Comparative Studies on Permanent Prostate Brachytherapy: Pre-Plan and Real-Time Transrectal Ultrasound Guided Iodine-125 Seed Implants at Korle-Bu Teaching Hospital, Ghana

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DECLARATION

Candidate's Declaration:

I hereby declare that except for the references to other publications, which have been duly cited, this thesis is the result of my own research work and that it has neither in part nor whole been presented for any degree elsewhere.

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ABSTRACT

This research was carried out to investigate and compare the real-time and pre-plan implant at the Radiotherapy Department of the Korle-Bu Teaching Hospital, Ghana. Prowess Panther 4.5 treatment planning system and Variseed 7.2 software were used for pre-plan and real-time implant respectively. The study was conducted for eighty - three (83) patients treated for prostate cancer through real-time implant brachytherapy between September, 2008 to April, 2013. Thirty one patients (31) whose Ultrasound images were available were selected for the pre-plan study. The slices of ultrasound images were re-drawn on transparent A-4 sheets and later on scanned, contoured and registered in the treatment planning system (Prowess 4.5) .After planning, the volume to be implanted, total number of needles, seeds and the total activity of the source were displayed. Comparison was done with the pre-plan and real-time implant. In both cases the variation was below 5% as recommended in dosimetry. About 30-40% of the imported seeds were left un-used due to over-estimation of seeds ordered from the manufacturer (BARD Company-USA) .Hence this work (pre-plan) aims to solve this problem. The comparison for dosimetric parameters was assessed for prostate, urethra and rectum as (V95%, V100%,V150%, D90Gy, D90%) , (D90Gy, D90%, D30Gy , D30%) and (V100% , D30Gy and D30%) respectively and the variation were within the limit of ± 5%. Comparison of dosimetric values for this work were done with other institutions, like Karolinska university hospital, Sweden, The institute of Curie / hospital Cochin Group Paris-France and European recommendations. The values reported at Korle-Bu teaching hospital (this work) were in good agreement with the international guidelines.

DEDICATION

To my parents Mr. and Mrs. Lawrence Kalolo who taught me the importance of education, learning, and doing that which should be done.

To my lovely wife, Elizabeth. K. Njelekela and our children: Freeman Kalolo (Son), Hellen Kalolo (Daughter) and Wenceslaus Kalolo (Son).

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LIST OF ABBREVIATIONS

AAPM	American Association of Physicists in Medicine
ABS	American Brachytherapy Society
AP	Anterior - Posterior
ASTRO	American Society of Therapeutic Radiology and Oncology
Au	Gold
AUA	American Urological Association
CaP	Cancer of prostate
cc	Cubic centimetre
cGy	Centigray
Co	Cobalt
CPU	Central Processing Unit
Cs	Caesium
CT	Computed Tomography
CTV	Clinical Target Volume
D30	Dose that cover 30% of the organ
D90	Dose that cover 90% of the organ
DRC	Democratic Republic of Congo
DRE	Digital rectum examination
DVH	dose volume histogram
e.g	For example
EAU	European Association of Urology
EBRT	External beam radiation therapy
EORTC	European Organisation for the Research and Treatment of Cancer

ESTRO	European Society for Therapeutic Radiology and Oncology
ɤ	Gamma
GBq	Giga Becquerel
GHz	gigahertz
HDR	High dose rate
HVL	half value layer
I	Iodine
IAEA	International Atomic Energy Agency
ICRU	International Commission on Radiation Units and Measurements
IGRT	Image guided radiation therapy
IMRT	Intensity modulated beam radiation therapy
IORT	Intra-operative radiation therapy
IPSS	International prostate symptom score
Ir	Iridium
KBTH	Korle-Bu Teaching Hospital
Kev	Kilo electron Volts
LAT	Laterally
LDR	Low dose rate
mCi	milli curie
MDR	Medium dose rate
Mev	mega electron volts
mm	millimetre
MRI	magnetic resonance imaging
ng	nano gram
PBRT	proton beam radiation therapy

Pd	Palladium
PSA	Prostate specific antigen
PTV	Planning target volume
QOL	quality of life
RAM	Random Access Memory
RD	Rectal dose
RIT	radio immunotherapy
T	Tumor
Te	Tellurium
TG	Task group
TPS	Treatment planning software
TRUS	Transrectal Ultrasound
TURP	Transurethral resection of the prostate
UrD10	Dose that cover 10% of the urethra
UrD30	Dose that cover 30% of the urethra
UrD90	Dose that cover 90% of the urethra
US	Ultrasound
USA	united States of America
Vs.	Versus
V100	Percentage of the organ that receive 100% of the dose
V150	Percentage of the organ that receive 150% of the dose
V95	Percentage of the organ that receive 95% of the dose
Xe	Xenon
α	Alpha
β	Beta

LIST OF SYMBOLS AND CONSTANTS

$P(r_0 , \Theta_0)$	Reference point that lies on the transverse bisector of the source at a distance of 1 cm from the origin
$D(r, \theta)$	The dose rate at point, r, in the medium from a radioactive source
$G(r, \theta)$	Geometry factor
$F(r, \theta)$	Anisotropy function
S_k	Air kerma strength of the source
Λ	Dose rate constant
θ	Angle
$g(r)$	Radial dose function
r_0	Reference point on the transverse axis

