Technical Conditions and Organizational Aspects for Remote Treatment Planning: a Developing Country's Perspective

JOHAN SUVANEN

KTH Technology and Health

Master of Science Thesis in Technology and Health
Stockholm 2014

This master thesis project was performed in collaboration with
Scandinavian Care AB
Supervisor at Scandinavian Care AB: Göran Hellers

Technical Conditions and Organizational Aspects for Remote Treatment Planning: a Developing Country's Perspective

Tekniska förutsättningar och organisatoriska aspekter för dosplanering på distans: ett utvecklingslandsperspektiv

JOHAN SUVANEN

Master of Science Thesis in Technology and Health
Advanced level (second cycle), 30 credits
Supervisor at KTH: Malin Hollmark
Examiner: Sjoerd Haasl
School of Technology and Health
TRITA-STH. EX 2014:103

Royal Institute of Technology
KTH STH
SE-141 86 Flemingsberg, Sweden
http://www.kth.se/sth

Abstract

Radiotherapy (RT) is the most common treatment for cancer. The state-of-the-art modality for RT is the linear accelerator. However, the availability for linear accelerators in the developing world is limited due to costs, infrastructure and need for educated personnel. The development in telecommunications can help to increase the availability by connecting radiation RT-centers and have a central treatment planning unit. Scandinavian Care is a company that builds RT-centers in developing countries and has a project in India where three centers should to be connected.

The thesis objectives were to evaluate technical conditions and discuss organizational aspects for remote treatment planning applied on Scandinavian Care's project in India. The technical conditions were evaluated with two models derived from Swedish case studies. The models were analyzed using a SWOT-model. The organizational aspects were divided into the organization of medical physicists and three importtant communication channels.

The thesis concludes that the technical conditions are possible for the project in India. The best model depends on the frequency of disturbances in the WAN-connection and patient throughput sensitivity. The organization of medical physicists suggests a rotation schedule to promote education, informal communication and variation of tasks. Telemedical conferences and use of software possibilities could ease the feedback.

Sammanfattning

Strålbehandling är den vanligaste behandlingsmetoden för cancer. Den bästa enheten för strålbehandling är en linjäraccelerator. Däremot är tillgängligheten av linjäracceleratorer i utvecklingsländer begränsad på grund av kostnader, krav på infrastruktur och utbildad personal. Utvecklingen inom telekommunikationer gör det möjligt att öka tillgängligheten genom att koppla ihop strålbehandlingsklinker och exempelvis centralisera dosplaneringen. Scandinavian Care är ett företag som bygger strålbehandlingskliniker i utvecklingsländer och har ett projekt i Indien där tre kliniker är tänkt att sammankopplas.

Målet med uppsatsen var att utvärdera tekniska förutsättningar och diskutera organisatoriska aspekter för dosplanering på distans, applicerad på Scandinavian Cares Indienprojekt. De tekniska förutsättningarna utvärderades genom två modeller härledda från svenska fallstudier. Modellerna analyserades med hjälp av en SWOT-analys. De organisatoriska aspekterna delades in i organisationen kring strålfysiker och tre viktiga kommunikationskanaler.

Uppsatsen kommer fram till att de tekniska förutsättningarna är genomförbara för Indienprojektet. Den bästa implementeringen beror på hur störningsfrekvensen i WAN- anslutningen påverkar patientflödet. För organisationen av strålfysiker föreslås ett rotationsschema för att främja utbildning, informell kommunikation och variation i arbetet. För att underlätta återkoppling föreslås att utnyttja möjligheterna i mjukvaran och telemedicinska konferenser.

Acknowledgements

First I would like to thank my supervisor Malin Hollmark from CTMH for her support and ideas and my supervisor Göran Hellers his for interesting discussions, great knowledge and thoughts in the subject.

I would also like to express my gratitude to the persons interviewed at each clinic, Lunds University Hospital, Regional Hospital of Sundsvall-Härnösand and Karolinska University Hospital, for taking the time and having interesting and valuable discussions .

Furthermore, I would also like to thank the representatives from Elekta AB and Varian Medical Systems.

A special thanks to my project pal Simon Lundberg for your contribution and our discussions, for the coffees and cupcakes, for your support along the road.

Contents

List of Figures

List of Tables

List of Abbreviations

EBRT	External Beam Radiation Therapy
GTV	Gross Target Volume
JC	Joint Center
Linac	Linear Accelerator
Mbps	Megabit per second
MP	Medical Physicist
OAR	Organ at Risk
OIS	Oncology Information System
PTV	Planning Target Volume
RO	Radiation Oncologist
RT	Radiation Therapy
SWPR	Swedish Workgroup for Pediatric Radiotherapy
TPS	Treatment Planning System
TPU	Treatment Planning Unit
WAN	Wide Area Network

1

Introduction

This chapter details the background and objective of this report. The chapter starts with a brief introduction of the challenges to make radiation therapy more available for developing countries. Thereafter follows a short description of Scandinavian Care and their project in India. Lastly the objective and demarcation of the report are presented.

1.1 Background

Every year 7.6 million persons die due to cancer, which makes it the second most common cause of death in the world [1]. Cancer can be treated with three different methods; chemotherapy, radiation therapy or surgery. Radiation therapy (RT) is used in more than half of all cancer treatments. The state-of-the-art modality for RT is the linear accelerator (Linac), another option is the ^{60}Co-unit. The combined availability of the two treatment modalities is illustrated in Figure 1.1. As the figure indicates, there is a difference between developed and developing countries[1]. The difference would be even larger if only Linacs would be considered. [2]

The challenges to make Linacs more available in developing countries are due to costs, the need for good infrastructure and experienced personnel [3]. One solution to make Linacs more available is to take advantage of the development in telecommunications, as the International Atomic Energy Agency (IAEA) states in the report *Planning National Radiotherapy Services* [4]. There are several examples where telecommunications have been used to connect RT-centers. In Sweden the hospitals in Umeå and Sundsvall collab-

[1]Referring to countries that are grouped as developed markets by FTSE Group's definition

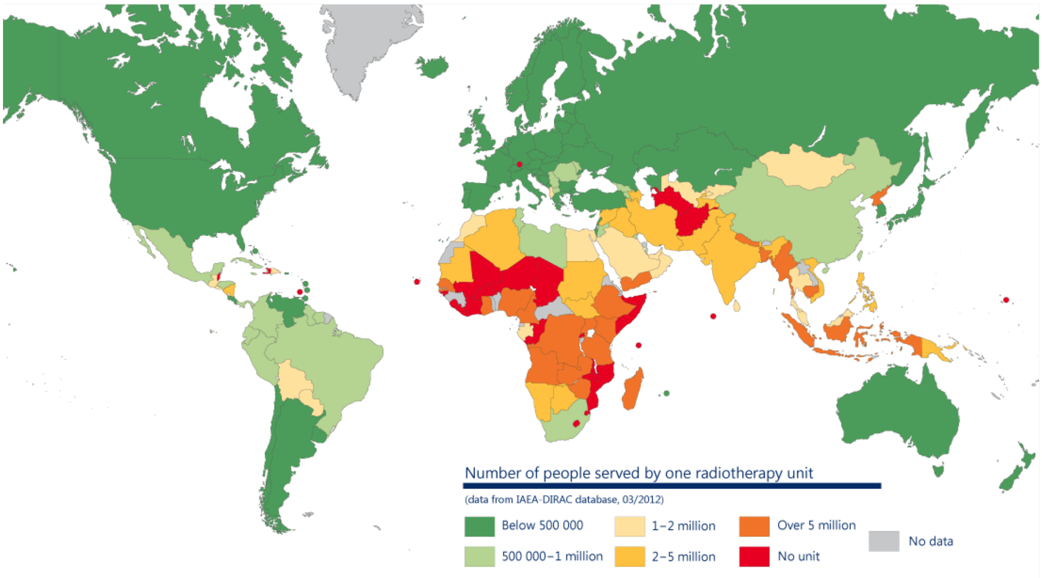

Figure 1.1: Availability of radiation therapy machines: number of radiation machines per million people.
(Source: DIRAC/IAEA)

orate with treatment planning. For the proton therapy center, the Skandion Clinic in Uppsala, all university hospitals in Sweden cooperate. The idea to connect RT-centers is also presented by Datta and Rajasekar [5] as a solution to make RT more available in developing countries. The solution proposed is a three-tier system with RT-centers that have different functions; primary level centers only deliver RT; secondary level centers deliver and create treatment plans for primary centers; tertiary level centers are complete RT-centers that deliver complex treatments and audit secondary level centers. [4]

Scandinavian Care is a company that is a partner for RT-center development in developing countries. Currently Scandinavian Care has a project in India with a hospital group that primarily operates in the state of Maharashtra. The hospital group has 13 hospitals, but none that offers RT. Scandinavian Care's project is to build three RT-centers for the hospital group. The intention is to connect the three RT-centers and have a central treatment planning unit (TPU).

1.2 Objective

The report's objectives are to evaluate technical conditions and discuss organizational aspects for remote treatment planning applied on Scandinavian Care's project in India, based on Swedish case studies.

1.3 Demarcations

The report is demarcated to only focus on RT as a treatment option. The equipment of the RT-centers are delimited to a Linac and CT. The software systems are delimited to the oncology information system (OIS) and treatment planning system (TPS). Software programs are limited to the two vendors Elekta AB and Varian Medical Systems. The organizational aspects are divided into organization of medical physicists and three feedback relations. The organization of medical physicists consider the key activities and staffing levels. The communication channels are delimited to the following three cases:

- Tumor Board ↔ Responsible physician
- Radiotherapist & Radiation Oncologist ↔ Treatment Planning Unit
- TPU ↔ Radiotherapist and Medical physicist

2

Theoretical Background

The theoretical background starts with a brief introduction of radiation therapy and the procedures that precede the delivery of radiation. Thereafter a section with a brief overview of India is presented. Lastly, a section with related work for the technical conditions and organizational aspects are provided.

