with malignant tumors (0–100, 0 = dead, 100 = no complaints and signs of the disease). All the treatments in this study had a curative intention, and patients undergoing psychiatric treatment or patients suffering from psychiatric disorders before the radiation therapy were excluded. The total sample of patients was 103, and all the patients were analyzed thrice during the study.

This analysis was carried out before radiotherapy (T1), a week after finishing the treatment (T2) and during the one-month follow-up (T3). Hernandéz Blázquez et al. used the Mini-International Neuropsychiatric Interview (MINI) procedure, which

is a short interview that explores essential psychological disorders, and the HADS (again HADS-A and HADS-D plus HADS-T for total score). The evaluation was performed by three clinical psychologists with special training in psycho-oncology.

The study showed that 53.4% of the patients did not have any disorders in any evaluated moment, while 46.6% suffered from at least one disorder, while 17.5% of the patients had a disorder before radiotherapy started and improved till the last measurement. Table 2 shows how often an HADS-A score with at least 7 points and with at least 10 points occurred. More than 33% showed sufficient symptoms of clinical anxiety but a significant reduction was achieved for HADS-A > 7 and a clear but not significant reduction for HADS-A > 10. Another result of the study was that women had higher average levels of anxiety compared to men and a higher frequency of anxiety was detected in patients who had undergone surgery, while chemotherapy patients only had a higher prevalence of psychopathological disorders like depression. It has been repeatedly observed that the anxiety before the first treatment appears to be the highest. In addition, a link between increased anxiety and gender, age, and education status is revealed [30].

Table 2 Course of the anxiety, depression and total values (modified).[30]

	Onset of RT	End of RT	Follow-up
HADS-A > 7	35.9%	18.4%	22.3%
HADS-D > 7	19.4%	16.5%	10.7%
HADS-T > 14	27.2%	17.5%	18.4%
HADS-A > 10	16.5%	9.7%	8.7%
HADS-D > 10	8.7%	3.9%	1.9%
HADS-T > 20	12.6%	6.8%	3.9%

Halkett et al. examined [31] in their 2012 study, “Information needs and preferences of women as they proceed through radiotherapy for breast cancer”, the information needed by cancer patients, the information sources used, and the impact of this information on anxiety. The measurement, with questionnaires, was done four times: before the appointment for planning (T1), after planning appointment (T2), the first week of treatment (T3) and after the last session (T4). The participants had to be at least 18 years old, diagnosed with primary breast cancer, and without any record of past radiotherapy. In all, 123 women participated in this study, and the response rate of the questionnaires was over 85% at all points of time measured. Similar to the other studies, the feeling of fear was at the highest level before the starting of the first treatment. In this study, the number of patients

with anxiety scores higher than 8, as a shown by the HADS-A, was 30%. The overall mean anxiety did drop when patients commenced treatment (Table 3) [31].

Table 3 Anxiety score over four time waves (modified).[31]

	Mean	SD
Anxiety–Time 1	6.070	3.889
Anxiety–Time 2	5.641	3.480
Anxiety–Time 3	5.327	4.150
Anxiety–Time 4	4.956	4.150

The other study results concerning information needs and sources are presented in the next chapter, where the topic – information procurement of cancer patients – is examined.

Summary

All studies conclude that anxiety is at its highest level before the first radiotherapy treatment, while a good patient-oriented education can reduce the extent of anxiety. VIPER is intended to help make the patient education even more comprehensible to reduce the patients' fear and nervousness.

3.2 Information Procurement of Patients

As mentioned in Chapter 3.1 poor patient education and the resulting information gaps can cause stress and anxiety in cancer patients. Patients who feel badly informed are likely to be dissatisfied with their treatment. In order to cater to patient education, the information needs, preferences, and sources must be identified. This chapter deals with studies debating this problem to define and determine the most trustworthy source of information for cancer patients and to detect the information needs.

One measurement method in the study of Halkett et al. [31] was the use of an "RT information needs scale". This scale was developed to determine information needs of cancer patients regarding their radiation therapy. It contains 22 questions relating to patients' information needs. For each item, values between 1 (least important) and 9 (most important) could be selected on a Likert scale. To mark the patients' preferences for information sources, six single items measuring patients' preferences for information on radiation therapy were evaluated. They used a Likert scale again, in which 1 meant "least preferred" and 9 denoted "most preferred". The result of this study was that the most preferred information sources were written (mean 8) and verbal (mean 9), but an additional one-on-one talk with a radiology technologist (mean 6.8) was also of help. "Different information sources

need to be provided to patients' in order to address their information needs and reduce their anxiety and depression levels as they proceed through treatment" [31].

Zeguers et al. examined in their study, "The information needs of new radiotherapy patients: How to measure? Do they want to know everything? And if not, why?" in 2012 [32] the kind of information new radiation therapy patients wanted. They developed the Information Preferences of Radiotherapy Patients Questionnaire (IPRP). With these questions, they tried to cover relevant information pertaining to radiotherapy. The items addressed the patient's preference for information about treatment options, desire for support, diagnosis, prognosis, and the chance to talk about worries. The patients could choose a value from 1 (I want to know nothing about it) to 5 (I want to know all about it). The patients had to be over 18 years old and about to undergo their first radiotherapy. Patients with cognitive problems or brain tumors were excluded.

The finding of this study was that the need for information among new radiation therapy patients was high. Averages above 4 indicated that cancer patients wanted to know much in general. All the inquired aspects (disease, treatment, procedures, side effects, and prognosis) except psychosocial information (mean value 3.39) had a value higher than 4. The treatment itself was most important for the patients (Table 4). It is, therefore, important to offer tailored information to them. This meant that the information had to be precisely identified and the information appropriately offered. The radiation therapy patients want information to get a sense of control over the situation. The conclusion of this study was that new radiotherapy patients preferred getting detailed information at their first consultation but patients having difficulty understanding could require greater communicative skills and more attention [32].

Table 4 Information preferences of cancer patients (modified).[32]

	Mean	SD
Total	4.2	0.74
Disease	4.09	0.93
Treatment	4.44	0.81
Procedures	4.38	0.77
Side effects	4.42	0.74
Prognosis	4.31	0.89
Psychological	3.39	1.05

A study by Smets et al., "Does being informed and feeling informed affect patients' trust in their radiation oncologist?" done in 2013 [33] investigated how patients' education by oncologists influenced the confidence of the radiotherapy patients. Fifteen radiation oncologists in the Netherlands agreed to participate. The exclusion criteria for this study were: < 18 years old, patient who already had

radiotherapy, and those unable to read and write Dutch. Eligible patients got a mail with a baseline questionnaire before their first radiation therapy, a letter confirming their appointment, an informed consent, and a brochure about radiotherapy. Patients who gave informed consent were requested to complete the baseline questionnaire within a week before the selection consultation and got a follow-up questionnaire that had to be completed one week prior to the first follow-up, which was, on average, 34 days after the selection consultation. To measure the trust of the patients in their oncologists a 5-item version of the Physician Trust Scale was used. Five questions were asked that could be answered with values between 1 (totally disagree) and 5 (totally agree) with higher scores indicating greater trust.

In addition, the information conversation was recorded on videotapes. With special software, the time spent by the oncologists on each information category was measured. The four categories were: information about radiotherapy in general, specific information about procedures, about radiotherapy side effects, and about the prognosis of the disease. The average total consultation time was 46 minutes and 48 seconds and the conversation was structured in five parts (initiation session and setting the agenda, medical information about patient plus work and family situation, physical examinations, explanations about possible treatments and their effects, and, finally, suggestion about the next steps). Thirty-six seconds during the entire consultation were spent in providing information about prognosis, 2 minutes and 54 seconds were spent in explaining the radiation treatment in general, 4 minutes and 32 seconds on radiation procedures, and 3 minutes and 34 seconds on the side effects. The conclusion of this study was that the average trust score was 4.5 and the variation within physicians was limited. All patients received considerable information about their upcoming radiation therapy but there were differences among the oncologists regarding the extent of the therapy. In sum, cancer patients had a high trust in their radiation oncologists [33].

The aim of the study, “Internet use among head and neck cancer survivors in the North West of England” by Rogers et al. [34] was to report on internet access among survivors of head and neck cancer. They wanted to indicate the way this practice met the patients’ need for information, how they might use it in future, and how they had used it already. Around 67% of the households in the North West of England have access to the internet. So far, there are no official statistics about the number people using the internet to look for information on health topics, but it was estimated to be 30–50%. The exclusion criteria were older than 85 years, recurrence or ongoing disease, cognitive impairment and a palliative intention.

Postal questionnaires were sent to all patients known to be alive in the spring of each year from 2006 to 2010. The patients were asked about the access to and frequency of internet use but also about other information sources. In addition, it was asked how the quality of the health-related information (especially head and neck cancer) was assessed and whether the internet sources could be

recommended. Data showed 55% (482 of 870) of the eligible patients responded to the internet questionnaire. The access to the internet increased from 32% in 2006 to 54% in 2010 but there was a considerable variation by age. In 2010, 83% of the patients less than 55 years of age had access to the internet, while only 40% of the patients between 65 and 84 years had the possibility to use the web.

One of the findings of this study was that, collectively, the most common information sources for head and neck cancer patients came from oncologists. For those with internet access, 58% had used the internet to find information about health matters and, overall, 31%. It was also found that 25% of the participants were very satisfied with the quality of online head and neck cancer information, while 29% were somewhat satisfied, 9% on a bit, 4% not very and not at all satisfied. The role of the internet for information gathering by cancer patients is still minor compared with that of healthcare professionals and leaflets but, interestingly, it was found to be used more than other traditional sources like magazines, television, videos, or helplines (Figure 4).

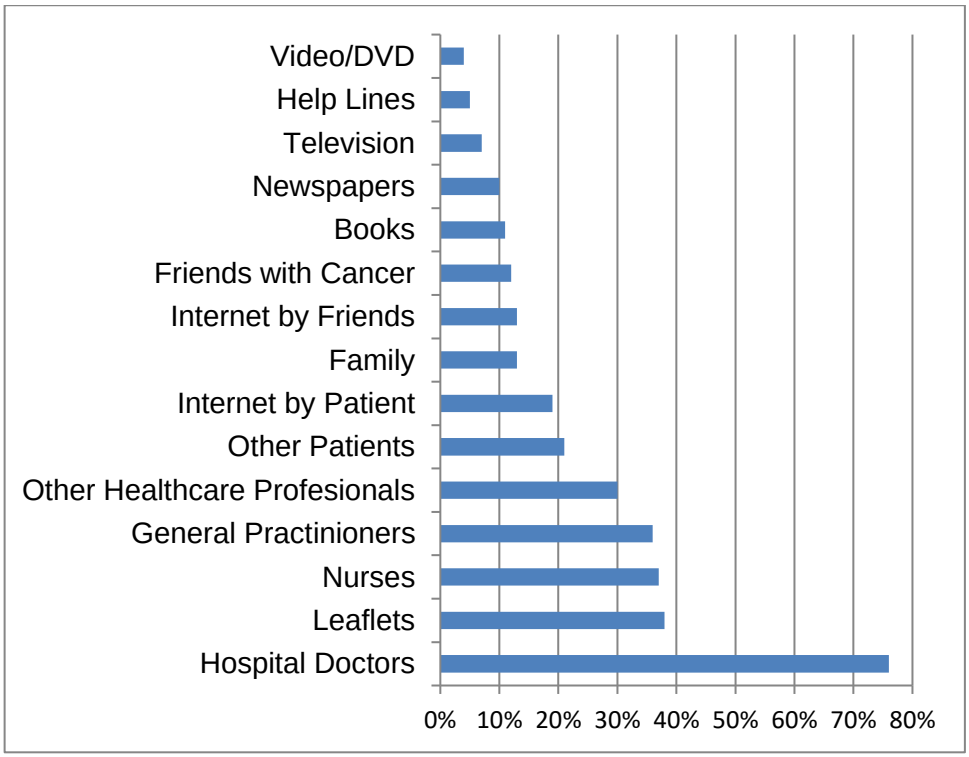


Figure 4 Information sources of head and neck cancer patients (modified).[34]

Summarizing, half of the patients (51%) wanted to learn about treatment and about the side effects (51%). Only 44% would contact doctors online to ask questions [34]. “Our results imply that people are willing to make use of e-health services in various ways, and they indicate which branches of e-health have the greatest potential, and presumably which ones should be of particular interest to policymakers when allocation resources for the development of e-health” [34].