CHAPTER ONE

INTRODUCTION

1.1 Background

Brachytherapy is a term used to describe the short distance treatment of cancer with radiation from small, encapsulated radionuclide sources. This type of treatment is given by placing sources directly into or near the volume to be treated. The dose is then delivered continuously, either over a short period of time (temporary implants) or over the lifetime of the source to a complete decay (permanent implants). Most common brachytherapy sources emit photons; however, in a few specialized situations beta or neutron emitting sources are used. There are generally two main types of brachytherapy treatment; intracavitary in which the sources are placed in body cavities close to the tumour volume and interstitial, in which the sources are implanted within the tumour volume (Podgorsak et al., 2005).

There are also two types of brachytherapy that are used in the treatment of prostate cancer: permanent low dose radiation (LDR) and temporary high dose radiation (HDR). LDR brachytherapy uses iodine-125 and palladium-103 stored in titanium cases usually referred to as brachytherapy seeds. As the name permanent brachytherapy suggests, the seeds are permanently left inside the prostate gland. Over the course of their radioactive lives, the seeds will continuously emit low radiations until they decay completely. HDR brachytherapy uses a single radioactive seed made of iridium-194 which is sometimes referred to as an iridium wire. Soft flexible plastic catheters are inserted through the perineum and into the prostate gland. HDR brachytherapy entails an overnight stay in the hospital during which a patient undergoes two or three treatments with the wire through each catheter. In LDR brachytherapy, tiny radioactive particles each of the size 3.8 x 0.5 mm^2 are implanted

directly into the site of the tumour. These particles are known as 'seeds', and they can be inserted linked together as strands, or individually into the prostate. Because the seeds are inserted or implanted directly into, or very close to, the tumour, they deliver high doses of radiation to the tumour with minimum effect to the normal healthy tissues around it. This means that the procedure is less damaging than conventional radiation therapy where the radioactive beam irradiates other organs (Khan, 2003; Podgorsak et al., 2005).

Brachytherapy has gained wide acceptance as a treatment modality for early stage prostate cancer, in which the disease is confined to the prostate gland .According to Jakub Pritz (2011) ,treatment of prostate cancer with brachytherapy began when Pasteau and Degrais (1914) inserted radium into the prostate through the urethral catheter (Pasteau et al.,1914). Interstitial implantation of radium needles was first used by Barringer (1917). By the mid 1970's, modern interstitial brachytherapy for the treatment of prostate cancer developed its formalism, after the discovery of ^{125}I radionuclide in the early 1970's. The delivery of the ^{125}I radioactive isotopes was done through needles inserted retropubically. Depth coordinates for the needles were determined through palpation of the prostate through the rectal cavity (Holm et al., 1981). Since 1972, several improvements have been made to the implantation process and radiation delivery of permanent seed implant brachytherapy (Whitmore et al., 1917). The first brachytherapy planning was optimized through use of patient images obtained either through transrectal ultrasound probes or CT scans. Using the patient images sets as well as dose calculation software (such as Variseed), better dose delivery by permanent seeds could be performed.

Prostate cancer has the highest prevalence of any nonskin cancer in the human body, with similar likelihood of neoplastic foci found within the prostates of men

around the world regardless of diet, occupation, lifestyle, or other factors. Essentially all men with circulating androgens will develop microscopic prostate cancer if they live long enough. The factors that determine the risk of developing clinical CaP are not well known, although a few have been identified. There are three well-established risk factors for CaP which includes, increasing age, heredity and ethnicity (Heidenreich et al., 2012). According to age, the older a man is, the greater his risk for getting prostate cancer especially at the age above fifty (50) years. Family history (genetically) certain genes (the functional and physical units of heredity passed from parent to offspring) that a son inherited from the parents may influence the prostate cancer risk. Currently, no single gene is sure to raise or lower the risk of getting prostate cancer. However, a man with a father, brother, or son who has had prostate cancer is two to three times more likely to develop the disease himself. The highest incidence rates for prostate cancer in the world are among African- American men, who have a higher risk of prostate cancer than white American men. However, racial differences may reflect differences in access to care (exogenous factors), differences in the decision-making process of whether to seek medical attention and follow- up, and differences in allelic frequencies of microsatellites at the androgen receptor (AR) locus or polymorphic variation (Bostwick et al., 2004).

Some findings indicate that there are other exogenous factors affect the risk of progression from so-called latent CaP to clinical CaP. Factors such as food consumption (Diets high in animal fat, especially polyunsaturated fat), pattern of sexual behaviour(men who had suffered from sexual transmitted diseases like gonorrhoea and syphilis are at high risk (Howard et al., 2001), exposure to ultraviolet radiation, chronic inflammation (Nelson et al.,2003) and occupational exposure (Exposures reported to be associated with prostate cancer are pesticides especially

herbicides), cadmium, aluminium, polycyclic aromatic hydrocarbons, engine emissions (particularly diesel exhaust), and mineral oil (Boers et al., 2006) may also lead to the development of prostate cancer.