2.1 Basics of Radiation Therapy

X-rays were discovered by Wilhelm Röntgen in 1895. A year after that, it is believed that Emil Grubbe was the first to use X-rays for cancer treatment. [6] Radiation therapy (RT) is nowadays used in more than half of all cancer treatments. The radiation is delivered either through external beam radiation therapy (EBRT) or brachytherapy. EBRT is delivered from a source located outside of the body, in contrast to brachytherapy where the source is inserted in the body. [7]

The radiation beam used in RT consists of either photons, electrons, protons or light ions. Photons are used for the majority of treatments. Electrons are the second most used particle, whereas protons and light ions are rarely used. The goal with RT is to deliver a lethal dose of radiation to tumors. Since radiation is accumulated in the body it possible to divide the dose into fractions. Fractionated therapy is preferred in most cases since it delivers lower dose to the surrounding healthy tissue. [4]

2.1.1 Modalities that Deliver Radiation

The modalities used for the delivery of radiation in RT are ^{60}Co-units, linear accelerators (Linac) and cyclotrons. A brief description is presented below.

^{60}Co-Unit

A ^{60}Co-unit is used for RT with photons. The modality consists of a radioactive source, ^{60}Co, that naturally emits γ-radiation. The radioactive source has a half-life of 5.27 years, which is also the functional time for the modality. Once half life is reached the radioactive source needs to be substituted. [8]

Linear Accelerator

A Linac is used for RT with photons or electrons and is the state-of-the-art modality. The beam with either photons or electrons is collimated before it reaches the patient. The collimation is performed with a multi leaf collimator[1] that shapes the beam. The ability to shape the beam is what makes more advanced treatments possible. [4]

Cyclotron

A cyclotron is used for RT with protons or light ions. Protons and light ions have a more desirable deposition of energy in tissue than photons and electrons. Although the energy deposition is desirable, the cyclotron is considerably more expensive and incorrect treatments cause more severe damage.

2.1.2 Preceding Steps Before Delivery of Radiation

There are several steps that precede the delivery of radiation in RT. The steps are illustrated in Figure 2.1 and elaborated below.

Assessment of Patient & Decision to Treat
The assessment of patient and the decision to treat is crucial to provide a good treatment. The best practice to assess and decide treatment is in a multi disciplinary team meeting, also called tumor board. The tumor board includes at least a medical oncologist, a radiation oncologist, a surgical oncologist a pathologist and a physician. [7, 9]

[1] The multi leaf collimator is a device with multiple leafs that can be used to block a part of the radiation beam, hence shape the beam. The leafs are usually made of tungsten.

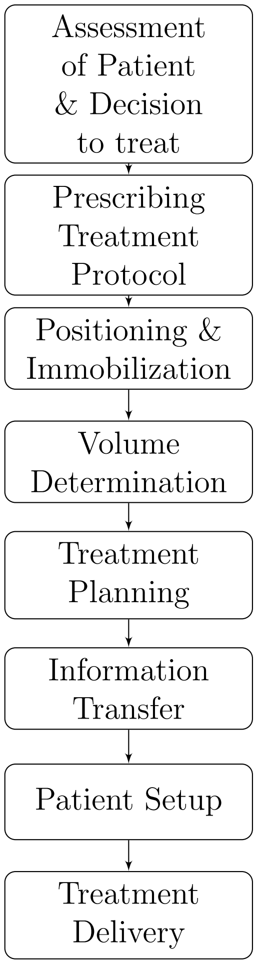

Figure 2.1: Illustrating the process prior to the delivery of radiation in a process scheme.

Prescribing Treatment Protocol

The protocol is prescribed with the intended treatments. For RT the prescription includes for example total dose, number of fractions, dose per fraction, immobilization, the use of bolus/boli[2]. [7, 9]

Positioning & Immobilization

The positioning and immobilization are made to assure the patients are positioned, comfortable and immobilized on the couch. The immobilization devices are standardized for easy setups. For fixation of larger areas whole body frames are used and for head-and-neck patients individual masks are crafted to stabilize the head. A laser reference system is used to position the patient correctly on the couch. Small dots

[2]bolus or boli is a tissue equivalent material put on the skin to be able to create a good dose distribution

are tattooed on the skin to ease repetition of patient setup for every fraction. [7, 9]

Volume Determination

The target volumes are delineated by a radiation oncologist. The volumes include the gross tumor volume (GTV), clinical target volume (CTV) and organs at risk (OAR). The GTV and CTV together make up the planning target volume (PTV). [7, 9]

Treatment Planning

The treatment planning is made to optimize the dose to the delineated PTV and spare the OARs. A software system, the treatment planning system (TPS), is used to position beams and calculate the dose to the volumes. [7, 9]

Information Transfer

The information transfer refers to the transfer of the treatment plan from the TPS to the treatment modality. The transfer is considered a separate step since many incidents are related to information transfer.[7, 9]

Patient Setup

The patient setup is crucial for the outcome of the treatment. The patient is positioned with the same immobilization devises as for the preparation. To assist patient setup the treatment modality has a laser reference system. [7, 9]

Treatment Delivery

Prior to the delivery the responsible medical physicist (MP) at the clinic should verify the treatment plan through dosimetry. The treatment plan is delivered to a phantom or device with sensors to display the distribution of radiation in clinical setting. If the distribution is correct, the treatment delivery to the patient can start. [7, 9]

2.2 India

India is a developing country with a population of 1.2 billion people and the seventh largest country by land in the world. Although, India is considered as a developing country, the Indian middle class is around 250 million. Hence, there are large discrepancies in wealth the country, and the denotation of India as developing country can be misleading. However, one of the greatest challenges for India is to provide healthcare to the entire population. The healthcare is governed by the states, but it is the federal government that decides the policy making, planning and coordination. [10, 11]

The availability for RT in the world is illustrated in Figure 1.1 in section 1.1. The illustration shows the availability for both Linacs and ^{60}Co-units. The illustration shows that there are between 2-5 million people per treatment modality in India, whereas for example Sweden has below 500 000 people per treatment modality. The illustration does not however distinguish between the modalities. If only Linacs were considered, the number for India would be over 5 million people per Linac whereas Sweden would still have below 500 000 people per Linac. This is illustrated in Table 2.1[3]. For comparison, in *Planning National Radiotherapy Services*, IAEA estimates that there is a need for one treatment modality per 180 000 persons. [4, 12]

	Linac	^{60}Co	Total
Sweden	78	0	78
People per modality	120 000	-	120 000
India	167	333	500
People per modality	7.2 million	3.6 million	2.4 million

Table 2.1: Displays the number of treatment modalities in Sweden and India, divided into number of linear accelerators and ^{60}Co-units. The number of people per modality is also illustrated.
(Source: DIRAC/IAEA)

In 2010 the Telecom Regulatory Authority of India presented recommendations for national broadband. The recommendations stated that the need for broadband is important for many industries e.g. healthcare. The expansion includes an increase in bandwidths in urban areas. Possible bandwidths today are up to 100 Mbps in major cities, 50 Mbps in a large number if cities. [13]

[3]Calculations are based on a population of 9.5 million for Sweden and 1.2 billion for India.

2.3 Related Work

This section provides an overview of related work for the technical conditions and organizational aspects. The technical conditions first describe the standard communication for digital images in medicine. Thereafter follows related work from Japan and Norway. The organizational aspects covers some organizations and their recommendations for MPs staffing levels. This is followed by the risk profile for radiotherapy and two audit investigations; one in Australia and one in a developing country in Asia.

2.3.1 Technical conditions

DICOM is the standard for the communication of digital images and information related to the images. The DICOM standard was established in 1993 with an addition for RT, DICOM-RT, released in 1997. [14] Although the standard is established and vendors conform to the standard, errors do happen. Nordström et al. [15] did independent tests on communication between oncology information systems (OIS) and TPS from two vendors. The tests showed that some information was corrupted in the transfer, but the errors were less if the two systems shared the same database.

Japanese teams were early adopters of remote connections in oncology. Connections for oncology purposes has been experimented with since the 1990s. Among the earliest connections included video conferences between two hospitals. A summary of different oncology projects in Japan is presented by Mizushima et al. in [16]. One of the projects experimented with the connection of two computers with the intent to perform remote treatment planning. Both computers had the same TPS installed .The connection between the computers consisted of a WAN[4] with a leased line and a bandwidth of 1.5 Mbps. With this connection Ogawa et al. succeeded to plan treatments from Tohoku University hospital at an affiliated hospital. [16, 17]

In Norway telecommunications in oncology was considered to be a cost effective solution for RT at remote facilities. The requirements and applications for remote assistance are presented by Olsen et al. in [18]. Three different levels of application are described; the first level consisted of video conference and image display; the second level consisted of database replication in addition to level one; and the third level consisted of dealt time remote operations in addition to level two. The requirements on bandwidth were

[4]Wide Area Network

1-10 Mbps for the first and second level connection and 10-50 Mbps for third level connection. [18]

2.3.2 Organizational aspects

The organizational aspects of RT are related to the complexity of the treatment and the patient load. The MPs at an RT-center are the experts on physics and responsible for the safety. The number of MPs needed at an RT-center depends on the complexity of treatments and the patient load. There are no harmonized regulations on the staff level needed for an RT-center, but several organizations offer recommendations. One of the first organizations that offered recommendations was the Inter-Society Council for Radiation in [19]. These recommendations are outdated, and better examples are provided by the European Commission (EC) [20], The Institute of Physics and Engineering in Medicine (IPEM) in the UK [21] and IAEA [4, 22].