In 2011, Güleser et al. published their study, “The Experience of Symptoms and Information Needs of Cancer Patients Undergoing Radiotherapy” [35]. The aim of the study was to detect the symptoms and information needs of patients receiving radiation therapy. The total sample of patients participating in the study was 345 and they were treated from September 2004 to February 2005 at the Radiation Therapy Department at Erciyes University Gevher Nesibe Hospital in Turkey. The inclusion criteria were that the patients had to be 18 years or above, that they only received radiotherapy and no other therapies, and that it was their first radiation therapy. The cancer patients were asked to complete a questionnaire with 50 questions designed by the authors of the study. For the design, the researchers held information-gathering talks with patients, doctors, nursing staff, and radiographers, and, at the end, the questionnaire consisted of three main sections (information needs and sources, the experience of symptoms, socio-demographic information). The final data was collected by semi-structured interviews, while the duration of the talk was approximately 30 minutes. To determine the information sources, a list of potential sources was presented, including professional sources like clinic nurses, radiotherapy technologists and general practitioners. Other offered source possibilities were media sources like magazines and newspapers, written information contained in leaflets or medical books, and non-health professionals like friends/family or other patients. If the patients received radiotherapy information from a particular source, they were asked to indicate on a 3-point Likert-scale (1 = never, 2 = some, 3 = lots) if they were satisfied with the information.

It was found that 80.9% of the patients indicated that they wished to obtain information, 79.9% wanted to know all the aspects of the diagnosis, and 56.2% were interested in information concerning side effects. Finally, the study clearly showed that radiotherapy patients wanted information about all aspects of their treatment and that most the respondents indicated that they had received information from more than one source, while the main information sources were health professionals. However, only 32.1% were really satisfied with the extent of the information they got (Table 5) [35].

Summary

Patients want to be precisely prepared for their upcoming radiotherapy. Before the therapy starts, possible side effects, the treatment procedure and the prognosis are of particular interest. The favored information sources are in the written or verbal forms, but internet sources, too, are used, though their quality is doubtful. The oncologist is by far the most widely used source and is also highly trusted. It is important to use and offer tailored and various forms of information. VIPER is supposed to support the most trusted source – the oncologist – and provide a modern form of patient education.

Table 5 Knowledge distribution regarding radiotherapy (modified).[35]

	N	%
Source of information		
Doctor	133	85.2
Radiation therapist	20	12.8
Other patients	11	7.0
Family	3	1.9
Nurse	1	0.6
Patients' satisfaction with received information		
Alot	50	32.1
Some	67	42.9
None	39	25.0

4 VR/MR for Cancer Patients

The aim of this chapter is to deal with the first research question and answer it. To achieve this, studies are being carried out which deal with the use of virtual and mixed reality devices in the treatment of cancer patients. The main areas of use are divided into subchapters for a better understanding. These subchapters are Distraction, Rehabilitation, and Patient Education. Studies since 2002 have been used since virtual and mixed reality has been available for several years.

4.1 Distraction

It has been proved that humans only have a limited attention capacity to focus on pain and cognitive tasks. Distraction in medicine aims to draw attention away from thoughts related to the treatment. Virtual and Mixed reality has the qualities of making distractions possible in an interactive, interesting, and immersive way [36]. For example, distraction can be used for painful procedures, long stationary hospital stays, and chemotherapy treatments. The effect of the use of Virtual Reality as a distraction in these areas is determined in the following subchapters with the help of studies.

4.1.1 Painful Procedures

A study by Gershon et al. aimed [37] to determine the feasibility of the use of an immersive VR distraction technique and to find out the benefits for children using this technology while undergoing medical procedures. Participating children had to be between seven and 19 years with a cancer diagnosis.

All children had a port catheter during their treatment. A port catheter is used subcutaneously to ensure permanent venous or arterial access. This port is used later, for example, to administer chemotherapy. Access to the port is obtained by a needle pierced into the catheter. This port access is relatively quick but painful.

A possible benefit of using VR for distraction is examined during this painful access. Children unable to speak English were excluded from the study. The final sample for the data collection consisted of 59 patients. 22 children were assigned to the no distraction control group, 15 to the Non-VR distraction group and 22 patients to the VR distraction group. The assignment itself was randomized. The

VR distraction group and the NonVR distraction group used a virtual gorilla program. In this program, the user plays a young gorilla in his natural habitat and he/she could interact with other gorillas. The patients in the VR distraction group used a head-mounted display with earphones and the patients of the NonVR distraction group played the game on a computer monitor. In both cases, the child used a joystick for navigation. After agreeing to participate, the parents were given a consent form and a VAS, while nurses and the child also received the VAS. All three raters could draw a point on the scale to indicate the level of anxiety and pain. In addition to the VAS, the pulse rate was also measured before, during, and after port access, and the Children's Hospital of Eastern Ontario Pain Scale (CHEOPS) was recorded. The pulse data obtained during the port access was collected later because of logistics problems, while the CHEOPS served as a behavioral observance scale for pain assessment with high correlation to the VAS. The CHEOPS examines six target behaviors (crying, facial expression, verbalization, torso posture, touch, and leg movement) ranging from 0 to 3 (0 = antithesis of pain, 3 = severe pain). The children in the VR and NonVR distraction group practiced 5 minutes before the port access preparation started. The whole access procedure lasted around 5 to 10 minutes.

Significant differences emerged during the procedure. The patients in the VR distraction group had a significantly lower rate than the children in the no distraction group (Table 6). There was no significant difference in the VAS before the procedure started. During the access, the nurses' rating for pain was significantly lower in the NonVR distraction group and the VR distraction group in comparison to the control group. The patients in the no distraction group also had significantly higher torso muscle tension than the patients in the VR distracted condition and more leg tension than among patients in both the other groups. Overall, the results showed a possible benefit of using VR devices as a distraction during painful procedures. The VR distraction clearly appeared to decrease the distress experienced by these patients with cancer during access procedure. A limitation of this study was that the treatment conditions were not completely blind, but this pilot study demonstrated the practicality of using VR tools as distraction technique [37].

Table 6 Pulse ratings during different time points by treatment condition (modified).[37]

	VR	NonVR	Control	
	Mean	Mean	Mean	p
Mean pulse before port access	92.6	99.3	96.0	0.28
Mean pulse during port access	96.3	103.8	110.3	0.04
Mean pulse after port access	91.7	96.6	98.5	0.19

Similar to the study by Gershon et al. Wolitzky et al. examined [38] the effectiveness of VR during a port access procedure applied to pediatric cancer patients. The author predicted that the feeling of distress would decrease if children received a VR intervention. The sample size was 20 children between the ages of seven and 14, while 13 of those children had been diagnosed during the previous six months. Ten children were randomly assigned to the VR distraction group and the other 10 to the no-distraction group. To measure the data, the VAS, the CHEOPS, pulse rate, and a How-I-Feel questionnaire was used. This questionnaire consisted of 20 questions with a three-point scale by which the children could estimate their anxiety specifically while being subjected to the port access procedure.

Like in the study by Gershon et al., the nurse, the parent, and the child rated the pre-procedure anxiety level and predicted the pain of the child. The children in the VR distraction group got an VR device equipped and could play the gorilla game of controlling a young gorilla in a virtual habitat mentioned in the previous study. The training of the child and the setup of the equipment took less than five minutes. While accessing the port, the pulse rate and the CHEOPS behaviors were measured, and, after the procedure, the nurse, the parent, and the child again rated the anxiety and pain for the VAS as they did before the intervention. The children in the no-distraction group could play with the VR devices for entertainment after the procedure. Before port access, no significant data differences regarding anxiety, distress, or pulse rate occurred. During the procedure, however, significant differences between the groups regarding the CHEOPS and the pulse rate were seen. The children in the VR-distraction group also had less anxiety, pain, and distress than the patients in the control group, but the results were not significant (Table 7).

Additionally, it was determined that children in the VR group had a better recollection of the clinic visit and could recall it in greater detail. These findings suggest that a distracted child with lower feeling of distress may be better able to emotionally and cognitively process what is happening around him/her.

Table 7 Means by some measures by condition (modified).[38]

	VR	Control	
	Mean	Mean	p
Pre-procedure			
How I feel	29.1	34.0	0.58
Pulse before	99.2	100.1	0.91
Distress before	19.0	37.4	0.24
During procedure			
Pulse during	95.8	117.6	< 0.05
CHEOPS	4.9	8.3	< 0.01
Distress during	12.0	34.5	0.1

Although the study showed a strong support of VR for children undergoing painful medical procedures, there were limitations as well. The small sample, the varied ages, and the different amounts of previous port access procedures should be mentioned, but, overall, the results indicated that VR might be an effective intervention for children during (painful) treatments in hospitals [38].

The aim of a study by Wint et al. [39] was to determine if the use of virtual reality distraction was effective in reducing the cognition of pain and distress during a painful intervention. The total sample of patients was 30 and the procedure was a lumbar puncture (LP). Lumbar puncture (LP) is a medical technique to collect cerebrospinal fluid. For a successful collection, a needle is inserted into the spinal canal and the collected fluid is used afterwards for diagnostics. A total sample of 30 children (10–19 years) was randomly assigned to the experimental VR group and the standard care comparison group, while all of them already had at least one LP. The LP was performed by six certified nurses, who were instructed in the following areas: How to use and how to teach patients about VR glasses, methods to obtain informed consent, and how to collect demographic data. The young patients in the control group received standard care for LPs, including weight-based conscious sedation, local sedation with cream, an exact explanation of the procedure (for parents and patient) and parental support.

Even though the participants were sedated, all of them were able to move, respond, and verbalize anxiety and discomfort during the LP. The members of the intervention group used, in addition to the standard care, VR glasses with earphones. The patients were made to lie on their side with a television (TV) placed in front of them. On this TV, they could watch a 3D-video of a total duration of 64 minutes. This VR video showed experiences of an explosive drag racing, a stroll down Paris sidewalks, skiing down the Swiss Alps, and visions of quiet mountain streams. Like in many other mentioned studies, the VAS (in this case 0–100 mm) was used to evaluate pain. In addition, the nurse performed the LP sedation using the Sedation Assessment Scale. This scale ranged from 0 (highest level of sedation) to 11 (complete recovery from sedation). Before the patients could rate the pain after the LP, a minimum score of 8 on this scale had to be reached, which happened usually in about 30 minutes after the procedure. To evaluate the VR-experience, the authors developed a 10-item questionnaire consisting of a combination of set response questions and open-ended questions.

17 patients were in the intervention group, while the other 13 patients completed the control group. The median pain score of all patients was 8.0 with no statistical difference. Nevertheless, the median VAS score of the intervention group (7.0) tended to be lower than the score of the control group (9.0). It was seen that 77% of the patients in the VR group felt well distracted by the intervention, and 88%

said the whole procedure was more pleasant than the LP they already had without distraction. This also explained why 69% of the VR group reported that the current LP was much less difficult than their last one, while 42% of the control group made this statement. In conclusion, the VAS-score was low in both groups, while less pain was reported by those in the VR group [39]. “Distracters, such as VR glasses, appear to be indicated for patients who are undergoing painful procedures that are mild to moderate in intensity and are time limited (a few minutes to an hour)” [39].

4.1.2 Hospitalization

Even if the survival rate of children with cancer is higher than ever before, the treatment to cure the disease (surgery, chemotherapy, and radiotherapy) is still a very stressful experience. As a result of this, Li et al. examined [40] the effectiveness of therapeutic play, using VR games to minimize anxiety and depressive symptoms during long in-patient stays.

The study was done in one of the largest hospitals in Hong Kong with a pediatric oncology unit and was divided into two phases. In the first phase, all participants received the same oncology care as usual (control group). A one-month break was inserted after the collection of all the necessary data.

The second phase was carried out later. All patients in the oncology unit in this phase received the usual care plus regular distraction using VR computer games (experimental group). Children between eight and 16 years in age, able to speak Cantonese and read Chinese, and diagnosis done at least two months ago could participate in the study.

The total sample of patients was 122, while 70 formed the control group and 52 the experimental group. The experimental group received 30 minutes of therapeutic play using VR computer games daily (Monday to Friday). The intervention was accomplished by a nurse in groups having a maximum number of four children. The patients were invited to use the daily VR intervention when they were not occupied by any psychological care or medical treatment.