Different criteria are considered before a patient is admitted for prostate cancer implant. These include, the prostate volume less than 50cc (if larger and otherwise suitable, 3 months of neo-adjuvant hormone treatment will usually bring the volume down to 50cc or less). Those patients with a volume of greater than 50 to 60 cc should have hormonal cytoreduction if they are to be considered as candidates for brachytherapy. This does not always reduce the risk of side effects but it is necessary to achieve a satisfactory implant (Ash et al., 2000). Disease confined within the prostate capsule i.e no metastases from DRE review and bone scan should be negative. Gleason score which is a pathological grading system for measuring the degree of differentiation of prostate tumours should be less than 7 (Gleason, 1977). A prostate specific antigen (PSA) test is also performed to find the concentration of the PSA protein within the patient's blood and this should be less than 20ng/mL (Heidenreich, 2012; Thomson et al, 2004).The international prostate system score (IPSS) should be less than 12. Those with a score of 0 to 8 do well with a low risk of acute retention and prolonged urethritis (Ash et al., 2000). Also a DRE is performed to check for any abnormalities. Patients not meeting these requirements may be candidates for a combination of brachytherapy with external radiation therapy, including intensity-modulated radiation therapy (IMRT) or conformal External beam radiotherapy (EBRT). There is also evidence that enlarged prostates can be successfully implanted.

Several treatment options exist for early stage prostate cancer, these include; hormone therapy, chemotherapy, cryotherapy, permanent seed implant brachytherapy,

external beam radiation therapy and prostatectomy (Heidenreich et al., 2012). Each form of treatment has its own associated risks and side effects. Urinary incontinence and impact on sexual function (impotence) may occur after prostatectomy. Sexual dysfunction and irritative gastrointestinal and genitourinary side effects are commonly reported following external radiation treatment for early stage prostate cancer. In permanent seed implant brachytherapy complications such as urinary retention, urinary incontinence, and radiation proctitis may arise (Ash et al, 2000; Stone et al., 2002). At the present time the monotherapy seed implant technique is used to deliver the prescribed dose to the tumours (Ash et al., 2000). ^{125}I and ^{103}Pd are the most common radioactive isotopes used for prostate seed implant. Based on their decay rates, ^{125}I or ^{103}Pd, has been prescribed to tumours considered slow-growing and fast-growing as designated by their Gleason grade, respectively (Ling et al., 1995). However, prescribing an isotope based on Gleason score has been criticized since no advantages have been observed. Nevertheless, differences in long-term complications between the two isotopes have been reported: a grade III-IV complication rate with ^{103}Pd (2%) compared to ^{125}I (6%) (Peschel et al; 1999) .Similarly the increased risk of proctitis when ^{125}I is used compared to ^{103}Pd and radiation prostatis (Herstain et al., 2005).

Even though ^{125}I and ^{103}Pd are the two most frequently used isotopes in permanent seed implantation, other radionuclides like gold-198, caesium-131, and iridium-192 have been in use for LDR and HDR respectively. ^{125}I has a half-life of 60 days, this means that significant radioactive decay will therefore occur over one year following the implant. About eight-seven per cent (87.5%) of the dose will decay after six months following the implant .With a half-life of 17 days, ^{103}Pd seeds have a higher dose rate than ^{125}I at the time of implantation with 99.9 % of decay occurring

during the first six months. However, overall, no difference in efficacy between ^{125}I and ^{103}Pd has been shown and there is no evidence that caesium-131 seeds, which have recently been introduced, offer any advantage over either ^{125}I or ^{103}Pd (Cha,1999 ,Khan ,2003).

At Korle-Bu Teaching Hospital, the radionuclide iodine-125 is used for prostate brachytherapy treatments. Palladium-103 is an alternative nuclide for the treatment but only ^{125}I is currently used in Ghana. The priority for opting Iodine-125 seeds is because it has a low photon energy which is convenient for storage as it requires less shielding .As well as the longer half-life of the isotope is more appropriate for clinical use (Khan, 2003).

Table 1.1: Half-life and energy range of emitted photons for the radionuclides used for brachytherapy ((Mayles et al,. 2007; Khan, 2003).

Radionuclide	Iodine-125	Paladium-103	Caesium-131
Half-life (days)	59.4	17.0	10
Energy range (keV)	27-36	20-23	29-34

1.2 Statement of the problem.

The accuracy and efficiency in the treatment of prostate cancer under brachytherapy has been a topic of discussion for many decades. In brachytherapy the treatment of cancer demands very high accuracy in dose calculation and distribution with adverse radiobiological effects if there is a significant deviation from the actual prescribed dose. Although the treatment of the prostate brachytherapy has been in existence since 1901 (Degrais et al., 2006), there has not been a uniform method of defining and calculating the dose. This makes it difficult to compare values reported

by different researchers on permanent seed implants and the significant dosimetric parameters. Hence this work aims assess the treatment planning software (TPS) by doing pre-plan implant prior to the real-time implant so as to maintain the accuracy of the dose delivered to the patients. The selection of treatment modality is based on the later advantage, therefore more research helps to produce data that will enable us to develop and utilize an optimal protocol for treatment of prostate cancer under brachytherapy in Ghana as no such work has been done before.