The report *Radiotherapy Risk Profile* [9] by the World Health Organization (WHO) provides an overview of the risks connected to RT. The report includes a risk profile, based on the potential impact on adverse events in the RT-process. Also a summary of incidents by Shafiq et al. [23] is presented in the WHO report. From the summary of incidents it is concluded that many incidents are preventable and the RT-center should focus on three key areas, frequent formal and informal communication, competence-based education, and regular audits.

In Australia, Shakespeare et al. [24] investigated the quality of two single machine units[5] and compared it to two hubs. All relevant information such as treatment plans, images, electronic records and treatment chart, were audited by an external auditor following the set standards in Australia. They could not find any significant difference in quality. However in another study by Shakespeare et al. [25], a similar external audit was made as the one in Australia. The focus was a clinic in a developing country in Asia. The results from the clinic in the developing country showed that the clinical performance, which includes documentation, quality assurance decision making criteria, was adequate in 80.2 % of the time. Despite this, only 48 % of the patients received optimal treatment. The poor result for treatments were believed to be caused by the absence of quality assurance steps; absence of peer review and excessive workload. Shakespeare also concluded that "expensive equipment does not guarantee quality practice". [25]

[5]A RT center with only one treatment modality, usually located in a rural area

3

Method

The chapter first details the method used for the technical conditions.

3.1 Literature Study

An initial literature study was made to establish a theoretical knowledge of the state-of-the-art process in RT, find related work and find Swedish case studies.

3.2 Technical Conditions

The technical conditions for remote treatment planning were derived from: the Swedish case studies, the related work and information from the two vendors. The case studies provided an organizational overview and possible deployments. Each case study was complemented with field visits to a related clinic in the study . The related work and information from the vendors supplemented the case studies with technical details.

The models were analyzed with a SWOT analysis. The SWOT analysis is a method developed to create strategic plans in business management. The basis of the plan is to identify strengths and weaknesses within the company and opportunities and threats to the company. The model can be applied for different cases, this report is based on the cause analysis view. The cause analysis view of the SWOT analysis is to gauge what practice should be continued in the future. [26]

4

Vendors

The two major vendors for radiation therapy equipment are Varian Medical Systems and Elekta AB. This chapter briefly presents the two vendors and their corresponding software systems for treatment planning and oncology information.

4.1 Varian Medical Systems, Palo Alto

Varian Medical Systems is company based in Palo Alto, California. The company was founded in the 1940s, and started to manufacture treatment modalities for RT in the 1950s. In the 1980s Varian bought a system developed in Finland called Cadplan developed by Dosetec. The current treatment planning system (TPS) offered by Varian, called Eclipse, is based on the systems developed by Dostec. Eclipse was released in the early 2000s, however several major upgrades have been made since the first release, for example the inclusion of virtual simulation.

4.1.1 Eclipse™

Eclipse has all necessary functionalities for the treatment planning needed in the project. The software is capable to plan treatments e.g. IMRT, 3DCRT, IGRT and proton therapy. It is also possible to delineate/contour structures in the TPS. Dose calculations can be made for photons, protons and electrons. For plan evaluation and commissioning Eclipse offers isodose curves display, a plan comparison tool and DVH. Varian set requirements on the workstation computers and organization at the hospital. [27, 28]

Smart Segmentation® Knowledge based contouring

A product closely related to Eclipse is Smart Segmentation®Knowledge Based Contouring. The system includes a library of templates for easier and faster delineation that can create a more efficient work flow. Furthermore, the clinic can create own templates in the system for various treatments. This is a tool that can be used to implement a standard delineation for specific cancer types and to assure that the quality of delineations for different cancer types are the same.

4.1.2 Aria®

Aria is the oncology information system (OIS) provided by Varian. The oncology system complements the TPS and together they make up an integrated software solution. In Aria, an oncology specific patient record can be created. The OIS can handle both medical and radiation oncology. For radiation oncology, plans can be reviewed easily with if Eclipse is the TPS since they share database. Aria also supports TPS from other vendors and offers options for documentation in the oncology specific patient record. Aria has the possibility to implement electronic signature procedures and recommend standard protocols. The communication follows international standards for medical information such as DICOM and HL7[1]. [29, 30]

4.2 Elekta AB, Stockholm, Sweden

Elekta is a Sweden based company with headquarter in Stockholm. The company was founded by the neurosurgeon Lars Leksell in the 1970s. Initially Elekta was a one-product-company, with the stereotactic modality called the Gamma Knife . Nowadays® Elekta offers several products for RT, that includes software products and treatment modalities. Just as Varian, Elekta acquired smaller divisions and companies to provide an integrated system. Among the companies acquired were Philips radiotherapy division, IMPAC medical systems, CMS and Nucletron.

4.2.1 Monaco® 5

Elekta, has several TPS on the market (e.g. XiO and Oncecntra External Beam) but Monaco is the flagship. The software is capable to plan for all

[1]HL7 refers to a set of standards that refers to how data are transfered between hospital information systems

standard treatments, including 3D CRT, IMRT and VMAT. Furthermore, it is possible to delineate target volumes in the TPS. The dose calculations are based on Monte Carlo simulations, and can be used for photons and electrons. The TPS is capable of displaying isodose curves, DVH and comparison for plan evaluation tool. Another feature is biological modeling[2]. [31]

ABAS

Elekta also have a product for easier delineation. The system is called atlas-based auto segmentation (ABAS), where previous reference images in an atlas are scanned and propose a delineation to the user. ABAS can increase the efficiency for delineation and the clinic can build up an atlas of standard procedures for easier and clinic specific delineation.[32]

4.2.2 MOSAIQ®

MOSAIQ is the OIS Elekta provides. It is a complement to the TPS and together they create an integrated solution for RT. It is possible to create an oncology specific patient record, and connect images from different image systems e.g. MRI and CT to the record. The OIS can handle both medical and radiation oncology. MOSAIQ is compatible with TPS from other vendors since it follows the international standards for communication in medicine such as DICOM and HL7. The OIS also able to save documentation and implement signature procedures for treatment protocols. [33]

[2]Biological modeling is when the biological effects due to irradiation are considered in the model

5

Swedish Case Studies

The chapter presents three Swedish case studies where telemedical conferences have been used in all of them and remote treatment planning in two of them. The first section describes a collaboration between the University Hospital of Umeå and the Regional Hospital of Sundsvall-Härnösand. The next section describes how pediatric radiotherapy in Sweden started to use telemedical conferences to unite all experts. Thereafter is a case which details the intended treatment planning for the proton therapy center, the Skandion Clinic. The chapter ends with a summary and lessons learned from the cases.

5.1 Case I, Joint Center, Umeå-Sundsvall

Case I describes a collaboration between Norrlands University Hospital in Umeå and the regional Hospital in Sundsvall-Härnösand. The section starts with a brief background to the project and the set up used in the collaboration. Thereafter the workflow is presented followed by quality assurance considerations. Lastly a short summary and final notes are presented.

5.1.1 Background

A report by the Swedish Council on Health Technology Assessment [34] clarified that cancer patients in Sweden were offered radiation therapy (RT) as a treatment option less frequently than in comparable countries. One reason was believed to be the large distances between the RT-centers in Sweden. The northern part of Sweden covers 55 % of the total area, but only has 10 % of the inhabitants. Only one hospital in the northern part offered RT at the time, which was the University Hospital of Umeå. The report suggested that an RT-clinic could be opened in the Regional Hospital of Sundsvall-

Härnösand to better cover the need for RT. The RT-center opened in 2002, and the collaboration between the hospitals was called "Joint Center" (JC). [35]

5.1.2 Setup

The JC was to treat patients with radiation at both hospitals but all treatment plans were made in Umeå. The apparatus and software at each corresponding clinic are summarized in Table 5.1. The main goal of collaboration was to establish a setup that ensured that the quality of the treatment was equal for both hospitals. The treatments in Sundsvall focused on the most common forms of cancer e.g. breast, lung and brain cancer, in contrast to Umeå that provided full RT service. All treatment plans for both hospitals were created by the treatment planning unit (TPU) in Umeå. Prior to the delivery of the treatment plans a joint conference was held. The conferences were held in a dedicated room with three displays. The displays were shared and showed the patient information, suggested treatment plan and a video link to the other hospital. The purposes of the telemedical conferences were to assure the quality of treatments and unite the cancer care in the northern part of Sweden. [35]

5.1.3 Workflow

The workflow and routines were important to deliver equivalent care at both hospitals. The basis to deliver equivalent care was to have the same preparation and idea of how to treat patients. To prepare the patients equivalently a joint handbook was developed. The handbook described how the patients should be prepared before treatment. The assessment of patients from Sundsvall was made in Sundsvall. The patient information was stored in an electronic patient folder (EPF) on a server located in Sundsvall. The server was replicated every other minute with the server in Umeå, which made the information on the two servers identical. The immobilization and fixation of the patients were made in Sundsvall, along with the delineation of the target volumes. Since the servers were identical the EPF with the delineated images were available in Umeå. The treatment plan was created in Umeå by the TPU. Once the treatment plan was created all new patient cases were brought up on a weekly joint telemedical conference where the treatment plans were discussed, evaluated and accepted. The accepted plans were verified in Sundsvall through dosimetry before the treatments started. [35]

Sundsvall
1 Linac (Elekta, Precise), with 2 photon energies, 6 electron energies, MLC, electronic portal image system (Elekta iView GT), amorph silicon detectors.
1 Therapy x-ray (Gulmay)
Conference room with three displays
Umeå
5 accelerators, (From Linac to racetrack)
1 therapy x ray (Therapax)
1 conventional x-ray simulator
Treatment Planning system, TMS and OTP (Nucletron)
Conference room with three simultaneous images.
Both
Virtual CT based simulator (GE advantage sim)
Information and verification system (Oncentra RV, Nucletron)
Electronic patient record system Oncentra EPF and RS (Medfolio, Nucletron)
Migra
Connection to SJUNET
Fixation devices
Handbook

Table 5.1: Materials used in at the two different clinics in the Joint Center collaboration.