To make the VR intervention possible, a PlayMotion system was installed in the oncology playroom of the department. PlayMotion is a device that transforms ceilings, walls, and floors into interactive and virtual playgrounds, while no goggles, gloves or helmets are used. All children can sit or stand during the intervention, depending on their ability and type of disease. The anxiety of the participants was measured by the Chinese Version of the State Anxiety Scale for Children (CSAS-C). This scale consists of 10 objects with scores from 1 to 3 with a total possible score of 30, with higher scores indicating greater anxiety. Additionally, the depressive symptoms of children were measured with the Studies Depression Scale for Children (CES-DC). It consists of 20 standardized items to evaluate the

symptoms in which 0 means “not at all” and 3 means “a lot”, with a score greater than 15 indicating depression.

The results showed that the intervention group revealed a statistically significant lower depressive score on Day 7 of the stay, while the anxiety scores had no statistically significant differences. The use of VR for distraction during long in-patient stays had specific advantages. The main advantage was that this VR intervention could improve the skill to overcome this demanding time in the hospital and, additionally, decreased the distress. Even if the implementation of such interventions needed extra resources, the realization was expected to result in a long-term increase in the quality of inpatient care for children with cancer [40].

The study, “A positive psychological intervention using virtual reality for patients with advanced cancer in a hospital setting: a pilot study to assess feasibility”, by Baños et al. aimed [41] to examine the acceptance and the benefits of VR techniques on in-patients. It was a single group study to explore whether this VR intervention could be meaningfully used in a hospital. Participants had to be diagnosed with metastatic cancer with a stay period of at least one week, while the KPS had to be at least 50 and the minimal life expectancy over two months. The final sample of cancer patients was 19, while the most frequent forms of cancer were those of the breast, stomach, bladder, rectum, and lung. For measurements, they used three modified VAS:

- VAS—mood: Five items rated the intensity of emotions (vigor, sadness, joy, relax and anxiety) on a scale from 1 (not at all) to 7 (completely), while a final question was asked after the intervention regarding the change of the actual feelings, from -3 (much worse) to +3 (much better).
- VAS—physical discomfort: Three items to rate the fatigue level, pain and physical discomfort before and after the VR sessions with a Likert scale from 0 (not at all) to 10 (very much so).
- VAS—satisfaction: Two questions were asked after the sessions regarding the enjoyment and usefulness from the perspective of the patient (0—not at all, 10—completely).

In addition, the level of satisfaction was measured regarding five aspects: logic, satisfaction, recommendation, utility, and discomfort. The questioning ended with open questions regarding the experienced difficulties, side effects, medical conditions and the level of involvement. The intervention was on four days a week and lasted around 30 minutes, while two sessions were aimed at inducing joy and two sessions to induce relaxation.

The environments used were called “emotional parks” (walk through an urban park) and “walk through nature” (walk in a forest) and a mouse and a keyboard were used to interact with an LCD (liquid crystal display) TV. The interventions

were carried out by a psychologist in the patients' room and the participants were trained to navigate through the VR environments.

The first result of the study shows statistically significant correlations between before-session and after-session measurements, where the participants reported they liked the applications and had fun while being distracted. This feeling of distraction was – beside the purposefulness, usefulness, and ability to relax – one reason for recommending the VR intervention.

As seen in Table 8, after the first session, the patients rated the intervention as pleasant and moderately useful, while 11 participants evaluated their mood as "a little bit better" and one described it as "much better". The second session had the best values for utility and pleasantness, while the third session was positively assessed for pleasantness and utility. These values were moderately positive after the last session. Overall, the patients felt the VR system was easy to use but other difficulties, linked to the hospital room, caused some problems. For example, sessions were disturbed by visitors or medical staff, roommates were watching TV or the telephone was ringing [41].

Table 8 VAS scores of Pleasantness and Utility after four sessions (modified).[41]

	VAS	
	Pleasantness	Utility
First session	6.97	5.50
Second session	7.11	6.43
Third session	6.54	6.29
Fourth session	6.10	4.30

Overall, this VR intervention was rated positively by cancer in-patients and the main benefits reported were relaxation, distraction, and entertainment. The feasibility of its implementation in a real hospital setting was confirmed. The study results were limited by the small sample size, the evaluation of only one group (there was no control group and, hence, no comparison) and by the short intervention period (one week; maybe, there could have been better results after longer intervention periods), but, in conclusion, the mood induction strategies with VR served as a good procedure to raise the mood in cancer patients [41].

4.1.3 Chemotherapy

Innovative treatment methods, including various types of chemotherapy, have a great impact on the improvement of the life expectancy of cancer patients. Depending on the treatment protocol, the administration of chemotherapy may take several hours or days. VR devices can be offered and used to facilitate the waiting period during treatment.

Chirico et al. made a secondary analysis [42] with the help of collected data from three trials done in the past. In sum, 47 female patients with breast cancer were recruited in a cancer institute in Italy. The participants had to be between 18 and 70 years, with a diagnosis of breast cancer requiring chemotherapy. Exclusion criteria included diabetes, addictions, metastasis, wearing of glasses, and epilepsy. All patients were randomly assigned to a Music Therapy (MT) group or to a VR treatment group.

The first chemotherapy session was without any distraction, while the patients received MT or VR during the second session. The duration of the intervention (MT or VR) lasted 20 minutes in all. The VR group got glasses interfacing a computer capable of 3D visualization. The VR intervention consisted of relaxing landscape animations, while the MT participants listened to relaxing music via headsets during their chemotherapy.

The researchers of the study measured the elapsed time while the patients received the distraction (VR or MT). The time measurement started when the glasses were placed on the head of the patient at the start of the chemotherapy infusion and ended when the glasses were removed (after 20 minutes), even if the chemotherapy was still being administered. Directly after the removal of the glasses, the patients were asked to estimate the elapsed time during which the intervention was performed.

The results of the efficacy evaluation of VR devices during chemotherapy showed that 62.5% of the patients in the VR distraction group underestimated the elapsed time, while no one overestimated it. The results of the MT group were contrary to those of the VR treatment group. They showed that 69.6% of the MT participants overestimated the time spent with no one underestimating it, indicating a significant difference between these two groups (Table 9).

This study showed the positive effect of VR distraction during chemotherapy but more studies were needed to understand the role of other variables like anxiety, mood, symptoms, and self-efficacy. Once all these factors were understood and examined, tailored distress intervention could be offered [42].

Table 9 Descriptive statistics of time perception in minutes vis-a-vis the actually elapsed time of 20 minutes (modified).[42]

	Patients	Mean	Minimum	Maximum
VR	23	15.435	10	25
MT	22	21.364	15	30
Total	45	18.333	10	30

In 2007, Schneider et al. wanted to determine [43] the long-term and immediate effects of a VR distraction on symptom distress levels. The patients for the study

were recruited from a cancer center in the United States. In all, 123 of 191 eligible cancer patients agreed to participate. All of them received an initial chemotherapy for colon, lung or breast cancer. The patients had to be at least 18 years of age with a first diagnosis of colon, breast or lung cancer. In addition, the treatment plan had to provide at least two cycles of intravenous chemotherapy. Patients who could not read and write English and those with brain metastasis and/or motion sickness were excluded. The design of the study was meant to examine the immediate and 48-hour effects of symptom distress.

The participants were randomly divided into two groups: Group 1 received the VR distraction during their first chemotherapy treatment and Group 2 during their second chemotherapy treatment. For distraction, the authors used a VR headset during the intravenous chemotherapy and the patients could choose different scenarios such as deep sea diving, exploring ancient worlds, solving a mystery, and walking through an art museum. Each of these scenarios was long enough to last through the entire duration of the chemotherapy administration, while it was possible to change the scenarios any time.

To evaluate the distraction quality, the Present Questionnaire (PQ) and the Evaluation of Virtual Reality Intervention were used. The PQ is a 32-object questionnaire with a seven-point semantic differential scale to measure the level of distraction with a possible score range of 19–133, while the Evaluation of VR is an open-ended questionnaire to evaluate the equipment, distraction effectiveness, scenario choices, and the desire to use VR during other treatments. To measure the distress level, the Adapted Symptom Distress Scale (ASDS, 31-item Likert scale to measure patients' perceptions of occurrence and distress associated with 14 symptoms), the State Anxiety Inventory for Adults (SAI measures the state of anxiety on a 20 item Likert Scale with a possible item score of 0–3 and a possible total score of 0–60), and the Revised Piper Fatigue Scale (PFS, 22 items on a 0–10 numeric scale, while the total score is divided by 22 , indicating the level of fatigue).

On average, each chemotherapy session lasted about 45–90 minutes. Before any VR intervention, the patients were informed about the handling of the equipment and, in addition, they had five minutes to familiarize themselves with it. After the administration of chemotherapy, the patients were asked to answer the ASDS, SAI, and PFS, and got an additional questionnaire, which had to be completed at home 48 hours after chemotherapy.

A finding of the study was that the cancer patients had an altered perception of time while using VR distraction because the average chemotherapy lasted 58 minutes but only felt like 47 minutes. In addition, it was found that the effects of VR distraction were independent of age, diagnosis, and sex. It was feasible to implement the entire distraction procedure in the clinical setting and could be seen

as a noninvasive and cost-effective intervention to distract patients during long medical procedures. It was found that 82% of the patients said they wanted to use the VR tool again during their next chemotherapy because it made the procedure more tolerable and was easy to use. Although lower distress values were measured in the VR-distraction group, these findings were not significant compared to non-distraction chemotherapies. Patients with a VR distraction during their first chemotherapy had significantly less anxiety before their second chemotherapy session than the control group, which received the VR distraction during the second chemotherapy administration and none during the first one [43].

Schneider et al. made an additional secondary analysis [44] in 2010 from three studies with a total sample of 137 participants. Each of the three studies had a cross-over design in which the patients had two chemotherapies – one with VR distraction and one without. In addition, each study evaluated the effectiveness of VR distraction to reduce chemotherapy-related distress. The authors wanted to examine the influence of state anxiety, fatigue, age, gender, and diagnosis on time perception while using VR glasses for distraction.

All patients had to be at least 18 years old with their first diagnosis of cancer and must have received at least two intravenous chemotherapies. Patients with metastases and/or simulator sickness were excluded. As in the study mentioned above, the SAI and PFS were used for data collection. As in the other two studies, the elapsed time during chemotherapy was measured while the starting and the endpoints were the placement and the removal of the glasses on patients' head. Patients did not know that they would be asked about their time perception after chemotherapy. The participants estimated, in minutes, the time taken for the chemotherapy. This value was subtracted from the elapsed time and the time difference in the studies was compared.

The average actual elapsed time during chemotherapy was 62 minutes. Most participants underestimated the duration due to VR intervention. However, there were large differences, depending on the cancer diagnosis. The authors explain the result by the fact that lung cancer patients usually have more pronounced symptoms, which cannot be easily masked by a VR distraction. Breast cancer patients underestimated the elapsed time by 23 minutes, colon cancer patients by 12 minutes, and lung cancer patients only by less than 4 minutes (Table 10). In summary, the time was underestimated by an average of 17.5 minutes (28%) and there was no significant relationship between age and time perception, and gender and time perception. Overall, the sample size was too small to find significant differences in distress symptoms among the diagnosis groups [44].

Table 10 Elapsed time during chemotherapy with VR intervention fort diagnosed cancer (modified).[44]

	Actual time (min)	Estimated time (min)	Time difference (min)
Breastcancer	62.3	39.3	23.0
Colon cancer	75.8	63.9	11.9
Lung cancer	56.9	53.4	3.5
Pooled sample	62.9	45.4	17.5

4.1.4 Review on Efficacy

Chirico et al. made a systematic review [45] with the aim of providing an overview of all studies that used VR interventions for cancer patients. The first study of all the studies in the review was made 1999, showing a significant decrease of anxiety, pain, and negative emotion during chemotherapy. This study was crucial to investigate more closely the effects of VR on the treatment of cancer patients. The searched articles in this review ranged from January 1999 to December 2013 and described the use of VR during cancer treatments. From 830 potential articles, 19 were finally used. Reasons for the exclusion of a large number of other studies were the massive use of VR in the training of oncologists and intervention for home-based care. In this master's thesis, the use of VR as a distraction tool has been classified in the categories of chemotherapy, hospitalization, and painful procedures.

Eight of 19 studies evaluated the efficacy of VR distraction during chemotherapy, and all of them found a reduction in anxiety, distress, and fatigue. Six studies evaluated the benefit of VR during painful procedures. Three studies found a significant reduction in pain, while, in two other studies, the pain tended to be lower but not significant. Only one study did not find any difference. The remaining studies examined the effects of VR in promoting emotional well-being in inpatients with a cancer diagnosis.