1.3 Objective of the study.

The main objective of this work is **to** compare the pre-plan against real-time plan for patients undergoing prostate brachytherapy at Korle-Bu Teaching Hospital using patient images captured during pre-evaluation study prior to the order of seeds.

The specific objectives to be addressed are to:

(i) assess the number of seeds and needles ordered from the manufacturer prior to implantation.

(ii) assess the dose optimization prior to implant so as to speed up the implant procedure.

(iii) check the correlation between the real-time plans and the pre-plans.

(iv) Make the relevant recommendations to ensure patient safety during and after implant of seeds.

1.4 Relevance and justification.

This work provides guidelines to prostate cancer patients treated with brachytherapy. It also help to assess the accuracy of the treatment planning system (TPS) at Korle-Bu Teaching Hospital using data and information obtained from the study.

Currently the amount of seeds to be implanted into the patient are ordered in excess from the manufacturer and this increases the cost to the patient. This pre-plan work will present the exact amount of seeds needed before the implant. Hence minimizing the cost to patients while increasing the accuracy during implant, and simultaneously minimizing the duration of implant to the theatre. Dose optimization will be achieved since the exact allocation of needles and seeds will be known as guided by the template. Finally the work will serve as a data base for prostate cancer patients at the centre.

1.5 Scope and delimitation.

This study was carried out at the Korle-Bu Teaching Hospital in Accra, Ghana. The study was limited to patients who had undergone prostate brachytherapy from the period between August, 2008 to April 2013.

1.6 Organization of Thesis

This research work would be in chronological order of five chapters. Chapter one focuses on overview of the current state of knowledge relevant to the study. Chapter two reviews existing literature relating to the research problem. Chapter three focuses on the material used and methodology of the study. Chapter four contains results and discussion while Chapter five, provides conclusions and recommendation from the findings.

CHAPTER TWO

LITERATURE REVIEW

This chapter provides an overview on prostate cancer, cancer treatment modalities, and international guidelines.

2.1 Dosimetry associated with brachytherapy.

Radiation dose roughly falls off with the inverse square of the distance from the source. Therefore placing the source very close to the target gives the target a very high dose. If some distance can be kept from neighboring normal tissue structures, then the dose will be lower there hence sparing them from injury.

2.1 .1 Interstitial treatments

The dosimetry information recommended in ICRU Report No. 58 for reporting of interstitial implant treatments consists of;

i. A description of clinical target volumes.
ii. The sources, technique and implant time, the total reference air kerma.
iii. A description of the dose: prescription point/surface, prescription dose, reference doses in the central plane, mean central dose and peripheral dose.
iv. A description of the high and low dose region and dose uniformity indices and dose–volume histograms (DVHs).

The report emphasizes the need to report, as a minimum, four different dose related quantities to adequately describe an implant treatment. In addition to the total reference air kerma, the next significant parameter is the mean central dose, which is representative of the plateau dose region inside the target volume. The minimum dose is important in tumour control — hence the need to report the peripheral dose. To help

correlate dose and any late damage, high dose regions (>150% of the mean central dose) and low dose regions (< 90% of the peripheral dose) are also to be reported.

2.1.2 Dose distributions around sources

Dose calculations are presented in this study for photon emitting sources only. The dose calculations are divided into two categories: The first category represents the AAPM TG 43 formalism, which can be considered as the most complete formalism available today. This approach is used in modern TPSs and is suitable as a method for commissioning and the second category (Independent protocol developed on the centre) may be used for quick checks and verification of treatment plans.

2.1.3 AAPM TG 43 algorithm

In 1995 the AAPM introduced in TG 43 a dose calculation formalism to establish the 2-D dose distribution around cylindrically symmetric sources. It is based on measured quantities such as, dose rate constant, geometry factor, anisotropy function, radial dose function and air kerma strength.

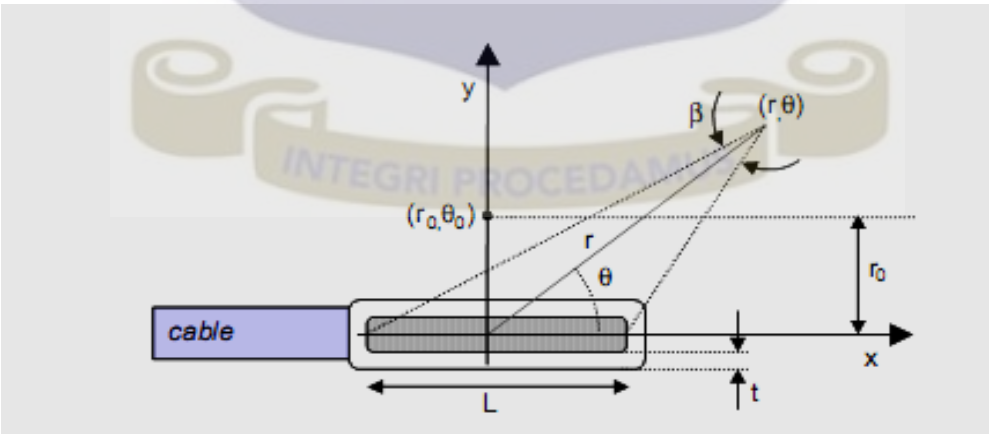

Figure 2.1: The geometry and the definitions used for the TG 43 protocol.