5.1.4 Quality Assurance

The quality assurance for the JC was crucial to deliver an equivalent treatment at the two hospitals. The added quality assurance in the JC were the joint handbook and the telemedical conferences. The handbook was developed to ensure that the preparation before each treatment was made the same and that information about the patients was stored in the same way at both hospitals. The telemedical conferences were held to establish a communication channel where the treatment plans could be discussed and evaluated. The intention was especially made to make the medical physicists (MP) in Sundsvall involved and understand the treatment plans. Furthermore, the telemedical conferences also functioned as an educational tool to maintain the competence in treatment planning for the MPs in Sundsvall. [35]

5.1.5 Summary and Final Notes

The aim of the JC was to make RT more accessible in the northern part of Sweden. The JC achieved the aim through a tight collaboration, identical servers for patient information, and added quality assurance steps with the development of a handbook and joint telemedical conferences with image displays.

Some final notes of the JC are that the collaboration was abandoned when a procurement for new systems was made. After the procurement the hospital in Sundsvall acquired their own TPS. The telemedical conferences are still in use to unite the cancer care for the northern part. The servers are no longer replicated but shared, so the treatment plans are accessible for both hospitals if necessary.

5.2 Case II, Remote Children's Radiotherapy

This section presents a case study where telemedical conferences was used to unite the experts in pediatric radiation therapy in Sweden. The telemedical conferences had two main functions, ensure that the best treatment is provided to all children and to expose the experts to more cases.

5.2.1 Background

Nearly 250 children are diagnosed with cancer each year in Sweden, which can be compared to 55 000 adults [36]. Of these 250 children, approximately one third undergo RT. Children with cancer are rare and there are few experts

Material	
Network	SJUNET (from 4Mbps to 1Gbps)
Video Conference room	Tandberg
	Polycom
Dedicated Server	Windows 2003 server, dual 3.2 GHz Intel Xeon CPUs, 4 GB RAM
Application sharing	Citrix MetaFrame Presentation XP Server 3.0
	Citrix MetaFrame Conference Manager 3.0)
Application	Oncentra Master Plan ver. 1.5 SP1 (DICOM-RT viewer)

Table 5.2: Materials used for the in the project to combine the Swedish Workgroup for Pediatric Radiotherapy

in the field. The Swedish Workgroup for Pediatric Radiotherapy (SWPR) unites the experts in Sweden, and in November 2005 a project started to create a new communication channel for the SWPR. The main goal was to involve more experts for each treatment plan and hence provide the best treatment possible for each child. The project lasted from November 2005 until December 2006 when it was evaluated. [37]

5.2.2 Setup

The setup for the project based on telemedical conferences. The aim with the telemedical conferences were to engage more specialists for each patient and provide the best possible treatment to every child. The materials for the set up are shown in Table 5.2. To provide the best possible treatment, all patient cases and treatment plans were discussed on a SWPR conference before the treatment was delivered. The conferences were managed from Umeå, where the display information to conferences were shared to the members via Citrix[1]. Hence the members in the SWPR were shown the same information and could discuss and evaluate the cases together. Physical meetings were held twice annually to promote informal communication and were believed to play an important role for the discussions in the telemedical conferences. [37]

[1] Citrix is a program that allows the user to take remote access of a computer and virtualize its applications.

5.2.3 Workflow

To connect the members in SWPR the intranet called SJUNET was used. SJUNET connects all healthcare providers in Sweden with a common network that supports bandwidths up to 1000 Mbps [38]. The connection and the desired bandwidth were pre-booked on SJUNET prior to each telemedical conference. Each hospital had a conference system installed. The patient cases, including treatment plans, were exported to a dedicated server located in Umeå prior to the conference. The technical support for the conferences was managed from Umeå where the information was shared via Citrix. The applications used for the information sharing were the DICOM-RT viewer, Microsoft Excel and Adobe Reader. In this way all specialists got access to same information and could discuss the patient cases. In the conferences target volumes, treatment plans and diagnostic images were discussed. [37]

5.2.4 Summary and Final Notes

The aim was to create a platform for the experts in the field of children's RT, which succeeded. The exposure to more patient cases was concluded to be the main benefit of the project. The majority of the involved persons stated that the project had a significant impact on their competence in the field. However, there were complaints on the quality of the video and audio links.

The technology has improved since the project was evaluated, and all university hospitals have dedicated rooms for teleconferences with good video and audio quality. Furthermore, the knowledge acquired in this project was adopted by the project with the Skandion Clinic described in the next section.

5.3 Case III, The Skandion Clinic

The Skandion Clinic is a proton therapy center located in Uppsala that will start treatments in mid-2015. The clinic is jointly owned and managed by the counties in Sweden. The section starts with a brief background followed by the set up and workflow. Thereafter quality assurance in the project is described. The section ends with a summary of the case.

5.3.1 Background

Proton therapy has been used since the 1950s in Sweden at the Svedborg Laboratory in Uppsala. The laboratory is still in use, however the capacity is limited and only used in rare cases for treatments. A pilot study presented by Mattson et al. [39], was made in 2002 leading up to the final decision to build the Skandion Clinic. The clinic is managed and owned by the counties in Sweden and the proton therapy treatments are estimated to start in mid-2015. [40]

5.3.2 Setup

The Skandion Clinic is managed through distributed competence. Distributed competence means that the competence for proton therapy should be available at all university hospitals and not only at the Skandion Clinic. The reasons to have distributed competence are to involve the university hospitals in the treatments and develop the staff at the university hospitals. To prepare and educate the staff for proton therapy a program called the "Proton School" was started. The Proton School uses telemedical conferences as the main communication channel and the same workflow as the Skandion Clinics intends to have. The telemedical conferences used the same set up as for SWPR, which means that there is a conference room at each university hospital with teleconference equipment (e.g. such as presented in Table 5.2). [41, 42]

5.3.3 Workflow

The university hospitals are responsible for their own patients and are responsible for all preparation prior to proton therapy. Hence, the assessment is made at each respective university hospital. Thereafter the immobilization and positioning are made followed by an export of the reference images to the central server in Uppsala. The delineation of target volumes is made on the central server, and thereafter a treatment plan is created on the central server. The treatment planning unit (TPU) logs on to the remote server via Citrix and create a plan on the central server in Uppsala. Before the patients are sent to Uppsala, a telemedical conference is held to discuss the patient cases an treatment plans. The responsible university hospital thereafter makes the follow up. [41, 42]

5.3.4 Quality Assurance

The added quality assurance for the Skandion Clinic are the Proton School and the telemedical conferences, which functions as a national board for proton therapy. The Proton School enables personnel at all university hospitals to learn treatment planning for protons and discuss treatment plans, delineations of target volumes and patient cases for proton therapy. The telemedical conferences also enable the hospitals to discuss different treatment options. This is necessary since some hospitals use different methods to treat different cancer types. [41, 42]

5.3.5 Summary and Final Notes

The conclusions from the project are that remote treatment planning is possible with this method. The telemedical conferences serve as a communication channel and promote both education and secondary audits.

6

Models

The chapter presents two models derived from the three Swedish case studies. The models are derived from case I and III that included remote treatment planning. Model I is derived from case I, the Joint Center collaboration and model II is derived from case III, the Skandion Clinic.

6.1 Model I

Model I is derived from the Joint Center collaboration (JC). The main features of the JC were, one central treatment planning system (TPS) and identical databases. Model I is illustrated in Figure 6.1. Important network considerations and the equipment placement are described in Table 6.1.

In the JC the TPS was only installed in Umeå, but with identical databases the information was automatically transferred and accessible at both sites. Model I is derived from these properties. However, in model I the TPS and oncology information system (OIS) are both installed at the central server in the hub. The TPS is only managed from the central server. Whereas the OIS has workstations at the satellites that are connected to the central server through Citrix. In this way the server and database for the hub and satellites are not only identical, they are the same. Although the server is located at the hub it is possible to have a backup hard drive for local storage of the treatment plans at the satellite. Local storage of the treatment plans should be made for approved treatment plans. The main reason for local storage is to be able to deliver all fractions of a started treatment even if the connection between the satellite and hub is down. [29]

Satellites
1 CT
1 Linac
1 OIS workstation (MOSAIQ or ARIA workstation)
Local hard drive
Hub
1 CT
1 Linac
1 TPS (Monaco or Eclipse)
1 OIS (MOSAIQ or ARIA)
Both
Standard fixation devices
Common handbook and protocol (develop handbook)
Dosimetry devices
Telemedical Conference room with multiple displays
Network Configurations
VPN/WAN connection to satellite
At least 1.5 Mbps internet connection