All studies showed improved effects regarding the emotional status and cancer-related symptoms. All 19 studies found a significant difference in the psychological variables but not significant changes in distress while using VR.

As a result of all these collected results, it can be said that VR can definitely support cancer patients during their treatment and, in addition, it is noninvasive, does not need much training, and is very inexpensive for medical conditions [45]. "These studies found that VR improved patients' emotional well-being, and diminished cancer-related psychological symptoms" [45].

4.2 Rehabilitation

The purpose of a work [46] by Camargo et al. was to present and evaluate the developed software for rehabilitation of women with breast cancer. The aim of this program was to improve the functionality of the motor and cognitive skills with the help of a VR tool, providing a unique experience with the patients' active participation in daily training. This case study had female participants only but aimed to validate the software to enable its use with larger patient groups to broaden the results. To collect data, a numeric pain scale (horizontal line with scores from 0 to 10, with 0 denoting no pain, and 10 indicating the worst pain possible) electromyography (procedure to evaluate the electrical activity of skeletal muscles), dynamometer of scapula force (device to measure power, force and torque) and a goniometry of the shoulder joint (to measure the angle of the joint) was used.

The image of the patient was displayed on a TV screen which was placed in front of her, providing a wide field of view plus a real-time feedback regarding the movements made. The position of the participants was 3 meters away from the TV, which had been calibrated automatically according to the height of individual patients. Eight different exercise protocols were performed during 30 minutes, while all the exercises were designed to rehabilitate the upper limb region.

The evaluated software used an infrared-based motion tracking device of the patients' body. The patient could see the body on the TV screen as a skeleton. The movements of the patients were reflected by the skeleton. During the procedure, the patients had to touch specific and highlighted red marks. If the attempt was successful, the mark turned green and a new red mark appeared. Once all the moves were successful, the patient heard applause and a congratulatory message was displayed.

This form of exercise therapy is very motivating and that is also the reason why the study results showed a 43% decrease in pain compared to the starting values. In addition, the motion of the shoulder was increased by 21% for the abduction, and 12% for the flexion. Even if the sample size was extremely low, it could be accepted that the VR produced good results regarding pain and shoulder motion [46].

Only 2% of all cancers are brain tumors and these are mostly associated with health restrictions. Possible restrictions can be cognitive impairment, motor weakness, visual-perceptual deficits, and sensory loss.

Yoon et al. did a study [47] to evaluate the possible advantage of VR-based rehabilitation on upper-extremity functions in patients with brain tumors. Patients for this study were recruited from March 2011 through March 2012 in Seoul and the inclusion criteria were: diagnosed with brain tumor having a stable status, a minimum of 20 points at the Mini-Mental State Examination score (a screening

procedure to evaluate cognitive deficit ranging from 0 to 30, while 30 stands for unrestricted and 0 for cognitive functions being severely impaired), a Brunnstrom stage of higher than 2 (2 means emergence of spasticity and synergies, hyperreflexia) of the affected upper-extremity and a motor power grade of the affected shoulder of higher than “poor”. Patients with decreased sitting balance, perceptual-cognitive dysfunction, a global aphasia diagnosis, a recurrent tumor in the head, medical instability and/or musculoskeletal problems were excluded.

The participants were divided into two groups – the control group received occupational therapy (OT) alone for three weeks, five days a week, 30 minutes a day while the intervention group received OT for three weeks, two days a week, 30 minutes a day and, in addition, VR interventional therapy for three weeks, three days a week, and 30 minutes a day. OT consisted of upper-extremity strengthening exercises, the range of motion exercises and fine motor training.

The VR training was performed with a TV monitor, a computer recognition glove (reads the patient reactions and responsive movements), a video camera and VR programs. The patient could see himself/herself on the monitor and his/her movements were transmitted in real time. Six VR programs were used for the rehabilitation procedure, which specifically demanded upper-extremity movements (shoulder, elbow). The difficulty levels of the programs were chosen by the therapist, depending on the performance and progress of the patient. In addition, the patient was also asked to use mainly the affected arm.

To evaluate the therapy results, the following measurements were performed: Manual Muscle Test (scale from 0–5, 0 means no function, and 5 normal function), Box and Block test (BBT—the patient had to put as many blocks as possible over a partition into a box with his/her affected arm within 60 seconds), Fugl-Meyer Scale (FMS—measures range of motion, reflexes, synergy, and fine and gross hand movements) and the Manual Function Test (MFT—measures fine and gross motor function in the upper-extremity).

In all, 40 patients (20 in the intervention group and 20 in the control group) with upper-extremity problems met the inclusion criteria and were evaluated. The study result showed the Brunnstrom stage and the initial power of the upper-extremity were similar among the two groups. A statistically significant improvement in the intervention group was found in the BBT and the MFT (in the shoulder, elbow, and forearm area), while the control group showed a statistically significant improvement in the MFT regarding hand dexterity. The FMS results were also statistically significantly and better in the intervention group (again, in the shoulder, elbow, and forearm areas) but, as in the MFT, hand dexterity was more advanced in the control group.

Overall, it can be said that an OT, combined with VR rehabilitation, is better than a conventional OT alone and that a VR-based rehabilitation demonstrates a good

improvement in the proximal upper-extremity. It is assumed in this study that the results of the hand tests were better in the control group than in the VR intervention where the patients mainly used the shoulder and the elbow to interact with the VR device and not the hands [47].

House et al. [48] used VR rehabilitation to reduce cancer-related upper body chronic pain. They used the BrightArm Duo Rehabilitation System to examine the effectiveness of VR intervention. This system is “an experimental robotic platform that modulates gravity loading on the upper extremities (UE), making it appropriate for patients with weak arm and diminished ability to grasp” [48]. In addition, it uses VR to offer cognitive training and effective relief to patients. In all, nine games were developed for VR intervention with Unity3D for cognitive/emotive training and unimanual/bimanual motor training. The total duration of the BrightArmDuo Rehabilitation System intervention was from 20 to 50 minutes, over a period of eight weeks, with two trainings every week. The difficulty of the tasks has been increased from session to session by increasing the table tilt (from 0° to 20°).

The inclusion criteria were: woman after breast cancer therapy, at least 20 years old, having regular pain medication, a minimal score of 4 on the Numeric Pain Scale (NRS, 0 = None, 10 = Worst pain imaginable), a minimal score of 10 on the Patient Health Questionnaire (minimal depression or higher) and the ability to move the upper-extremity at least 15°. The total female sample consisted of six individuals with cancer post-surgical chronic pain. All the data were collected pre-training, during training, post-training, and eight weeks after intervention. After four and after eight weeks of VR training, the participants completed an evaluation questionnaire on a 10-point Likert Scale from 1 (strongly disagree) to 5 (strongly agree). The evaluation before training, after training, and eight weeks after completion were carried out by a blinded occupational therapist.

The whole VR intervention started with 20-minute sessions and, at the end of the therapy, some patients were able to complete 50-minute sessions. The patients had to rate their pain on the NRS at the start and at the end of each session.

Four of the six participants showed an improvement but only one was statistically significant. Moreover, statistical significance could be found in the range of motion of the arms between pre-training measurement and post-training measurement, and between pre-training scores and follow-up scores eight weeks after the therapy was finished. The evaluated neuropsychological values also improved between pre-training and post-training but were not statistically significant.

Summarized, it can be said that this study showed an increased shoulder range of motion and improved deltoid strength plus a positive effect on emotional well-being at the time of VR use, stressing the feasibility of using the device. The small sample size and lack of additional measurements have to be mentioned in this study [48].

4.3 Patient Education

In this chapter, the question of the usefulness of a modern tool for patient education will be answered with the help of current studies (2015–2016).

Only one program was found in the literature search for the use of VR in patient education. This program is called the Virtual Environment for Radiotherapy Training (VERT) and includes models of a treatment room, a linear accelerator, a treatment machine, various treatment aids, a treatment couch, and furniture. For visualizing a patients' radiotherapeutic treatment method, the oncologist or radiology technologists can import the CT data set and the irradiation plan into the VERT to position the patient on the treatment couch. The movements and noises of almost all the devices in the virtual treatment room correspond to the reality and the individual irradiation plan of each patient (including anatomy, organs at risk, dose distribution and target area) can be presented three dimensionally (on a big screen, around 4 x 3 meters) and helps a lot to explain the complex and complicated procedure [49].

Sulé-Suso et al. tried [50] to understand which pieces of information were important for radiotherapy patients while going through the process and if the use of the VERT system increased the knowledge of the patients and their relatives of radiotherapy planning and delivery. In all, 150 patients were included in this study. The only inclusion criterion was a cancer diagnosis with an upcoming curative radiotherapy. Data collection took two years.

The CT data set and the irradiation plan were transferred to the VERT system for patient education. The patients and their relatives were taken to their own conversation room, where the VERT system was installed and they had the option to later pursue the patient education with 3D glasses. The treatment room and the linear accelerator were shown on the screen and a model of the specific patient was placed on the treatment table. Afterwards, the irradiation plan and the radiotherapy procedure were described to the patient and the relatives, based on the personalised CT dataset. At the end, the patients were asked to answer a questionnaire having seven points about the views regarding the procedure and one field for comments. The statements were rated with values from 1 to 4, in which 1 denoted "not applicable" and 4 indicated "high need". The entire information session talk lasted about 30 minutes and the patients could fill in the questionnaire at home.

It was found that 83% of all participating patients had a moderate or high need to better understand their irradiation planning procedure and 83.3% had a high or moderate need to understand how the irradiation was delivered. 87 of the 150 patients answered the open question at the end, mentioning a very positive influence of VERT information on their understanding of radiotherapy. By the 3D

representation of the treatment and the equipment, the anxiety level before the first irradiation was lowered. The results of this study highlighted that the patients welcomed this new method of imparting patient education. In addition, the relatives, who are usually very worried and have a high need for information, can be educated at the same time [50].

Stewart-Lord et al. examined [51] the perception of VERT of prostate cancer patients as an innovative information delivery tool. They wanted to determine the level of knowledge of patients attending the VERT information session and identify the advantage of using VERT as a patient information tool. All patients with a curative intent of radiotherapy had the chance to participate. The total number of participants was 38, who had the opportunity to read the explanation regarding the nature of the study for 45 minutes to decide whether they want to take part. After signing the informed consent, the patients were invited to attend a VERT information session four weeks before their appointment for CT planning. This session was used to explain to the patients all the preparatory steps for irradiation, the target area, the organs at risk, the irradiation techniques, and the reasons for possible side effects. This lecture was the patients' only source of information after agreeing to take the radiotherapy and before the commencement of the treatment.

To assess the influence of this form of patient education, a questionnaire was completed by the patients during the second week of their radiotherapy. The questionnaire only consisted of questions in which the patients were able to answer regarding their knowledge ("very important" to "not at all important" or "yes" and "no") or the frequency of event behaviors ("always" to "never"). The results of this study showed a high degree of satisfaction and a feeling of helpfulness among patients (97%). Only one patient reported that it was not an adequate patient education for him.

Since the filling of the bladder is important for the irradiation of the prostate, it was very important that the patients understood the meaning of this treatment preparation. Through the 3D presentation in the VERT system, 97% of participants indicated they understood the purpose of this step. In all, 89.5% of the patients were "very satisfied" and 10.5% "somewhat satisfied", while no dissatisfaction was rated. In addition, the VERT information session reduced the anxiety of the patients about their upcoming treatment and comments like "I was worried prior to the session but now all is ok", "Wanted full information, which I received" or that they were nervous until they had their VERT session.

Afterwards, the patients were to assess which information was the most important and which the least east during the VERT session. As a result, it was shown that the treatment preparation was of high importance (84.2%) [51]. "Results demonstrated a very positive response to the use of VERT for prostate cancer patients, in particular, to help gain an understanding of the importance of bowel

and bladder preparation prior to treatment to ensure reproducibility of organ position for daily treatment." [51]

Hansen et al. investigated [52] whether a patient education with VERT had an influence on the residual set-up errors during irradiation and whether the number of repositioning decreased. Data collection took place between September 2012 and February 2014 and the inclusion criteria were: female gender, at least 15 radiotherapy sessions, standard positioning (heel and knee fixation) and diagnosed with pelvic cancer like rectal, anal or gynecological cancer. Patients who needed an individual positioning device or were not able to follow instructions were excluded.