The quantities used in the calculation of absorbed dose in the TG – 43 formalism is measured for the specific type of source. This implies that, aside the photon spectrum and medium, the TG – 43 depends on source construction and geometry as well. Figure 2.1 summarizes the geometry and coordinate definitions used in the TG 43 dosimetry protocol. A source of an active length, L, the encapsulation geometry and the guidance wire are shown. This is the usual configuration of a PDR iridium source. The origin of the coordinate system is positioned at the centre of the active core of the source. The z-axis is along the tip of the source. A cylindrical symmetry for the activity distribution within the core is here assumed. The point of interest, P, is at a radial distance, r, from the origin and has a polar angle coordinate, θ, in the cylindrical coordinate system.

According to the protocol, the dose rate at a point $P(r,\theta)$ in water can be expressed as

$$\dot{D}(r,\theta) = S_K \Lambda \frac{G(r,\theta)}{G(r_0,\theta_0)} g(r) F(r,\theta) \ldots\ldots\ldots\ldots 2.1$$

Where r is the distance from origin to the point of interest P, and θ is the angle with respect to the long axis of the source, as shown in Figure 2.1 θ_0 defines the source transverse plane and is equal to $\theta/2$ radians, S_k is the air kerma strength of the source, Λ is the dose rate constant in water, $G(r,\theta)$ is the geometry function, $g(r)$ is the radial dose function, and $F(r,\theta)$ is the anisotropy function (Ravinder and Jeffrey, 1995).

2.2 Radioisotopes used in prostate brachytherapy.

2.2.1 Classification of brachytherapy sources.

Brachytherapy developed largely through the use of sealed radium and radon sources. In the 1950s, alternative artificially produced nuclides became available, and gradually radium and radon were replaced with ^{137}Cs, ^{192}Ir, ^{60}Co, ^{198}Au, and ^{125}I sources (Godden ,1988). Although radium and radon are no longer used, many of the techniques that are used currently are based on the clinical experience gained with those sources over more than sixty years. Brachytherapy sources are classified into three categories, the first category is based on source loading where we have hot loading (LDR only such as ^{125}I ,^{131}Cs and ^{103}Pd) sources and after loading (both HDR &LDR are applicable) sources. The second category is based on the treatment duration which specifies the temporally dose rate and permanent dose rate. The third category is named with respect to dose rate as high dose rate sources (HDR) in which high energy photons emitters such as ^{192}Ir, ^{98}Au ,^{137}Cs and ^{60}Co, are used.

Table 2.1: Brachytherapy treatments classified with respect to dose rate (Podgorsak et al., 2005).

Dose rate	Numerical value of the dose rate at the dose specification point(s)
Low dose rate (LDR)	0.4–2 Gy/h
Medium dose rate (MDR)	2–12 Gy/h
High dose rate (HDR)	>12 Gy/h

Brachytherapy sources are available in various forms such as seeds, wires, needles and pellets. They are commonly used as sealed sources. The sources are doubly encapsulated in order to provide adequate shielding against the alpha (α) and beta (β)

radiation emitted from the source and to prevent any leakage of the radioactive material.

2.2.2 Description of brachytherapy sources used in prostate cancer.

The use of radioactive material for diagnostics and therapy purpose has been in the field of medicine since the 19th century, however more innovations came up along the way since some of the radioactive sources have very long half-life and higher energy hence not suitable for clinical use and difficult for radiation protection. Thus, it is necessary to have a detailed description of these radioisotopes. The commonly prostate brachytherapy sources are described in the next sections.

2.2.2.1 Iodine-125.

^{125} I decays exclusively by electron capture to an excited state of ^{125}Te, which spontaneously decays to the ground state with the emission of a 35.5 KeV photon (Figure 2.3). Characteristic x-rays in the range of 27 to35 KeV also are produced due to the electron capture and internal conversion processes (Khan, 2003). The isotope is produced by thermal neutron irradiation of ^{124}Xe; activity concentrations as high as 3.7 GBq mm^{-3} can be obtained by encapsulating an iodide-activated ion exchange bead (Mayles et al., 2007). Titanium encapsulation serves to absorb liberated electrons and x-rays with energies less than 5 KeV. The model 6711 seed emits two additional photons at 22.1 KeV and 25.2keV energies. These are fluorescent (characteristic) x-rays produced by the interaction of ^{125} I photons with the silver wire (Khan, 2003). When implanted to the patients, it takes 204 days for 90% of the prescribed dose to decay (Rivard et al., 2007). Figure 2.2 shows the structure of I-125 seeds with its encapsulation.