Table 6.1: Lists the equipment and network configurations for model I

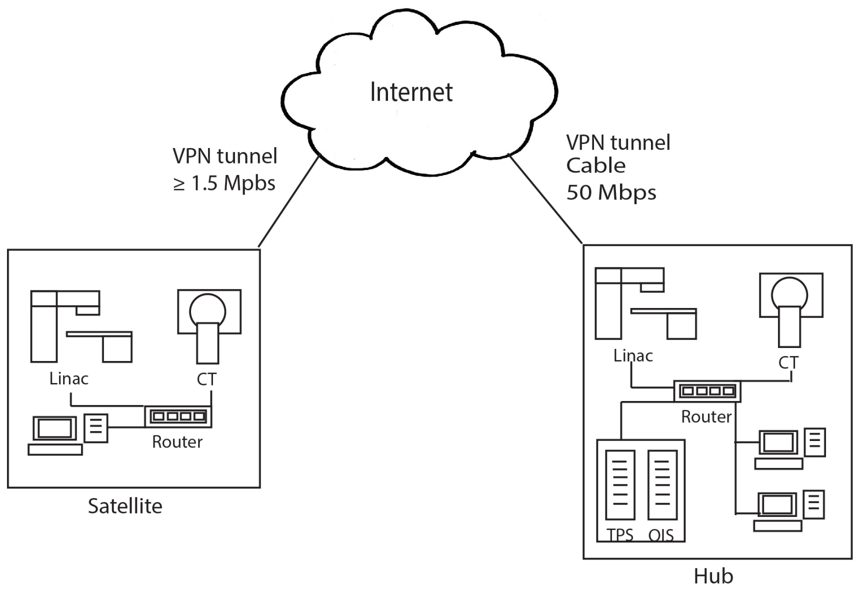

Figure 6.1: Illustration for the organization in model I

Each clinic should operate on a dedicated subnetwork of the radiation oncology network. The satellites need a router that connects the modality, workstation and CT. The router also connects the satellites to the hub via the Internet. A WAN strategy that will work is to create a virtual private network (VPN) with IP security between the satellite and the hub over the internet, which provides good integrity and security. [30]

Transfer of treatment plans to the workstation can be achieved by a bandwidth of 324 kbps. However the workstation is connected to the main server via Citrix which requires larger bandwidth. A stable connection of at least 1.5 Mbps should be available at the satellite to meet the requirements. Though it is desirable with larger bandwidth to reduce disturbances. [30]

The hospitals' IT-management is responsible for all network connections up to the switches and routers connecting the devices. Furthermore, the vendors have requirements on servers and hardwares where their software is installed. [30]

6.2 Model II

Model II is derived from the Skandion Clinic where the main feature is distributed competence. In model II the competence is not distributed but the software, and hence have the possibility to operate independently if necessary. The TPU is still centralized and can access the satellites via e.g. Citrix. Figure 6.1 illustrates the connections between the hub and satellites, and Table 6.2 determines important network considerations and where the software are installed and modalities are located.

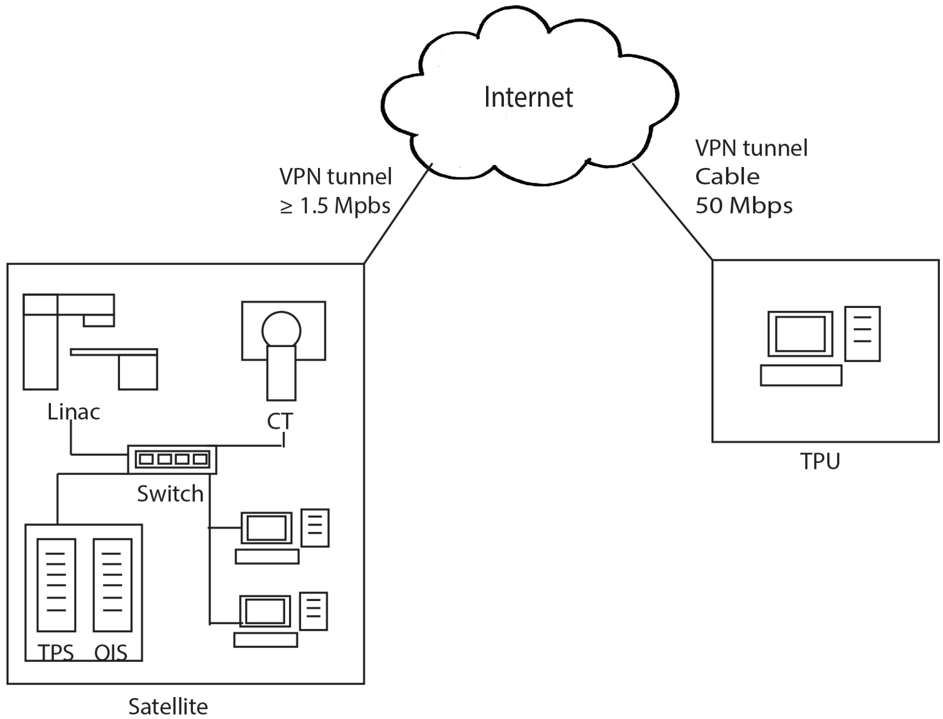

Figure 6.2: Illustration for the organization in model II

In the Skandion Clinic all university hospitals create treatment plans on a central server in Uppsala. In contrast to the Skandion Clinic, model II centralizes the TPU but decentralizes the modalities and software. Hence each center (satellites and hub) has their own TPS and OIS and functions as an own RT-center in network topology. Thus, each RT-center has own servers and databases where the software systems are installed. The modality, CT and software system can be connected with a switch. The switch can be connected to the adjacent hospital's IT-network. The hub can connect to the

Clinics
1 CT
1 Linac
1 OIS (MOSAIQ or ARIA)
1 TPS (Monaco or Eclipse)
Standard fixation devices
Common handbook and protocol (develop handbook)
Dosimetry devices
Telemedical Conference room with multiple displays
Treatment Planning Unit
Computers with Citrix installed
Network Configurations
VPN/WAN connection to satellite
At least 1.5 Mbps internet connection

Table 6.2: Lists the equipment and network configurations for model II

server where the TPS is installed via e.g. Citrix, and control the computer via virtual network computing. In this way the TPU can be centralized and operate at the hub. [30]

The remote control of the computer is achieved through data transmission between the computers. Video information is transferred from the remote computer to the Citrix computer, and mouse and keyboard information is transferred to the remote computer. Hence the remote computer can be controlled, and any operations from applications on the remote computer use the performance of the remote computer. The Internet connection between the clinics is made using a VPN tunnel with IP security. From the Citrix performance statements the need for medical imaging purposes is 1.5 Mbps with a latency of 200 ms. [30, 43]

The hospitals IT management are responsible for all network topology up to the switches and routers connecting the devices. Furthermore, the vendors have requirements on servers and hardwares where their software systems are installed. [30]

7

Technical Analysis

In the analysis chapter, the two models presented in the previous chapter are analyzed with the SWOT-analysis. Lastly a comparison of the two models based on the analysis is presented.

7.1 Model I

An overview of the SWOT analysis for model I is presented in Table 7.1 and elaborations are provided below in separate subsections.

7.1.1 Strengths

The strengths of model I are central software management, the use of the same database and fairly low bandwidth requirements. The central software management eases the implementation of upgrades and the control of network status. All treatments are stored in the central server which eases the transfer of patients to other clinics if a modality breaks down. The fairly low requirements on bandwidth and the possibility to transfer data (treatment plans, images) any time during a day is advantageous.

7.1.2 Weaknesses

The weaknesses are a complex network topology, dependency on the Internet connection and an inflexible organization. The network topology includes all radiation therapy(RT)-centers since all clinics should be connected to the central server, thus making it complex. The model puts more responsibility on the hospital's IT management since they are responsible for the network connections. The Internet dependency is due to the absence of a locally

Strengths	Weaknesses
• Central software management • Database and server park the same • Flexible bandwidth demand	• Complex network topology • WAN dependency
Opportunities	**Threats**
• Increase the number of satellites • Expand at the satellites • Sell the service • External audit • Easier delineation tool	• Breakdown/attack on main server

Table 7.1: SWOT analysis of model I

installed treatment planning system (TPS), and without Internet connection the treatment plans cannot be sent to the satellite. Hence if the connection is down the throughput of patients is compromised. The model is inflexible since the delineation and TPS must be completed at the hub where the TPS is installed.

7.1.3 Opportunities

The opportunities of model I are to expand at the satellites, increase the number of satellites, sell the service, and co-operate with larger clinics. The model is scalable and can incorporate more satellites and expand at the satellites. Expansion at the satellites might need more workstations for the oncology information system (OIS), and hence more bandwidth since more information will be transferred. The inclusion of more satellites is also possible since the number of clients for the software can be adapted to the total patient load. Another opportunity is to sell the service. Images can be transferred to the hub and the hub sends back a treatment plan. Furthermore, there is also an opportunity to co-operate with other clinics for e.g. audits and competence-based education. The last opportunity is to acquire an easier delineation tool such as ABAS or Smart Segmentation Knowledge based contouring.

7.1.4 Threats

The main threat is a breakdown of the central server. A breakdown would affect the RT at all clinics since the TPS and OIS are installed on the main server.

7.2 Model II

An overview of the SWOT analysis for model II is presented in Table 7.2 and elaborations are provided below in separate subsections.

Strengths	**Weaknesses**
• Independency of clinic • Local servers • Network topology at each clinic	• Need for more clients • Software management • Bandwidth dependent
Opportunities	**Threats**
• Organizational opportunities • Sell the service • Include more clinics	• Repeated remote access

Table 7.2: SWOT analysis of model II

7.2.1 Strengths

The main strength is that all necessary software systems are installed and located at the clinic, hence the clinic can function on its own if necessary. For example, if there are regular outages or internet breakdown, the treatment planning can be made at the clinic and ensure patient throughput. Furthermore, the independency is also favorable if the intention is to have local treatment planning in the future. The network topology at the clinic will be easier in the sense that it has no workstations that need to be connected with a central server at the hub.

7.2.2 Weaknesses

The weaknesses for model II are the need for more software management and software clients, and a connection dependency. With model II, each clinic needs at least an own TPS and OIS client. Thus upgrades in the software systems must be managed at each separate RT-center. Lastly the TPU is dependent on a stable internet connection during the workday.

7.2.3 Opportunities

The opportunities with model II are organizational, independency and to sell the service. Firstly, the organizational opportunity is to shift the focus to the satellite. With own software it is possible for the radiation oncologist (RO) to delineate target volumes at the satellite. However the connection to the hub can still be used as a quality assurance step, where more experienced ROs can audit the delineation. The same method can be made for treatment planning, however this compromises with a central TPU. The services, treatment planning and audits, can be sold as services to other clinics. The last opportunity is to co-operate with other clinics for e.g. audits and competence-based education.