Just before the planning of CT, the intervention group (22 patients) had a training session, while the control group (22 patients) did not receive this training. During this training session, the radiotherapy treatment and the importance of accurate patient positioning were explained three-dimensionally with the help of a VERT system. The influence of the patient movement on the dose distribution was explained with visualizations of the linear accelerator, skin markers, and the target area.

In addition to the VERT information, the participants of the intervention group had been given practical training on the treatment table. For this, the patient was laid on the table and the project coordinator visually demonstrated how to arch and flatten the back and rotate the hip. The exact position of the patients of both groups was verified by imaging methods immediately before each irradiation. If the deviation of the planned CT and the actual image was more than 5 mm, the patient was repositioned.

Each patient was asked to complete two questionnaires. For first questionnaire (before irradiation), socio-demographic and clinical characteristics were asked plus one question about their perceived involvement in their treatment. In addition, there were questions about problems regarding the pelvic mobility and prior experience of possible training. The second questionnaire (before the last session) asked the patients about their perception of cooperation with health care professionals during the positioning on a five-point Likert scale ranging from 0 (easy to understand) to 4 (difficult to understand). In addition, the patients of the intervention group were asked to evaluate the training sessions. The HADS meant to measure distress was part of both questionnaires. After the control pictures but before the irradiation the errors for pitch, roll, and yaw could be calculated.

The VERT information session and the training before treatment resulted in a significant lowering of the residual rotational errors in the intervention group than in the control group (Table 11), but no significant differences were identified in the number of repositioning. This result showed the importance of teaching patients the need of correct positioning to improve positioning prior to treatments [52].

Table 11 Pitch, roll, and yaw in intervention and control group (modified).[52]

	Intervention group	Control group	p value
Pitch	Mean 0.19°	Mean 0.41°	< 0.01
Roll	Mean -0.31°	Mean -0.18°	0.03
Yaw	Mean -0.05°	Mean -0.24°	< 0.01
Repositioning			
Yes	26	34	0.18
No	607	558	

5 VIPER—Prototyping

As already mentioned in the previous chapters, persons with a cancer diagnosis are in an exceptional situation. Many of these patients must undergo radiation therapy. The level of anxiety during the radiotherapy procedure is highest before the first irradiation. A patient-oriented, comprehensible, and trustworthy patient education about their upcoming therapy is essential and can help to reduce the anxiety and worries of all persons concerned.

The main source to obtain information about their radiotherapy is by far the oncologist, who also enjoys great confidence. It is precisely these facts that VIPER is supposed to address.

Since the progress of irradiation is usually explained only verbally, the patients' biggest anxiety is caused by the unknown treatment procedure. The aim of the VIPER program is to reduce the anxiety of the cancer patients before the first irradiation and, at the same time, to support oncologists and radiologic technologists as a dependable source of information.

This is done using a virtual patient education tool, which explains the exact process of irradiation. A virtual patient information tool in radiotherapy is so far only available through the VERT system. Since this system is locally bound and demands a lot of space, a requirement for the development of VIPER is to enable mobility, while, at the same time, ensure easy handling by the users. Easy handling suggests that the preparation for the use of VIPER is not time-consuming and, in addition, the provision of the tool remains user-friendly (small number of interactions until the program starts).

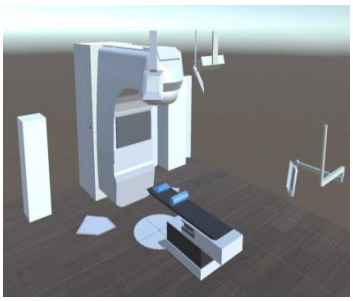
The first plan of this project provides that a VR device, like the Oculus Rift, Samsung Gear VR or the HTC Vive, is used for the patient information output. During the planning phase, the possibility arose to work with a Microsoft HoloLens. The Microsoft HoloLens is a mixed reality device that allows the user to display interactive 3D projections in the immediate environment with the support of a Natural User Interface (this allows a direct interaction through gestures or speech). It should be mentioned that these glasses work without a smartphone or an additional computer. The user looks through two transparent screens that make the projections visible. It is possible to control the HoloLens with gestures, speech or head movements. The device uses the operating system Windows 10 including the Windows Holographic Platform. In addition to a GPU (processor to calculate

graphics) and a CPU (central unit of the device), Microsoft HoloLens also uses an HPU (Holo Processing Unit), which is exclusively projects the light points. For an additional scan of the real surroundings and for the creation of a three-dimensional mesh, sensors comparable to the Kinect sensors are installed. The casing of the glasses is made up of two rings, which can be adjusted to a user-friendly position for a comfortable feeling and an optimal representation of the projections. Cancer patients may suffer from various physical limitations due to the disease and previous therapies, like movement, motor, sensorial, speech, and visual impairments. Owing to these possible limitations of the patients, interaction with the program with gestures or speech is best avoided.

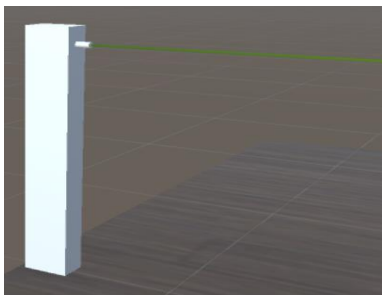
After the course of the treatment, which is to be shown, and the Microsoft HoloLens, as the output device, is designed for this study, the production of the program started.

To be able to represent the course of radiotherapy professionally, the models of the most important components in an irradiation room were necessary. Some models were available for developers and programmers free of charge (some could be used just as they were offered and some had to be modified), and others were created by the author. The program “Autodesk Maya 2017” was used to create or modify the necessary models. Maya is meant for 3D visualization and animation. Maya is used in the film and television industry as well as in the development of computer games. Other areas of the application are industrial production, architectural visualization, and research. Maya is one of the best-known and most widely used software products in 3D modeling, computer animation, and rendering. The following models were used for VIPER:

The basic model for the patient was freely available for developers but had to be adapted intensively. In addition to the appropriate position of the arms and legs for irradiation, the skin markings were also implemented. Since the projection is a prostate irradiation, the therapy is carried out without pants and that is the reason why the model also does not have any.



The model for the linear accelerator was also available online for free for developers. Positioning devices (head pillow and knee pad) were added and the position of the in-room monitors was changed to make them ideal for the camera positions. In addition, individual components of the treatment table were modified to ensure an optimal animation.



In addition, a laser system was added schematically for the real presentation of the radiotherapy course and to explain the meaningfulness of accurate positioning. In fact, the laser beams are not very visible in the room, but this representation promotes intelligibility. This laser system was positioned on both sides next to the treatment table.

The scene was animated after all the models were completed. The program “Unity” was used to perform scene animations. Unity is a run-time and development environment for games. The development environment user interface corresponded to popular 3D animation programs. The main window represented the 3D scene and various menus and forms allowed the manipulation of the camera and the scene. With the mouse, parts of the scene could be selected, moved, scaled, and rotated. Simple objects such as light sources or graphical primitives (cubes, spheres) could be created directly in Unity, while complex components were imported by Drag and Drop, for example, animations, textures, sounds, and 3D models created in other programs. An animation object could be moved over predefined paths, scripts, or through physical forces. With the help of such predefined paths (Figure 5) the animation was implemented for VIPER. The animation was done to achieve a close approximation of the real procedure.

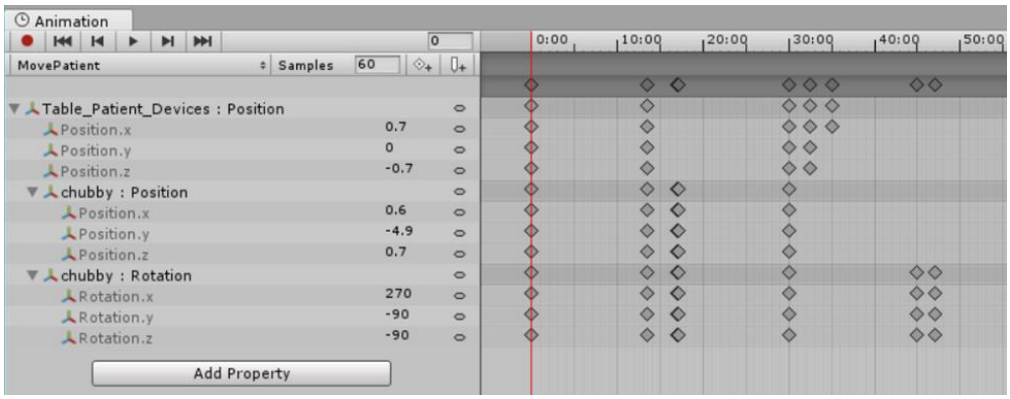


Figure 5 Part of the predefined paths for patient and treatment table using Unity.

At the beginning, the patient waits for a call to enter the irradiation room and places himself on the treatment table. Subsequently, the treatment table moves close to the irradiation position. Based the position of the laser and the skin markers (which have to be brought into alignment), the patient is laid crooked and a correction of the patient positioning is carried out. Then, the gantry moves to its initial position and, shortly thereafter, the irradiation starts. Care was taken that the irradiation duration of the animation matches the real irradiation duration. After the application of irradiation, the gantry device moves back to its original position and the table descends so that the patient can get up and leave the room.

After the modeling and the animation were completed, VIPER was provided with sound. In addition, all the animated events were explained and the movements of the linear accelerator and the treatment table also got sound. The text for the explanation of the irradiation process was recorded and subsequently reworked with the freeware program, Audacity. This program is a free audio editor and recorder. The sounds for the device movements were recorded with a microphone in a real linear accelerator room. In the end, the animations and the soundtracks were brought into correlation with each other to complete VIPER (Figure 6).

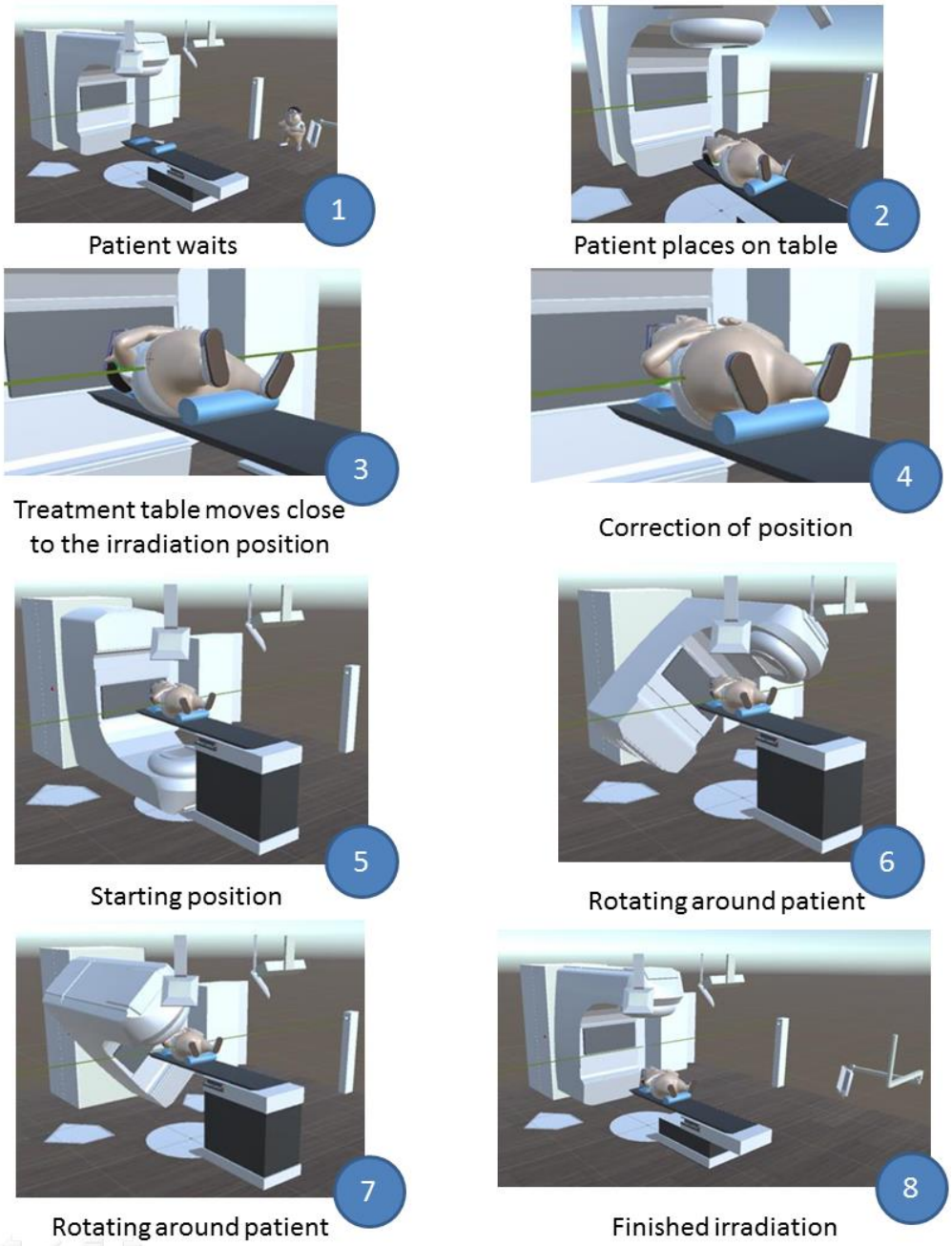


Figure 6 Sequence of the patient information of VIPER.