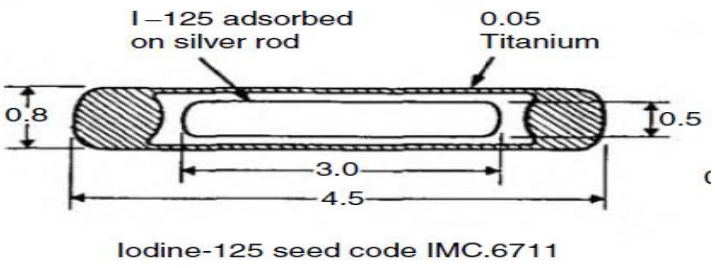

Figure 2.2: An example of I-125 seeds 6711 model used currently for prostate brachytherapy implant (Mayles et al,. 2007). The seeds used at KBTH are supplied by BARD Company from USA

Iodine-125 decay scheme

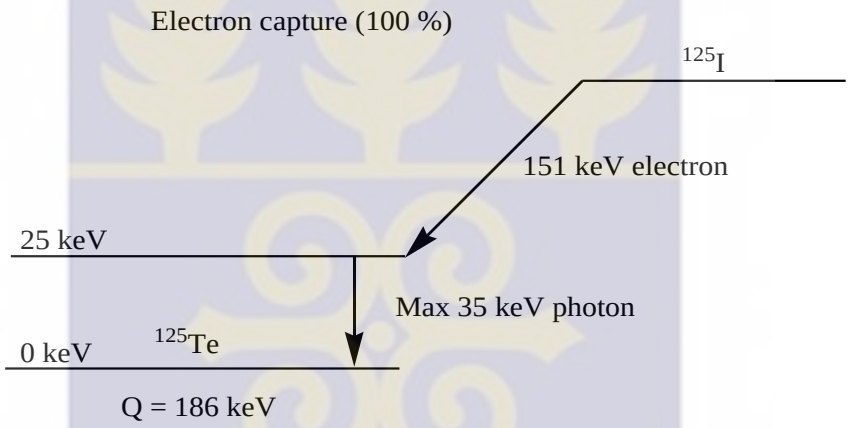

Figure 2.3: The decay scheme of I-125 (Nucleide, 2013).

2.2.2.2 Iridium-192.

^{192}Ir has a half-life of 73.8 days and emits gamma photons with energies ranging from 9 KeV to 884.5 keV, but the weighted average energy of a ^{192}Ir brachytherapy source is 397 keV (Goetsch et al., 1991). With a high maximum-activity concentration of 330 GBq mm^{-3}, ^{192}Ir is suitable for high-activity afterloading sources; it is also available in the form of seeds and flexible wires. In wire form it is produced by reactor irradiation of 75%/25% iridium/platinum alloy which is usually provided as wire, clad with 0.1 mm of pure platinum. Pure iridium is very hard and

brittle, and is difficult to fabricate. The iridium/platinum wire is available with 0.3 mm and 0.6 mm overall diameter. European manufacturers also produce wires with a 0.5 mm diameter. The wire should be cut to the required length by means of special cutters which are designed to minimise particulate contamination. For clinical use, wires are often sheathed in plastic tubing.

2.2.2.3 Palladium-103.

^{103}Pd seed has a half-life of 17 days, It decays by electron capture with the emission of characteristic X-rays in the range of 20 to 23 Kev (average energy of 20.9 Kev) and Auger electrons (Khan, 2003). The palladium-103 seed model 200 consists of a laser-welded titanium tube of 0.8 mm diameter and 4.5 mm long, containing two graphic pallets plates with laser welded end caps. The lead marker between the pallets provides radiographic identification. Absorption of incident photons by the titanium wall and the lead marker, and the self-shielding by palladium, result in an anisotropic emission pattern with an axial fluence much lower than the fluence along the transverse axis (Chiu-Tsao and Anderson, 1991). Figure 2.4 shows the structure of palladium-103 seeds with its encapsulation.

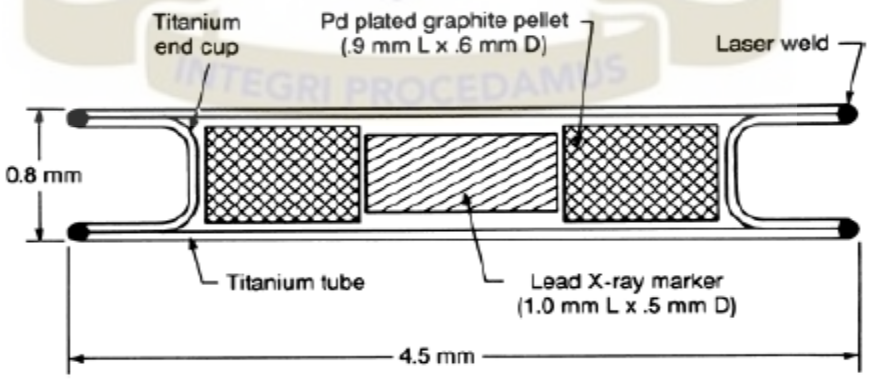

Figure 2.4: Schematic diagram of palladium-103 seeds (200 model) (Mayles et al, 2007).