7.2.4 Threats

The main threat for model II is that the hub repeatedly connects to the satellite, thus allows someone to connect the RT-centers network. This repeated connection may reduce the attention for hackers, thus compromise security.

7.3 Summary of Models

The main strength for model I is the IT-management, whereas the main strength for model II is the independency. With central servers it is only necessary to upgrade software at one location in difference to model II. Furthermore, investments in the main server park benefits all RT-centers. Model II is however less dependent on the internet connection to provide RT. The model II RT-centers have their own TPS and OIS and hence can work independently of the hub if the connection is down, thus secure the patient throughput.

The main weakness for model I is the internet dependency. Since the workstation is connected to the main server via a WAN-connection it is necessary that the connection is stable to ensure patient throughput. Model II is also dependent on the bandwidth and connection to some extent. However, model II is more flexible since it can work independently from the hub if necessary. The ongoing treatments for model I can still be delivered if the treatment plans are backed up locally. However, the initiation of new treatments is inhibited.

The opportunities for the centers are similar. It is possible to expand to more satellites and start an affiliated company that can sell the service. Model II have however more organizational opportunities, whereas model I can take advantage of smart delineating tools. Expanding to more RT-center is possible for both, but more suitable for model I since the IT management is less affected by the expansion.

The threats are connected to the centralization for model I and repeated connection for model II. Model I dependent on the operation of the central server, and if something happens to the it the whole RT-network is affected.

8

Organizational Analysis

The organization and feedback chapter is divided into two main sections and a final summary. The first section details the organizational aspects for the medical physicists. The aspects discussed are key activities and staffing level. The second section describes the three feedback relations where an incorrect action has high impact on the treatment outcome. Lastly, lessons learned from the two previous sections are combined and summarized.

8.1 Organization of Medical Physicists

The organization of the medical physicists (MP) is discussed with respect to the key roles of the MPs and the staffing recommendations for radiation therapy (RT). These aspects together with lessons learned from the case studies with respect to the three focus areas presented by Shafiq et al. [23] are the basis for the organization of MPs.

8.1.1 The key Roles of Medical Physicists

The key roles for the MP specific to RT are: (a) installation and acceptance testing of equipment, (b) safety, (c) dosimetry, (d) treatment planning, (e) quality management.

(a) Installation and acceptance testing

The installation and acceptance testing is performed to ensure that the equipment is functional before treatments start. The installation also includes the fulfillment of safety requirement of the design of the RT-centers. Tests on the equipment are not limited to the installation and commissioning, and are a part of the continuos maintenance. [22]

(b) Safety
The MPs are responsible to set up a safety program for the RT-center. The safety program should ensure that the staff, the patients, and the public are protected from unintended irradiation. [22]

(c) Dosimetry
The dosimetry is made by the MP to verify that the delivered dose is the intended dose. The treatment modality delivers the plan to a phantom with detectors. The dose distribution in the phantom can be displayed and verify that the treatment plan is correct. [22]

(d) Treatment planning
The treatment planning should aim to optimize dose distribution to the target volume. The MP is responsible for the creation of treatment plans for patients. [22]

(e) Quality management
The quality management is the continuous quality assurance at the RT-center. The management includes developing guidelines for procedures and treatments, creating a quality assurance program for treatment units, treatment planning and dosimetry, calibration of equipment, developing action plans for unintended exposures and investigation of incidents. [22]

8.1.2 Staffing Recommendations for Medical Physicists

There are no harmonized staffing requirements for MPs among organizations, but several organizations have recommendations e.g. IPEM, EC and IAEA.

The recommendations from the Institute of Physics and Engineering in Medicine (IPEM) in UK can be calculated using a template. The template is based on the patient load and the complexity of the equipment and treatments. An example calculation for the satellites and hub can be found in the appendix. A brief calculation of the satellite indicates that 2.1 MPs are needed for the satellites and for the hub 3.0, with a patient load of 500. The IPEM recommendations further states that the minimum level of MPs at a clinic should be two. [21]

The European Commission (EC) also provides recommendations for staffing levels in Europe. The recommendations from EC are in line with IPEM's recommendations for staffing level. In the report *Radiation Protection No. 174* [20] where the recommendations are presented, it is also noted that the

MPs can help smaller clinics. This is also suggested in an older recommendation from the European Federation of Medical Physics [44]. The report states that a clinic can operate with a single MP with assistance from another MP when needed (e.g. for installation of new equipment, vacancies).

The International Atomic Energy Agency (IAEA) also provides examples of MP staffing levels. For example, an RT-center with three ^{60}Co-units, a CT simulator, 2D TPS and a patient load of 1600 requires two clinically qualified medical physicists. Another RT-center with a Linac, a brachytherapy unit, CT simulator, TPS and dosimetry equipment is recommended 3-4 medical physicists. [4, 22]

8.1.3 Lessons Learned from Case Studies and the Three Focus Areas

The case studies showed proof of the three focus areas proposed by Shafiq et al. [23]. The three focus areas were frequent informal and formal communication, competence-based education and regular audits. The Joint Center collaboration used telemedical conferences to ease the formal communication. The telemedical conferences also functioned as a tool to maintain the competence in treatment planning among the MPs at the satellite and to audit the treatment plans.

In the case for pediatric RT the main goals were to educate the personnel and have audit more patient cases. The telemedical conferences facilitated the formal communication and physical meetings facilitated informal communication. Hence the telemedical conferences provided a communication channel to promote the competence-based education and allowed audits from other specialists. In the Skandion Clinic, regular telemedical conferences are held to ease the formal communication. Physical meetings and seminar ease the informal communication, and as in the previous case the goal is to educate and audit each others treatment plans and delineations.

8.1.4 Organization of Medical Physicists

The organization of MPs should take into account the key roles of the MP, the staffing level recommendations and the three focus areas proposed by Shafiq et al. [23]. A rotational schedule and telemedical conferences could be adopted to comply with the staffing recommendation and key activities of the MPs, but still promote the three focus areas proposed by Shafiq et al.

The key activities of the MPs suggest that there is a need for MPs on site at each RT-center, for e.g. dosimetry and calibration. There are other activities that not necessarily need the MPs on site, e.g. treatment planning, developing guidelines and action plans. However, the MPs need to know equipment, the procedure and the limitations for the clinic to be able to create treatment plans, develop guidelines and action plans.

The IPEM staffing recommendations states that there should at least be two MPs on site. However the EC has examples of clinics operated by a single MP with support from another MP. This is desirable for the project since since less staff is cheaper. However, the key activities performed by a remote MP must however know the clinic. Therefore a rotation schedule suggested. This would facilitate the activities that can be preformed remotely, but also create variation of the tasks. Furthermore, with telemedical conferences the RT-network can comply to the three focus areas proposed by Shafiq et alṪhus, informal communication and competence-based education is promoted by the rotation and the telemedical conferences promotes formal communication and audits.

8.2 Communication Channels

The feedback was based on three relations with high potential impact on the outcome and the communication that is made between the facilities. To ease the communication between the different professions, the RT-centers should take advantage of the functions in the software systems.

The feedback was demarcated to only include these special cases:

- Tumor Board ↔ Responsible physician
- Radiotherapist & Radiation oncologist ↔ TPU
- TPU ↔ Radiotherapist & MP

8.2.1 Tumor Board-Responsible Physician

The risk with poor feedback between the tumor board and the responsible physician is an incorrect prescription of treatment plan. The incorrect prescription is most likely to occur when the responsible physician does not consult a tumor board at all. The feedback from the tumor board can be made in the software, where treatment protocols can be prescribed. With a centralized tumor board all RT-centerssoftware systems can be accessed with the models proposed. The software supports electronic signatures, hence the responsible physician can sign the proposed treatment protocol in the software at the satellite. For uncertainty in the prescribed treatment protocol there should be a telemedical communication between the tumor board and responsible physician. [29, 33]

8.2.2 Radiotherapist & Responsible physician - RO & TPU

The risks with lack of communication between the radiotherapist and responsible physician and the radiation oncologist are incorrect delineation. The risks with lack of communication between the radiotherapist and responsible physician and the TPU are incorrect patient setup (including the use of boli) and failure to report the physical state of the patient.

Firstly the communication between the radiotherapist and responsible physician and the radiation oncologist needs to follow protocols so all parameters are included. Furthermore, it is also important to know the intended treatment method and physical status of the patient. The delineation becomes more important with the complexity of the treatment method. There is a need for strict protocols to assure that all information is included. [29] [33]

The communication from the radiotherapist and responsible physician to the TPU is important to make a good treatment plan. For the plan to be good, it is crucial that the MPs are aware of the possibilities and limitations at the satellites. The possibilities and limitationsare, the type of immobilization devices for patient setup, the treatment modality and the workflow. If these conditions are not known, the MP may do a plan that is impossible to deliver at the satellite, thus jeopardize the safety of patients. [29, 33]

The communication of the patients' physical status is more difficult to address. There is a possibility for documentation, where physical status can be adressed in the oncology specific patient record, but it is more difficult to formulate and interpret documentation correctly for the responsible physician and TPU. Documentation can be one tool to indicate that something with the physical status needs to be considered so the TPU can contact the responsible physician for further details. [29, 33]

8.2.3 TPU - Radiotherapist & MP

The feedback needed between the TPU and the personnel at the satellite are to assure that: the plan is interpreted correctly, the setup of patient is correct, and it is a the correct plan. To ensure that the interpretation of the treatment plan is correctly there must be a communication between the TPU and the satellite MP. The communication can use the telemedical conference system used in the case studies, where the use of multiple screens could display the case, treatment plan and a video link. This eases the communication for the treatment plan discussion. Once the treatment plan has been accepted at the telemedical conference, the MP at the satellite can import the plan. For the assurance of the correct plan, each treatment prescription should be preceded by a dosimetry measurement by the MP. To ensure the set up of the patient, a checklist should be implemented so no immobilization device or boil is missing, the laser system is used for positioning and compare the digital reconstruct radiographs with the beam's eye view.