The duration of the whole information animation was 2:45. Apart from starting VIPER (which can be done by the oncologist or the radiologic technologist), no further interactions were necessary. To simplify the upcoming utility test regarding the use of this patient education method, the program was added with scripts to restart the animation with gestures, and the animation automatically restarted after completion.

6 Utility Test

After VIPER was completed and the functionality was checked, it was of big interest to evaluate the program for its benefits and utility. For this, a survey was conducted in Austria under 22 radiotherapy experts, who were confronted with patient education during their daily work. Sixteen participants were radiologic technologists and six from the medical staff (four specialists for radiooncology and two assistant doctors). The following inclusion criteria had to be fulfilled in order to participate in the survey: (1) Currently working in a radiotherapy department, (2) conducting patient education, and (3) no known simulator sickness. To evaluate the VIPER tool, a questionnaire, consisting of two parts, was handed over. The first part contained general questions about the person such as age, gender, and work experience (Table 12), as well as knowledge or past experiences with VR devices. The participants were asked to answer this part before they tested VIPER.

Table 12 General information about the participants.

	n		
	All	Radiologic technologists	Medical staff
Gender			
Male	9	6	3
Female	13	10	3
Age			
20–30	6	6	0
31–40	9	6	3
41–50	6	4	2
> 50	1	0	1
Work experience			
< 1 year	1	1	0
1–3 year(s)	6	4	2
3–5 years	2	2	0
5–10 years	5	4	1
> 10 years	8	5	3

It was found that 40.9% of the respondents already knew about VR/MR devices (43.75% of the radiologic technologists and 33.33% of the medical staff), but only 22.73% had also already used one (31.75% of the radiologic technologists and none of the medical staff).

As for the question whether the participants already knew of other VR/MR programs for patient education (independent of the medical area), only three participants indicated that they knew one (all three called VERT). Responses to the VR questions can be found in Table 13.

Table 13 VR-related characteristics of the sample.

	n		
	All	Radiologic technologists	Medical staff
VR known			
yes	9	7	2
no	13	9	4
VR used			
yes	5	5	0
no	17	11	6
VR patient education known			
yes	3	3	0
no	19	13	6

After the first part of the questionnaire was completed, the participants could test VIPER. The execution of the testing took place in a quiet room with a table, where the hologram was placed. Before the program was started, the basic structure and the basic function of the HoloLens were explained. Afterwards, the participant was supported during the positioning of the HoloLens on the head to ensure an optimal position and, thereby, guarantee an optimal projection of the hologram. After the correct fit of the glasses was verified, the participant started the patient education program VIPER.

After patient information was active and the animation was still running, the participants could move freely in the room in order to allow different viewing angles to the three-dimensional projection of the treatment process. The entire VIPER patient information could be repeated as often as required to get every bit of information for a conscientious evaluation. For this, the second part of the questionnaire was handed out. This part consisted of nine items, while seven of them were statements that could be assessed on a Likert scale from 1 to 5 (1 – does not applies at all, 2 – rather not applies, 3 – partially applies, 4 – largely applies, and 5 – fully applies). The other two objectives were open questions.

One inquired in which other radiological areas a VR information tool would be useful and, at the end of the questionnaire, the participants were asked for a personal summary of the impression of VIPER. To better illustrate the answers to the individual questions, the mean values and standard deviations (SD) were formed, in each case for the total number of participants, radiologic technologists, and for the medical staff.

6.1 Results

Immediately after testing VIPER, the second part of the questionnaire was completed. In total, 22 participants answered all closed questions.

After the experience with VIPER, the participants were asked if they believed that digital media would influence patient education in the future. With a mean score of 4.09 (SD 0.85) obtained from the responses of all the participants, it is assumed that media technology will have a substantial impact on patient education. Radiologic technologists are more likely to be convinced than physicians (4.38 to 3.33).

Subsequently, it was asked how VIPER would influence the patient education made by the health professionals. On the one hand, it was interesting to know whether the support of VIPER would be useful and whether VIPER would be a time-saving program. There was, again, a considerable difference in the answers between radiologic technologists and medical staff. While the radiologic technologists would appreciate support through VIPER in patient education (4.19), physicians were not fully convinced of the utility of the tool (2.67). In absolute values, it means 13 (81.3%) radiologic technologists answered the question about utility with “largely applies” or “fully applies” and none with “not applies at all” or “rather not applies”.

Owing to the large numbers of radiologic technologists in the sample, the usefulness of VIPER was assessed positively on average (3.77). Although a benefit of VIPER is seen, the health professionals do not expect or are not sure that an application of this program would additionally save time (3.05). No participant answered this question with “fully applies”, while nine answered with “partly applies” or “largely applies” and 10 with “rather not applies”. A summary of the described average response can be found in Figure 7.

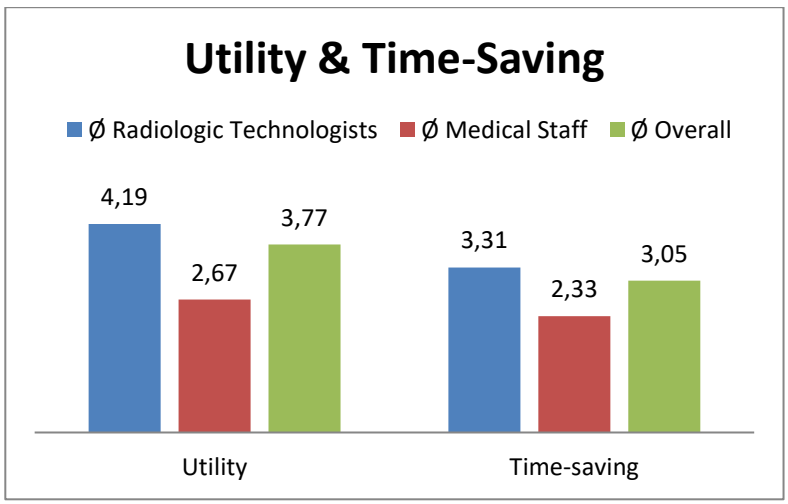


Figure 7 Estimation of the potential of VIPER in terms of utility and time savings when used as a patient education tool

As already mentioned, and based on the results of previous studies, the competence of the patients can be increased by a tailored information transfer and, at the same time, their anxiety can be reduced. Since one of the main objectives in the development of VIPER was anxiety reduction, the experts were asked if this tool could increase understanding and reduce anxiety.

The result, again, revealed a big difference between doctors and radiologic technologists. Regarding the increase in the understanding of the irradiation procedure, seven radiologic technologists responded with “fully applies” and eight with “largely applies”, while, among physicians, three answered with “largely applies”, one with ”partly applies”, and two with “rather not applies”. Regarding the reduction of anxiety by the use of VIPER, 16 sample participants answered with “fully applies” or “largely applies”, while four answered with “rather not applies” and none with “not applies at all” (Figure 8, Figure 9).

As evident from the distribution of the answers, a big benefit is seen in VIPER increasing the understanding of the course of irradiation in the cancer patients. The average value of all responses was 4.05 (radiologic technologists 4.38 and medical staff 3.17).

A positive influence on the reduction of anxiety can also be concluded on closer examination of the answers. Again, the radiologic technologists rated VIPER better for anxiety reduction (3.94) than the medical staff (3.33), but the average of all participants, 3.77, indicated they were convinced of the benefits of VIPER in anxiety reduction and treatment preparation (Figure 10).

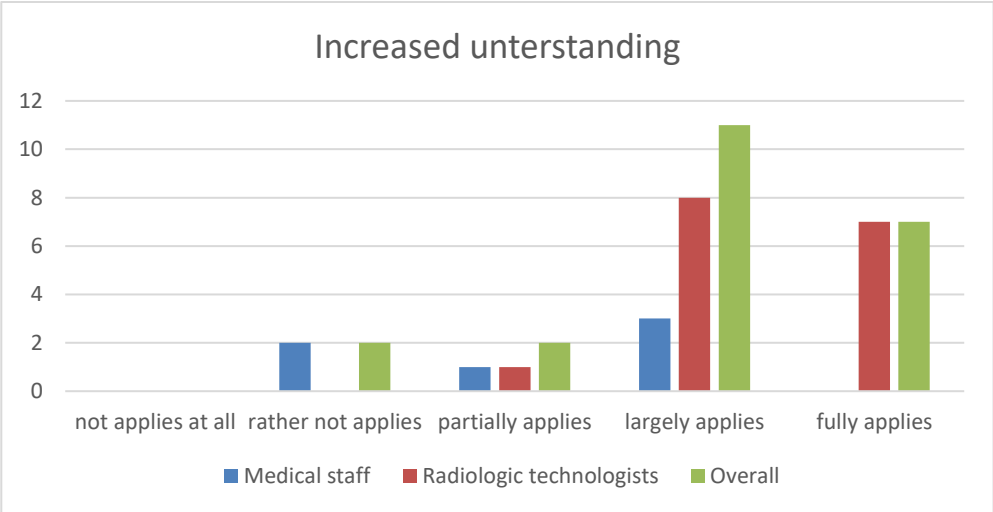


Figure 8 Answers regarding the influence of VIPER on increased understanding.

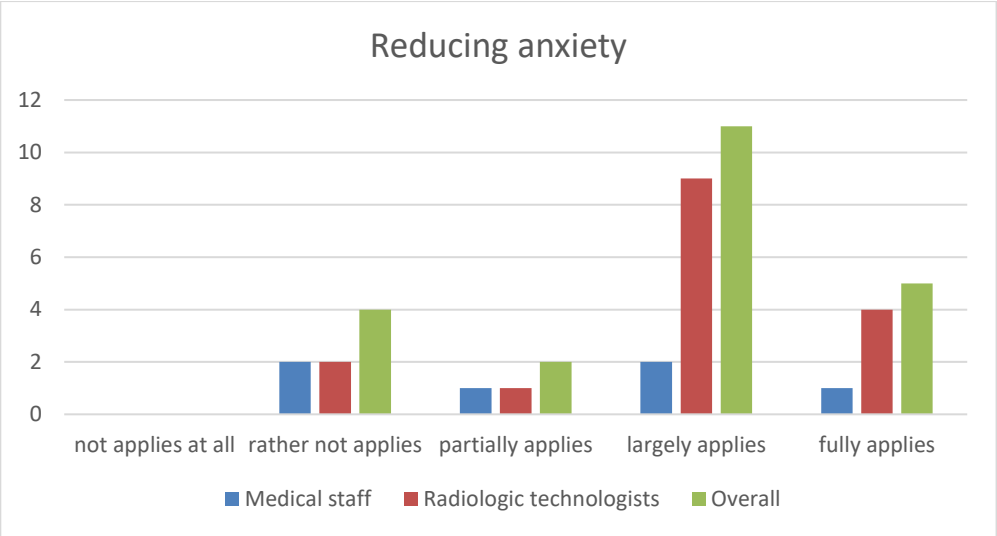


Figure 9 Answers regarding the influence of VIPER on reducing anxiety.