2.2.2.4 Caesium- 131.

^{131}Cs is a low energy x-ray emitter, with the most prominent peaks in the 29 keV to 34 keV region and has a half-life of 9.7 days. Brachytherapy seed sources (typically 4.5 mm long and 0.8 mm diameter) have been developed principally for prostate implantation. The shorter half-life is thought to offer advantages in biological effectiveness over ^{125}I and ^{103}Pd seed sources (Murphy et al., 2004).

2.2.2.5 Cobalt -60.

This nuclide is used in some high-dose-rate remote-loading machines since activity concentrations of up to 130 GBq mm^{-3} are available; ^{60}Co emits 0.318 MeV β-rays, 1.17 MeV and 1.33 MeV ɤ-rays and has a half-life of 5.27 years. Because cobalt tends to be corrosive, it is usually nickel plated; encapsulation with 0.1 mm to 0.2 mm platinum-equivalent is necessary to filter the β -particles (Mayles et al, .2007; Khan, 2003)

2.2.2.6 Gold-198.

This nuclide is produced by reactor irradiation of pure gold: activity concentrations of 7.4 GBq mm^{-3} can be readily produced. The active material is typically 0.5 mm in diameter and is sheathed in platinum of 0.1 mm to 0.2 mm wall thickness, which acts as an effective β filter. ^{198}Au emits β - rays and 412 keV ɤ - rays; it decays with a half-life of 2.7 days. Sources are available as grains, seeds and wires. Grains are usually 2.5 mm long and are supplied in magazines which fit directly into commercially available implantation guns (Mayles et al., 2007; Khan, 2003). Table 2.2 is a summary of radioisotopes which are used in prostate brachytherapy.

Table 2.2: Some characteristics of isotopes used in brachytherapy (Taylor & Francis, 2007)

Isotopes	Energy (Kev)	Half life	HVL in lead (mm)	Source form	Clinical Application
^{125}I	28	59.6 days	0.025	Seeds	LDR-Permanent interstitial.
^{103}Pd	22	17 days	0.013	Seeds	LDR-Permanent interstitial.
^{131}Cs	29	10 days	2.54	Seeds	LDR-Permanent interstitial.
^{192}Ir	380	78.3 days	2.5	Seeds and Flexible wires	HDR-temporary interstitial
^{198}Au	410	2.7 days	2.5	Grain, Seeds and wires	LDR-Permanent interstitial.
^{60}Co	1250	5.27 years	13	Pellets	HDR -temporary Intracavitary.

2.3 Treatment selection criteria according to European ESTRO/EAU/EORTC guidelines.

2.3.1 Gleason (Score) grade

This is a system of grading prostate cancer tissue based on how it looks under a microscope. Gleason scores range from 2 to 10 and indicate how likely it is that a tumour will spread. A low Gleason score means the cancer tissue is similar to normal prostate tissue and the tumour is less likely to spread, a high Gleason score means the cancer tissue is very different from normal and the tumour is more likely to spread (Gleason ,1977) Gleason lower grades are associated with small, closely packed glands. Cells spread out and lose glandular architecture as the grade increases. The Gleason Grading system is used to help evaluate the prognosis of men with prostate cancer. Together with other parameters, it is incorporated into a strategy of prostate cancer staging which predicts prognosis and helps guide therapy. A Gleason score is given to prostate cancer based upon its microscopic appearance. Cancers with higher

Gleason scores are more aggressive and have worse prognosis (Gleason, 1977).The pathologist assigns a grade to the most common tumour pattern, and a second grade to the next most common tumour pattern. The two grades are added together to get a Gleason Score. For example, if the most common tumour pattern was grade 3, and the next most common tumour pattern was grade 4, the Gleason Score would be 3+4 = 7 . For Gleason Score 7, a Gleason 4+3 is a more aggressive cancer than a Gleason 3+4 (Gleason, 1977).

2 .3 .2 Prostate specific Antigen (PSA)

PSA (prostate specific antigen) is also used to monitor men who have been treated for prostate cancer to see if they remain cancer-free. Elevated PSA levels in a man who has never been treated for prostate cancer may be a sign of any prostate problem. PSA rise may indicate prostatitis (infection). It may indicate benign growth or swelling of the prostate (BPH), Or it may indicate prostate cancer. It is measured in nanograms per millilitre of blood. Normally PSA levels in the blood remain very low, Any hurt to or injury of the normal prostate such as from inflammation caused by infection, may cause more PSA to leak into the bloodstream. In the past most doctors considered PSA values below 4.0 ng/ml as normal. However, recent research found prostate cancer in men with PSA levels below 4.0 ng/ml (Thomson et al: 2004). The following ranges are used to classify the level of PSA; 0 to 2.5 ng/ml is low 2.6 to 10 ng/ml is slightly to moderately elevated, 10 to 19.9 ng/ml is moderately elevated and 20 ng/ml or more is significantly elevated.

2.3.3 Digital Rectal Examination (DRE)

A digital rectal examination (DRE), performed as part of an annual physical check-up, is one of the most important tests for the early detection of prostate cancer. Because the prostate gland is located just in front of the rectum, it cannot be felt from the outside of the body.