8.2.4 Summary

The software can assist with workflow solutions, but the standardized format of the the information is not always optimal. For prescriptions and delineations it is necessary that the information is standardized, but for patient specific information it is not. Providing textual information on physical states or positions are complicated to describe and interpret correctly. There is a possibility to attach digital photographs to the patient record, but this alone cannot compensate for the need for verbal communication between the personnel. To work with the personnel involved at the different clinics (radiotherapists, RO, responsible physician and MPs) is important to develop a mutual understanding, but also to learn about the limitations and possibilities for all sites.

9

Discussion

The discussion chapter starts with a discussion of the methods followed by a brief discussion of the vendors. Thereafter are the models discussed and lastly the organizational aspects.

9.1 Method

The method used for the technical conditions provided information about radiation therapy (RT) in a developed country. The challenges in technology and organizations are not always transferrable to a developing country. The technical models are derived from setups that were possible in Sweden. Thus the downside with deriving the models from Swedish case studies are that easier models such as transport of images on a hard drive with the patient record were not considered. The SWOT analysis is a bit vague when real numbers and information are not included. The cause-analysis made in the report relays on reasoning rather than actual numbers, costs and revenues. For example the assumption that IT management for more systems is more expensive. It is logic, but it does not tell how much more expensive it is, or what the savings are. The method illustrates however the differences between the models, and their strengths.

The organizational aspects are discussed based on the literature and the case studies. However the discussion does not consider the experience level and the education of the MPs. The assumption is that MPs have proper education and clinical experience once they are educated, which makes them experts. This might be the case in developed countries but not certain for MPs educated in developing countries.

9.2 Vendors

The two vendors, Elekta and Varian, both have software systems that are suitable for the project. One difference is that Varian only offers one treatment planning system (TPS) whereas Elekta offers several, which could indicate that Varian's is more integrated than Elekta's. Another similarity is that both vendors offer a solution for easier delineation: Elekta with ABAS and Varian with Smart Segmentation® Knowledge Based Contouring.

With the use of any of these systems, model I is preferred for economical reasons, since the software only needs to be installed at the central TPS and can be used for all RT-centers.

9.3 Models

The two models provide two possibilities to centralize treatment planning but other models are also possible. Model I has a preferable architecture and needs less IT management, whereas model II emphasizes the independence and possibility to always treat the patients at the satellites.

If local independence or centralized management is optimal for the Indian project, or a developing country in general, depends on the frequency of disturbances in the WAN-connection and the throughput sensitivity. Model I is dependent on the WAN-connection, which is the main weakness of the model. With frequent downtimes in the WAN-connection it affects the operational capacity and the throughput of patients. The operational capacity is affected since the satellites only have a workstation for the OIS and with no Internet connection there is no access to the central server. The throughput of patients is affected since the workflow to introduce new patients to the system is compromised. With backup storage for the treatment plans, the ongoing treatments can still be delivered. Hence, with frequent downtime the throughput of patients is affected, and this in turn affects the costs and revenues. For model I to be preferable, secure uptime for the WAN-connection is necessary. Another strength of model I is the possibility to acquire an easier delineation tool at one site which benefit all RT-centers.

There are other possibilities for arrangement of central treatment planning. A basic model is to transport information physically by storing images on a hard drive. The hard drive and patient record can then be transported to a central unit where the treatment planning is performed. The treatment plan is thereafter, in the same manner, transported back to the satellite where the delivery is performed. Another possibility is to have TPS and OIS installed at both sites and transfer DICOM images via internet and back. The latter configuration is possible with the set up in model II. The advantages of such set up would be less need for bandwidth since no realtime operations are needed, however it still requires that an OIS and a TPS are installed at both sites.

To create the RT-network in general are a sustainable solution to make the Linac more available. It is more costly [3] but as Reddy points out [45] it is the better road to take for India. The treatment possibilities are much greater with Linacs than ^{60}Co-units. Furthermore, the requirements presented by Olsen et al. [18], Ogawa et al. [16] and in the Swedish case studies are possible to some extent in the project. India does not have a SJUNET for example but it is not necessary either to provide remote treatment planning and create a network similar to the three-tier system proposed by Datta and Rajasekar [5].

9.4 Organization

The key activities and responsibilities of the medical physicists (MP) suggest that there is a need for at least one MP at each satellite. A rotation schedule and telemedical conferences could comply the organization to the three focus areas proposed by Shafiq et al. [23].

An organization with only one MP at the satellites with backup at the hub would be most cost effective. The risk with the setup is that the MPs become isolated. In the Swedish case with the Joint Center-collaboration (JC) telemedical conferences were used to involve the satellite in treatment plans and decisions. Telemedical conferences were also used among the Swedish Workgroup for Pediatric Radiotherapy (SWPR) for audits and education. In the Skandion Clinic project telemedical conferences were used in the same way as for the SWPR. To create a sustainable RT-network and to comply to the three focus areas proposed by Shafiq et al. a rotation schedule and telemedical conferences are possible solutions. The benefits will be the creation of a RT-network.

However, there are problems connected to a rotation schedule e.g. workflow and physical. If the distance between the hub and satellites is long, it will not be possible to commute between them. Thus, MPs from the hub and satellites needs to live away from family and friends for periods of time with a rotation schedule. The workflow at both the hub and satellite may be affected since the satellite MP does not do any treatment plans most weeks and the hub MPs are not used to the satellite RT-center. Hence it is necessary with strict routines to execute a rotation schedule. Furthermore, it is important to understand that the education of the MPs in the RT-network is important, both to set up good routines and protocols, but also to implement the workflow. Thus, experienced MPs should start up the RT-network and teach the local personnel how to manage the systems.

The software systems have many features that can ease implementation of protocols but that cannot substitute verbal feedback completely. The development of a workflow and protocols to follow are needed, especially for a hub-satellite relationship since communication is hindered by the distance. The study in a developing country by Shakespeare et al. [25] suggested that lack of routines and the heavy workload caused the poor treatments. To implement new routines might be hard, the positive aspect for the three prospected RT-centers for the project in Indiia is that the centers are not built yet. Thus, good routines can be established from the beginning. Furthermore, building identical RT-centers will ease the implementation of the same routines and ease the rotation schedule of MPs.

Nonetheless, both the rotation of MPs and feedback relations would benefit from telemedical conferences. The conferences would also make the organization comply more to the three focus areas stated by Shafiq et al. The downsides for telemedical conferences are costs and bandwidth. It will cost to establish a conference room with the necessary equipment. It will require more bandwidth since video and audio transmission are demanding.
The challenge to make state-of-the-art treatment for radiotherapy (RT) more available in India can be achieved with current technology and efficient organizations. This report's objectives were to analyze technical conditions and discuss organizational aspects for remote treatment planning based on Swedish case studies.

Two models were created derived from Swedish case studies where remote treatment planning has been performed. The technical conditions for the two models were found to be implementable. Model I focused on a central management of the treatment planning system (TPS) and the oncology information system (OIS). A workstation for the OIS can be placed at each satellite and connected to the main server and database using Citrix. Model II put emphasis on the satellites and the ability to operate independently if necessary. For model II, the treatment planning unit (TPU) accesses the computer with the TPS at the satellite via e.g. Citrix, and make the treatment plan. The best model for the project depends on the frequency of disturbances in the WAN-connection and the throughput sensitivity. The vendors, Elekta AB and Varian Medical Systems, both have software that can be used for centralized treatment planning.

The organizational part concluded the need for at least one medical physicist (MP) at the satellites due to the key responsibilities in radiation therapy. To promote informal and formal communication, competence-based education and audits among the MPs, a rotation schedule and telemedical conferences should be considered. The rotation schedule promote education, informal communication and variation of tasks. The telemedical conferences promotes formal communication and audits.

The software systems have possibilities to ease documentation, protocols and signatures. Thus communication is essential for the organization, and feedback channels are needed. Telemedical conferences have been proven to be useful for the Swedish case studies and are a possibility for the project.

Cancer is a disease that increases in number, especially in the developing countries. To create RT-networks is one solution to make RT more available. But to make the RT sustainable it needs more than just good equipment. The education, organization and feedback are crucial for a quality practice; just as T.P. Shakespeare stated: “expensive equipment does not guarantee quality practice”.

Bibliography

[1] World Health Organization. *World Cancer Report 2008*. International Agency for Research on Cancer, 2008.

[2] IAEA. *Inequity in Cancer*. International Atomic Energy Agency, 2011.

[3] Piet-Hein van der Giessen, Jose Alert, Cholid Badri, Matija Bistrovic, Deepak Deshpande, Dimitris Kardamakis, Debbie Van Der Merwe, Neiro Da Motta, Luis Pinillos, Rena Sajjad, Ye Tian, and Vic Levin. Multinational assessment of some operational costs of teletherapy. *Radiotherapy and Oncology*, 71(3):347 – 355, 2004.

[4] International Atomic Energy Agency. *Planning National Radiotherapy Services*. Human Health Series. IAEA, 2010.

[5] Niloy Ranjan Datta and David Rajasekar. Improvement of radiotherapy facilities in developing countries: a three-tier system with a teleradiotherapy network. *The Lancet Oncology*, 5, 2004.

[6] Pioneer in x-ray therapy. *Science*, 125(3236):18–19, 1957.

[7] IAEA. Commissioning and quality assurance of computerized planning systems for radiation treatment of cancer. Technical report series no. 430, IAEA, 2004.