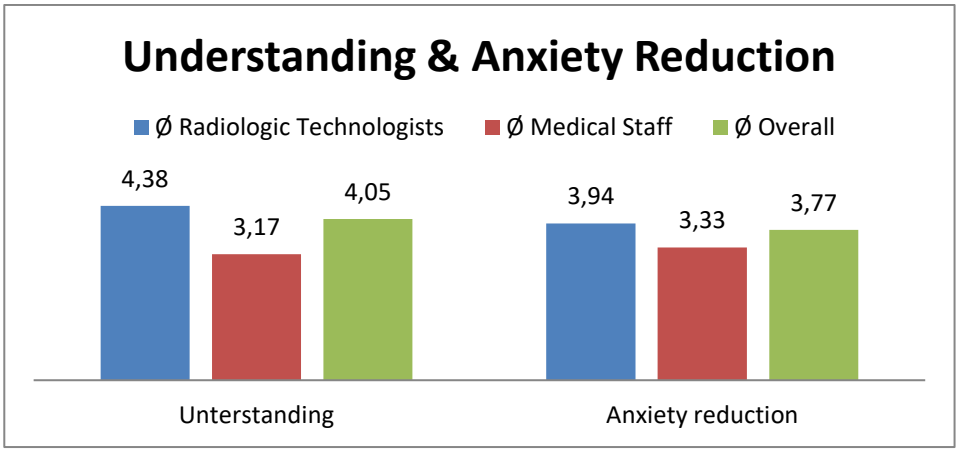


Figure 10 Influence of VIPER on increased understanding and anxiety reduction seen by the participants shown separately in professional groups.

There was a relatively clear result in the question of whether VR or MR media could carry out the complete standard patient education in radiotherapy without a doctor in future. Only one person was convinced that this being a future possibility. Another person answered this question with “partially applies” and two other participants with “rather not applies”. This means a clear majority of 18 people (82%) did imagine that this will be the state-of-the-art technology in future. These responses led to an average score of 1.36 (1.25 for radiologic technologists and 1.67 for medical staff), which is an obvious outcome.

In the final closed question, the author was interested in whether the participants would recommend the VIPER prototype to their colleagues. As it was often seen in this survey, there was, again, a big difference between the answers of radiologic technologists and medical staff. Six radiologic technologists (and one doctor) answered with “fully applies”, five radiologic technologists and no doctor answered

with “largely applies” and four radiologic technologists (and one doctor) answered with “partially applies”. That means that 77.2% of all participants would at least recommend the program partially. The rest of the sample answered either “rather not applies” (two doctors, one radiologic technologist) or “not applies at all” (two doctors). The average response to the question of the recommendation of VIPER was, for radiologic technologists, 4.00, and for the medical staff, 2.33, leading to an overall result of 3.55 (Figure11).

Twelve participants also answered the open question regarding the other areas of virtual patient education in radiology. Multiple responses were possible here. Nine times the MRI was referred to as an application for virtual patient education, four times as angiography, thrice the CT, twice the PET, and once the brachytherapy and the skin care in radiation therapy.

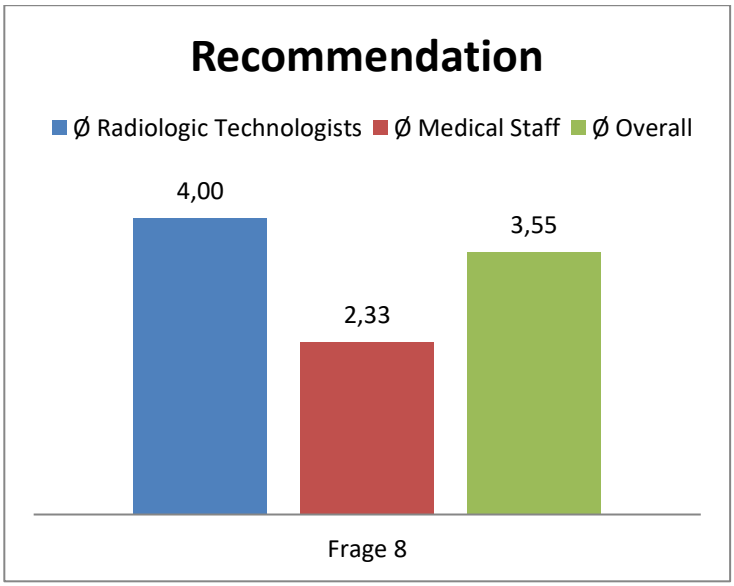


Figure11 Recommendation of VIPER.

7 Discussion

First, the limitations of this survey are discussed.

A limitation was the small number of participants. However, since radiooncology is only a small part of radiology, and not all the employees of radiooncology perform patient education, the number of persons who participated was well within expectations. Although the number of participants in the patient education studies using VERT in Chapter 4.3 was higher (150, 38 and 44 persons), it is worth mentioning that these studies have conducted a survey among cancer patients whose number is many times higher than those of the employees of a radiooncology department.

Another limitation was the place where the survey was conducted. On the one hand, only persons from one radiooncology department were asked to participate, making generalizations and comparisons difficult. On the other hand, the survey was conducted during the clinical routine in the department. Moreover, due time pressure, patient care, and other tasks, the participants often had limited time to deal intensively with VIPER and to assess the full scope of this information tool or to think about the consequences of its use.

It is, however, noticeable that the medical staff, in contrast to the radiologic technologists, in general, answered with lower values. On average, the doctors answered the questions by 0.94 points less than the radiologic technologists. It is important to note, that doctors are, on average, older than radiologic technologists (Table 14).

Table 14 Age distribution of participants.

Age	Radiologic Technologists	Medical Staff
20–30	37.5%	
31–40	37.5%	50.0%
41–50	25.0%	33.3%
> 50		16.7%

Morris and Venkatesh reported in their study [52] that increased age had also been shown that age-related technical acceptance was more pronounced when the information presentation was given in a new way (such as holographic presentation

with VIPER). The results of their study also suggest that there are clear differences with age in attaching importance to various factors in technology adoption and use. Whether this is the reason for the lower evaluation of the questions cannot be proven, but should be considered as a possibility and can be a subject of further investigations.

The open question about the other fields of application for virtual patient education has shown, with the most frequently mentioned procedures (MRI and angiography), that particularly long and complex treatments and examinations require a more detailed explanation, and that VR/MR could positively support this.

As already mentioned in this thesis, anxiety is an essential factor for patients in radiation therapy. One of the main objectives in the production of VIPER was to assist health professionals with their patient education and reduce anxiety in cancer patients. After the testing of VIPER by experts and the results of the survey, it can be said in summary that there is a great potential in this form of patient education and VIPER.

Finally, it should be emphasized, that VIPER left a positive impression among the experts and many of them would recommend this program to a colleague (mean score 3.55).

8 Conclusion

Since the path of cancer patients has now been presented in this thesis, the anxiety concerning radiotherapy can be better understood.

To quantify the extent and timing of anxiety during radiotherapy, several studies were analyzed. All studies concluded that anxiety reached the highest level before the first radiotherapy treatment. A well-executed patient-oriented education could reduce the extent of anxiety.

Subsequently, investigations were made to examine which sources of information were the most important for radiotherapy patients. It was found that patients wanted to be precisely prepared for their upcoming radiotherapy. Before the therapy began, the possible side effects, the treatment procedures as well as the prognosis created particular interest. Favored information sources were in the written or verbal forms, but internet sources, too, were used, though their quality was doubtful. The oncologist was by far the most widely used and trusted source. It is important to use and offer tailored and diverse forms of information.

To answer the first research question about the possible application areas of VR/MR in the treatment of cancer patients, several studies were analyzed. Results show that VR has positive effects regarding distraction during painful procedures and chemotherapy. Even during long-term hospital stays, patients' well-being can be enhanced using VR interventions. In addition, there are rehabilitation measures, which are carried out with the help of VR after cancer surgery that caused movement restrictions. Furthermore, a system called VERT is used for patient education and is the only VR information program identified in the literature. The studies confirmed that modern 3D patient education methods were accepted and considered in practice.

To offer a mobile and easy-to-use patient education program in radiotherapy, the development of VIPER for the Microsoft HoloLens began. For this purpose, an animation of the irradiation process in the form of a hologram displayed in a Mixed Reality environment was developed. This animation also included real sounds from the irradiation device to obtain a more realistic view of the treatment, leading to better preparation of the patient.

The finished prototype of the program was then provided to health professionals entrusted with the patient education in radiotherapy. After the test of VIPER, the

program was evaluated with the help of a questionnaire. Overall, VIPER received mainly positive feedback from the experts. On the one hand, the participants believe that the understanding of the process of irradiation increases among patients (mean score 4.05/5) and, at the same time, anxiety can also be reduced (mean score 3.77/5). However, the participants do not believe that the virtual medium can replace the doctor's role in patient education at any time (mean score 1.36/5).

The survey of the participants also showed that only three out of 19 people (15.8%) already knew of the VR/MR patient education tool. In all cases, the VERT system was used by the participants during their education.

As VIPER would be recommended by most participants (mean score 3.55/5), it can be assumed that such modern methods of patient education would be accepted and used by the health professionals.

As already mentioned in the limitations, the survey was conducted in only one department. Therefore, it would be interesting and necessary for future studies to ask, on the one hand, more health professionals entrusted with patient education to participate and, on the other, to do the survey in several radiotherapy departments.

In addition, only health professionals were asked to take part. To obtain more comprehensive results, it is necessary to let cancer patients test VIPER before their first irradiation and to let them evaluate the possible benefit afterwards.

This positive result of VIPER regarding acceptance, utility, and further development of the technical possibilities of virtual patient education can lead to a widespread use of this method in the future.

Literature

[1] „Krebs im Überblick“. [Online]. Verfügbar unter: http://www.statistik.at/web_de/statistiken/menschen_und_gesellschaft/gesundheit/krebserkrankungen/krebs_im_ueberblick/021776.html. [Zugegriffen: 25-Apr-2017].

[2] „Trends der Entwicklung von Krebserkankungen in Österreich - eine Prognose bis 2030“. [Online]. Verfügbar unter: http://www.bmgf.gv.at/cms/home/attachments/0/6/3/CH1480/CMS1422957020341/bericht_krebsprognose_3_2_2015.pdf. [Zugegriffen: 25-Apr-2017].

[3] H. Gelband, P. Jha, R. Sankaranarayanan, S. Horton, und World Bank, Hrsg., *Cancer*. Washington, DC: The World Bank, 2015.

[4] S. Shimotsu *u. a.*, „An investigation of anxiety about radiotherapy deploying the Radiotherapy Categorical Anxiety Scale“, *International Journal of Clinical Oncology*, Bd. 15, Nr. 5, S. 457–461, Okt. 2010.

[5] M. Breitenseher und A. Ba-Ssalamah, Hrsg., *Lehrbuch der radiologisch-klinischen Diagnostik*, 2. aktualisierte Aufl. Horn: Univ. Publ. 3.0, 2012.

[6] T. Hartmann, M. Kahl-Scholz, und C. Vockelmann, Hrsg., *Fachwissen MTRA: für Ausbildung, Studium und Beruf*. Berlin Heidelberg: Springer, 2014.

[7] M. Bamberg und F. Nüsslin, Hrsg., *Radioonkologie: Grundlagen*, 2. Aufl. München: Zuckschwerdt, 2009.

[8] J. Hübner und W. Schmiegel, Hrsg., *Onkologie interdisziplinär: evidenzbasiert - integrativ - patientenzentriert ; mit 87 Tabellen*. Stuttgart: Schattauer, 2014.

[9] S. H. Levitt, Hrsg., *Technical basis of radiation therapy: practical clinical applications*, 5th edition. Heidelberg ; New York: Springer, 2012.

[10] S. H. Heywang-Köbrunner und S. Barter, *Bildgebende Mammadiagnostik: Untersuchungstechnik, Befundmuster, Differenzialdiagnose und Interventionen*, 3., Vollst. überarb. Aufl. Stuttgart: Thieme, 2015.

[11] American Cancer Society, *Testing Biopsy and Cytology Specimens for Cancer*. Atlanta, Georgia, USA, 2015.

[12] „How Surgery is Used for Cancer“. [Online]. Verfügbar unter: https://www.cancer.org/treatment/treatments-and-side-effects/treatment-types/surgery/how-surgery-is-used-for-cancer.html. [Zugegriffen: 25-Jän-2017].

[13] „SEER Training: Curative Surgery“, *NIH - National Cancer Institute*. [Online]. Verfügbar unter: https://training.seer.cancer.gov/treatment/surgery/types/curative.html. [Zugegriffen: 10-Jän-2017].

[14] E. V. Ussiri und L. E. K. Lema, „Palliative cancer surgery“, *East and Central African Journal of Surgery*, Bd. 10, Nr. 2, S. 84–87, 2005.

[15] American Cancer Society, *A Guide to Cancer Surgery*. Atlanta, Georgia, USA, 2014.

[16] American Brain Tumor Association, *Surgery*. Chicago, 2016.

[17] Lancashire Teaching Hospitals, *Ovarian Debulking Surgery - Information for patients*. Preston, 2015.

[18] L. Wuellner, V. O’Callaghan, und Cancer Council Australia, *Understanding chemotherapy: a guide for people with cancer, their families and friends*. Woolloomooloo, N.S.W.: Cancer Council of New South Wales, 2012.

[19] The University of Pittsburgh Cancer Institute (UPCI), *Chemotherapy - Information for Patients and Families*. Pittsburgh, 2012.

[20] H. Stamatiadis-Smidt, C. Beitel, H. S.- Smidt, und Deutsches Krebsforschungszentrum, Hrsg., *Thema Krebs: [umfassende Information, verständliche Erklärungen, Antworten auf ihre Fragen]*, 3., Vollst. überarb. und erw. Aufl. Heidelberg: Springer Medizin, 2006.
[21] W. E. Aulitzky und W. Waldmann, Hrsg., *Handbuch Krebs: alles zur Vorsorge, Diagnose, Therapiemöglichkeiten und Heilungschancen ; mit Arzt- und Klinikführer*. München: Südwest, 2007.
[22] American Society of Clinical Oncology, *Understanding Immunotherapy*. Alexandria, Virgina, USA, 2016.
[23] Bundesministerium für Gesundheit, „Österreichischer Strukturplan Gesundheit 2012“. 2012.
[24] NÖ Landeskliniken-Holding, *Tumorboard Leitlinien*. St. Pölten, Niederösterreich, Österreich, 2014.
[25] K. Voigtmann, V. Köllner, F. Einsle, H. Alheit, P. Joraschky, und T. Herrmann, „Emotional State of Patients in Radiotherapy and How They Deal with Their Disorder“, *Strahlentherapie und Onkologie*, Bd. 186, Nr. 4, S. 229–235, Apr. 2010.
[26] F. Lewis *u. a.*, „Anxiety and its time courses during radiotherapy for non-metastatic breast cancer: A longitudinal study“, *Radiotherapy and Oncology*, Bd. 111, Nr. 2, S. 276–280, Mai 2014.
[27] J. Maurer, C. Schäfer, O. Maurer, und O. Kölbl, „Angst und Depressivität bei Tumorpatienten im Verlauf der radioonkologischen Behandlung“, *Strahlentherapie und Onkologie*, Bd. 188, Nr. 10, S. 940–945, Okt. 2012.
[28] H. Kaur, P. Pathak, S. Kaur, und F. Patel, „Effect of an Orientation Programme on Anxiety Level of Patients Undergoing Radiotherapy for First Time: a Randomized Control trial“, *Nursing and Midwifery Research*, Bd. 10, Nr. 4, S. 135, 2014.
[29] E. Kawase *u. a.*, „Estimation of anxiety and depression in patients with early stage breast cancer before and after radiation therapy“, *Breast Cancer*, Bd. 19, Nr. 2, S. 147–152, Apr. 2012.
[30] M. Hernández Blázquez und J. A. Cruzado, „A longitudinal study on anxiety, depressive and adjustment disorder, suicide ideation and symptoms of emotional distress in patients with cancer undergoing radiotherapy“, *Journal of Psychosomatic Research*, Bd. 87, S. 14–21, Aug. 2016.
[31] G. K. B. Halkett *u. a.*, „Information needs and preferences of women as they proceed through radiotherapy for breast cancer“, *Patient Education and Counseling*, Bd. 86, Nr. 3, S. 396–404, März 2012.
[32] M. Zeguers *u. a.*, „The Information Needs of New Radiotherapy Patients: How to Measure? Do They Want to Know Everything? And if Not, Why?“, *International Journal of Radiation Oncology*Biology*Physics*, Bd. 82, Nr. 1, S. 418–424, Jän. 2012.
[33] E. M. A. Smets, M. A. Hillen, K. F. L. Douma, L. J. A. Stalpers, C. C. E. Koning, und H. C. J. M. de Haes, „Does being informed and feeling informed affect patients’ trust in their radiation oncologist?“, *Patient Education and Counseling*, Bd. 90, Nr. 3, S. 330–337, März 2013.
[34] S. N. Rogers, A. Rozek, N. Aleyaasin, P. Promod, und D. Lowe, „Internet use among head and neck cancer survivors in the North West of England“, *British Journal of Oral and Maxillofacial Surgery*, Bd. 50, Nr. 3, S. 208–214, Apr. 2012.
[35] G. N. Güleser, S. Taşci, und B. Kaplan, „The Experience of Symptoms and Information Needs of Cancer Patients Undergoing Radiotherapy“, *Journal of Cancer Education*, Bd. 27, Nr. 1, S. 46–53, März 2012.

[36] B. Lange, M. Williams, und I. Fulton, „Virtual Reality distraction during pediatric medical procedures“, Dalhousie University and IWK Health Centre, 2006.
[37] J. Gershon, E. Zimand, M. Pickering, B. O. Rothbaum, und L. Hodges, „A Pilot and Feasibility Study of Virtual Reality as a Distraction for Children With Cancer“, *Journal of the American Academy of Child & Adolescent Psychiatry*, Bd. 43, Nr. 10, S. 1243–1249, Okt. 2004.
[38] K. Wolitzky, R. Fivush, E. Zimand, L. Hodges, und B. O. Rothbaum, „Effectiveness of virtual reality distraction during a painful medical procedure in pediatric oncology patients“, *Psychology & Health*, Bd. 20, Nr. 6, S. 817–824, Dez. 2005.
[39] S. S. Wint, D. Eshelman, J. Steele, und C. E. Guzzetta, „Effects of distraction using virtual reality glasses during lumbar punctures in adolescents with cancer.“, in *Oncology nursing forum*, 2002, Bd. 29.
[40] W. H. Li, J. O. Chung, und E. K. Ho, „The effectiveness of therapeutic play, using virtual reality computer games, in promoting the psychological well-being of children hospitalised with cancer: Effectiveness of therapeutic play“, *Journal of Clinical Nursing*, Bd. 20, Nr. 15–16, S. 2135–2143, Aug. 2011.
[41] R. M. Baños *u. a.*, „A positive psychological intervention using virtual reality for patients with advanced cancer in a hospital setting: a pilot study to assess feasibility“, *Supportive Care in Cancer*, Bd. 21, Nr. 1, S. 263–270, Jän. 2013.
[42] A. Chirico *u. a.*, „The Elapsed Time During a Virtual Reality Treatment for Stressful Procedures. A Pool Analysis on Breast Cancer Patients During Chemotherapy“, in *Intelligent Interactive Multimedia Systems and Services 2016*, Springer, Cham, 2016, S. 731–738.
[43] S. M. Schneider und L. E. Hood, „Virtual reality: a distraction intervention for chemotherapy“, in *Oncology nursing forum*, 2007, Bd. 34, S. 39.
[44] S. M. Schneider, C. K. Kisby, und E. P. Flint, „Effect of virtual reality on time perception in patients receiving chemotherapy“, *Supportive Care in Cancer*, Bd. 19, Nr. 4, S. 555–564, Apr. 2011.
[45] A. Chirico, F. Lucidi, M. De Laurentiis, C. Milanese, A. Napoli, und A. Giordano, „Virtual Reality in Health System: Beyond Entertainment. A Mini-Review on the Efficacy of VR During Cancer Treatment: EFFICACY OF VR DURING CANCER TREATMENT“, *Journal of Cellular Physiology*, Bd. 231, Nr. 2, S. 275–287, Feb. 2016.
[46] C. Camargo *u. a.*, „Virtual rehabilitation in women with post breast cancer—A case study“, in *Virtual Rehabilitation (ICVR), 2013 International Conference on*, 2013, S. 188–189.
[47] J. Yoon, M. H. Chun, S. J. Lee, und B. R. Kim, „Effect of Virtual Reality–Based Rehabilitation on Upper-Extremity Function in Patients with Brain Tumor: Controlled Trial“, *American Journal of Physical Medicine & Rehabilitation*, Bd. 94, Nr. 6, S. 449–459, Juni 2015.
[48] G. House *u. a.*, „A feasibility study to determine the benefits of upper extremity virtual rehabilitation therapy for coping with chronic pain post-cancer surgery“, *British Journal of Pain*, Bd. 10, Nr. 4, S. 186–197, 2016.
[49] A. Boejen und C. Grau, „Virtual reality in radiation therapy training“, *Surgical Oncology*, Bd. 20, Nr. 3, S. 185–188, Sep. 2011.
[50] J. Sulé-Suso *u. a.*, „Pilot study on virtual imaging for patient information on radiotherapy planning and delivery“, *Radiography*, Bd. 21, Nr. 3, S. 273–277, Aug. 2015.
[51] A. Stewart-Lord, M. Brown, S. Noor, J. Cook, und O. Jallow, „The utilisation of virtual images in patient information giving sessions for prostate cancer patients prior to radiotherapy“, *Radiography*, Bd. 22, Nr. 4, S. 269–273, Nov. 2016.

[52] H. Hansen, B. K. Nielsen, A. Boejen, und A. Vestergaard, „Teaching Cancer Patients the Value of Correct Positioning During Radiotherapy Using Visual Aids and Practical Exercises“, *Journal of Cancer Education*, Okt. 2016.
[53] M. G. Morris und V. Venkatesh, „Age differences in technology adoption decisions: Implications for a changing work force“, *Personnel psychology*, Bd. 53, Nr. 2, S. 375–403, 2000.

List of Figures

List of Tables

Appendix

A. Survey

Fragebogen

im Zuge der Masterthesenerstellung zum Einsatz des VIPER-Tools zur PatientInnenaufklärung in der Strahlentherapie

Teil 1 – vor der Testung

Alter:

- ☐ 20 – 30 Jahre
- ☐ 31 – 40 Jahre
- ☐ 41 – 50 Jahre
- ☐ > 50 Jahre

Geschlecht

- ☐ männlich
- ☐ weiblich

Berufsgruppe:

- ☐ OnkologIn
- ☐ Assistenzarzt / Assistenzärztin
- ☐ RadiologietechnologIn

Arbeitserfahrung

- ☐ < 1 Jahre
- ☐ 1 – 3 Jahre
- ☐ 3 – 5 Jahre
- ☐ 5 – 10 Jahre
- ☐ > 10 Jahre

Welche dieser Virtual Reality(VR) / Mixed Reality(MR)-Geräte kannten Sie vor Ihrer Teilnahme?

- ☐ Playstation VR
- ☐ HTC Vive
- ☐ Samsung Gear VR
- ☐ Oculus Rift
- ☐ Microsoft Hololens
- ☐ Keine der Genannten

Haben Sie schon mal ein Virtual Reality/Mixed Reality-Gerät benutzt?

- ☐ ja
- ☐ nein

Kennen Sie im medizinischen Bereich Virtual Reality/Mixed Reality -Geräte im Einsatz für die PatientInnenaufklärung?

- ☐ ja
- ☐ nein

Fragebogen

im Zuge der Masterthesenerstellung zum Einsatz des VIPER-Tools zur PatientInnenaufklärung in der Strahlentherapie

Teil 2 – nach der Testung

1. **Sind Sie der Meinung, dass digitale Medien und Techniken in Zukunft die Art der PatientInnenaufklärung beeinflussen werden?**

2. **Würde diese Anwendung Ihre Aufklärungsarbeit in der Strahlentherapie sinnvoll unterstützen?**

3. **Sind Sie der Meinung, dass die Verwendung dieses Programms eine wertvolle Zeitersparnis bei der PatientInnenaufklärung zur Folge hätte?**

4. **Sind Sie der Meinung, dass die dreidimensionale Mixed Reality Darstellung des Behandlungsablaufs inklusive realer Geräusche die Verständlichkeit bei den PatientInnen steigert?**

5. **Sind Sie der Meinung, dass die dreidimensionale Mixed Reality Darstellung des Behandlungsablaufs inklusive realer Geräusche die Angst vor der ersten Bestrahlung bei den PatientInnen verringert?**

6. **In welchen radiologischen Bereichen wäre der Einsatz dieser Aufklärungsmethode noch sinnvoll?**

7. **Sind Sie der Meinung, dass der Einsatz von Virtual Reality/Mixed Reality-Medien in Zukunft das Aufklärungsgespräch ersetzen kann indem die Standardaufklärung von einem Programm durchgeführt wird?**

8. **Würden Sie VIPER einem/r KollegIn für die PatientInnenaufklärung in der Strahlentherapie empfehlen?**

9. **Ihr zusammenfassender Eindruck dieses Aufklärungssystems in 2-3 Sätzen:**

Vielen Dank für Ihre Mitarbeit!