[8] U.S Environment Protection Agency. Cobalt. [Online] Available: `http://www.epa.gov/radiation/radionuclides/cobalt.html` [Last checked 2014-05-28].

[9] World Health Organization. Radiotherapy risk profile. Technical report, WHO, 2008.

[10] Gerard La Forgia and Somil Nagpal. *Government-Sponsored Health Insurance in India : Are You Covered?* Number 11957 in World Bank Publications. The World Bank, 2012.

[11] Peter Wennerholm Andreas Muranyi Scheutz. India's healthcare system. Technical report, Swedish Agency for Growth Policy Analysis, 2013.

[12] Directory of radiotherapy centres: International atomic energy agency. Available: `http://www-naweb.iaea.org/nahu/dirac/informationupdate.asp` [Last checked 2014-04-14].

[13] Telecom Regulatory Authority of India. Recommendations on national broadband plan. Technical report, Telecom Regulatory Authority of India, 2010.

[14] NEMA. *PS3 / ISO 12052 Digital Imaging and Communications in Medicine (DICOM) Standard*. National Electrical Manufacturers Association, VA, USA, 2011.

[15] Fredrik Nordström, Crister Ceberg, and Sven Å.J Bäck. Ensuring the integrity of treatment parameters throughout the radiotherapy process. *Rradiation and Oncology*, 103(3):299–304, 2012.

[16] Yoshihiro Ogawa, Kenji Nemoto, Yoshihisa Kakuto, Hiromasa Seiji, Kazuya Sasaki, Chiaki Takahashi, Yoshihiro Takai, and Shogo Yamada. Construction of a remote radiotherapy planning system. *International Journal of Clinical Oncology*, 10(1):26–29, 2005.

[17] Hiroshi Mizushima, Eiko Uchiyama, Hiroshi Nagata, Yoshihiro Matsuno, Ryuzo Sekiguchi, Hironobu Ohmatsu, Fumihiko Hojo, Tadakazu Shimoda, Fumihiko Wakao, Tetsu Shinkai, Naohito Yamaguchi, Noriyuki Moriyama, Tadao Kakizoe, Kaoru Abe, and Masaaki Terada. Japanese experience of telemedicine in oncology. *International Journal of Medical Informatics*, 61(2–3):207 – 215, 2001.

[18] Dag Rune Olsen, Øyvind S Bruland, and Brian J Davis. Telemedicine in radiotherapy treatment planning: requirements and applications. *Radiotherapy and Oncology*, 54(3):255 – 259, 2000.

[19] Inter-Society Council for Radiation Oncology. Radiation oncology in integrated cancer management. Technical report, ISCRO, Philadelphia, 1991.

[20] EC. Radiation protection no. 174: European guidelines on medical physics expert. Technical report, European Commission, 2014.

[21] Institute of Physics and Engineering in Medicine. *IPEM Recommendations for the Provision of a Physics Service to Radiotherapy*, 2009.

[22] International Atomic Energy Agency. Roles and responsibilities, and education and training requirements for clinically qualified medical physicists. Human health series no. 25, IAEA, 2013.

[23] Jesmin Shafiq, Michael Barton, Douglas Noble, Claire Lemer, and Liam J. Donaldson. An international review of patient safety measures in radiotherapy practice. *Radiotherapy and Oncology*, 92(1):15 – 21, 2009.

[24] TP Shakespeare, M Turner, and A Chapman. Is rural radiation oncology practice quality as good as the big smoke? Results of the Australian radiotherapy single machine unit trial. *Australasian Radiology*, 51(4):381–385, 2007.

[25] Thomas P. Shakespeare, Michael F. Back, Jiade J. Lu, Khai Mun Lee, and Rahul K. Mukherjee. External audit of clinical practice and medical decision making in a new Asian oncology center: Results and implications for both developing and developed nations. *International Journal of Radiation Oncology*Biology*Physics*, 64(3):941 – 947, 2006.

[26] Doug Leigh. *Handbook of Improving Performance in the Workplace: Volumes 1-3*, chapter 5, SWOT Analysis. John Wiley Sons, Inc., 2010.

[27] Varian Medical Systems. Hardware specifications and organizational needs. Available: http://www.varian.com/us/oncology/services_and_support/hardware_specifications/organizational_needs.html [Last checked 2014-05-28].

[28] Varian Medical Systems. Eclipse workstations. [Online] Available: http://www.varian.com/us/oncology/services_and_support/hardware_specifications/eclipse_workstation.html [Last checked 2014-05-28].

[29] Varian Medical Systems. ARIA®Oncology Information System. [Online] Available: http://www.varian.com/us/oncology/radiation_oncology/aria/radiation_oncology.html [Last checked 2014-05-28].

[30] Varian Medical Systems. Aria network configurations. [Online] http://www.varian.com/media/oncology/services_and_support/pdf/hardware_specs/ARIA_Network_Configuration_Guidelines.pdf [Last checked 2014-05-28].

[31] Elekta AB. Monaco 5. [Online] Available: http://www.elekta.com/healthcare-professionals/products/elekta-software/

treatment-planning-software/planning-software/monaco.html [Last checked 2014-05-28].

[32] Elekta AB. ABAS, Atlas-based Autosegmentation. [Online] Available: http://www.elekta.com/healthcare-professionals/products/elekta-software/treatment-planning-software/contouring-software/atlas-based-autsegmentation.html [Last checked 2014-05-28].

[33] Elekta AB. MOSAIQ®Radiation Oncology Information System. [Online] Available: http://www.elekta.com/healthcare-professionals/products/elekta-software/radiation-oncology.html [Last checked 2014-05-28].

[34] Statens beredning för medicinsk utvärdering. *Strålbehandling vid cancer*, volume Vol. 1. Statens beredning för utvärdering av medicinsk metodik (SBU), Stockholm, 1996.

[35] Anders Björeland, Michael Blomquist, Anders Sätherberg, Per Bergström, Mikael Karlsson, and Lars Franzén. Joint center - samarbetsprojekt för optimal strålbehandling i närmiljö. *Läkartidningen*, 2004.

[36] Socialstyrelsen. Cancerincidens i Sverige 2012. Technical Report 978-91-7555-126-5, Socialstyrelsen, 2013.

[37] Ingrid Kristensen, Mats Johansson, Jack Lindh, Per Nilsson, and Mikael Karlsson. Barnradioterapi på distans. *Läkartidningen*, pages 1188–1190, 2006.

[38] Inera AB. SJUNET. [Online] Available: www.inera.se [Last checked 2014-05-28].

[39] Sören Mattsson, Anders Brahme, Jörgen Carlsson, Juliana Denekamp, Eva Forssell-Aronsson, Mikael Hellström, Karl-Axel Johansson, Elisabeth Kjellén, Bo Littbrand, Bo Nordenskjöld, Bo Stenerlöw, Ingela Turesson, Björn Zackrisson, and Bengt Glimelius. Swedish cancer society radiation therapy research investigation. *Acta Oncologica*, 41(7):596–603, 2002.

[40] Skandionkliniken. The skandion clinic. [Online] Available: http://www.skandionkliniken.se [Last checked 2014-05-28].

[41] Ingrid Kristensen, Jack Lindh, Per Nilsson, Måns Agrup, Per Bergström, Thomas Björk-Eriksson, Jacob Engellau, Anna-Lena Hjelm-Skog, Beatrice Malmer, Ulla Martinsson, et al. Telemedicine as a tool for sharing competence in paediatric radiotherapy-implementation and initial experiences from a Swedish project. *Acta Oncologica*, 48(1):146–152, 2009.

[42] Mikael Karlsson, Thomas Björk-Eriksson, Olof Mattsson, Sören Mattsson, Anders Montelius, Per Nilsson, and Björn Zackrisson. "distributed proton radiation therapy"-a new concept for advanced competence support. *Acta Oncologica*, 45(8):1094–1101, 2006. PMID: 17118845.

[43] Citrix HDX Technologies. [Online] Available: `http://www.citrix.com/content/dam/citrix/en_us/documents/products-solutions/citrix-hdx-technologies.pdf` [Last checked 2014-05-28].

[44] S. Belletti, A. Dutreix, G. Garavaglia, H. Gfirtner, J. Haywood, K.A. Jessen, I.-L. Lamm, B. Mijnheer, A. Noël, F. Nüsslin, U. Rosenow, P. Schneider, W. Seelentag, S. Sheriff, H. Svensson, and D. Thwaites. Quality assurance in radiotherapy: the importance of medical physics staffing levels. Recommendations from an ESTRO/EFOMP joint task group. *Radiotherapy and Oncology*, 41(1):89 – 94, 1996.

[45] K.S Reddy. Choice of a teletherapy unit: Cobalt 60 unit vs linear accelerator. In S.P. Agarwak, editor, *Fifty Years of Cancer Control in India*. National Cancer Control Programme, 2002.

Appendix A

Appendix

This appendix provides an example calculation for staffing levels of medical physicists or WTE scientists as they are denoted in the recommendations.

The numbers for the staffing levels are based on an annual patient load of 500. The linear accelerator is a single mode unit at the satellites and multi mode units at the hub. Major items are CT, treatment planning system, oncology information system.

Item	MPs	Satellite	Hub
Multi mode accelerator	0.8	0	0.8
Single mode accelerator	0.6	0.6	0
Major item	0.2	0.2	0.6
Minor item	0.1	0	0
New courses treated EBRT per 1000	0.8	0.4	0.4
New courses treated 3D C	0.1	0.3	0.3
New courses treated brachytherapy	0.3	0	0
Special Techniques	0.3	0	0.3
Radiation Protection	0.1	0.1	0.1
Establish Quality System	0.5	0.5	0.5
Result		2.1	3.0

Table A.1: Example calculation for the hub and satellite from the using the IPEM recommendations.