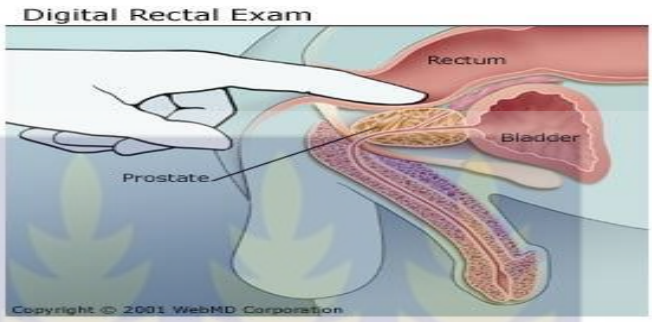

Figure 2.5: Demonstration on how digital rectal examinations (DRE) are taken (Wax, 2012)

During the DRE, a doctor inserts a lubricated, gloved finger into the patient's rectum to feel for lumps, enlargements, or areas of hardness that might indicate prostate cancer. The procedure lasts for less than minute and, while uncomfortable, should cause no pain. However, a painful examination could indicate the presence of other, benign conditions, such as prostatitis. To help detect prostate cancer in its early stages, the American Cancer Society recommends that men talk to their doctors about the benefits, risks, and limitations of prostate cancer screening before deciding whether to be tested. For most men at average risk, screening is started at age 50. However, some doctors recommend that men at higher risk of prostate cancer - African-American men or men with a family history of prostate cancer start screening earlier. The American Urological Association (1997) recommends a first-time test at age 40, with the schedule of follow-up testing to be determined on an individual basis.

The rectal exam should be done after a PSA test. There's some chance that a rectal exam before a PSA test may elevate the PSA and create a false positive result. About 25 per cent of men who have prostate cancer have a low PSA. So the rectal exam is an essential follow up to PSA test. The purpose of digital exam is to feel for "suspicious" places on the prostate. The prostate has a base, an apex, an anterior, a posterior and two lateral surfaces. The base (the broad end) touches the lower surface of the bladder. The apex points downward and is in contact with the fibrous tissue network between the skin and the underlying structure of muscle and bone of the urogenital diaphragm (Thomson et al., 2004). Urologists divide the prostate into zones - the transition zone, central zone and peripheral zone. The peripheral zone can be felt through the rectum, especially when enlarged. Benign Prostatic Hypertrophy is the abnormal enlargement of non-cancerous cells within the transition zone of the prostate.

2.3.4 International Prostate Symptom Score (IPSS)

The International Prostate Symptom Score (IPSS) is an 8 question (7 symptom questions + 1 quality of life question) written screening tool used to screen for, rapidly diagnose, track the symptoms of, and suggest management of the symptoms of the disease benign prostatic hyperplasia (BPH). Created in 1992 by the American Urological Association, it originally lacked the 8th QOL question, hence its original name: the American Urological Association symptom score (AUA-7). The 7 symptoms questions include feeling of incomplete bladder emptying, frequency, intermittency, urgency, weak stream, straining and nocturia, each referring to during the last month, and each involving assignment of a score from 1 to 5 for a total of

maximum 35 points (Rodrigues et al., 2001). The 8th question of quality of life is assigned a score of 1 to 6 (Lytton et al., 1968).

The IPSS was designed to be self-administered by the patient, with speed and ease in mind. Hence, it can be used in both urology clinics as well as the clinics of primary care physicians (i.e. by general practitioners) for the diagnosis of BPH. Additionally, the IPSS can be performed multiple times to compare the progression of symptoms and their severity over months and years. In addition to diagnosis and charting disease progression, the IPSS is effective in helping to determine treatment for patients. The detailed descriptions about IPSS questions are shown in appendix F.

2.3.5 Transurethral Resection of the Prostate (TURP)

Transurethral resection of the prostate (TURP) is a type of prostate surgery done to relieve moderate to severe urinary symptoms caused by an enlarged prostate. During TURP, a combined visual and surgical instrument (resect scope) is inserted through the tip of the penis and into the tube that carries urine from the bladder (urethra). Using the resect scope, a doctor trims away excess prostate tissue that is blocking urine flow. Patients who have undergone transurethral resection of the prostate or TURP before, may not be good candidates. If too much of the prostatic tissue was removed during TURP, then there may be insufficient tissue left to plant the radioactive seeds (Kollmeier et al., 2005).

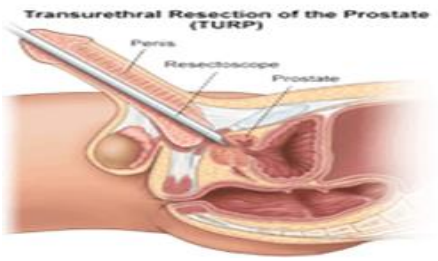

Figure 2.6: Transurethral Resection of the prostate (TURP) (Hopkins, 1991)

2.3.6 Pubic arch evaluation

Patients should have a pubic arch evaluation, which determines whether or not a patient has pubic arch interference. The pubic bones grow together to form a "V", which is in front of the prostate gland. A narrow pubic arch can make prostate seed implantation difficult. Patients with pubic arch interference may want to consider other prostate cancer treatments.

Table 2.3: The selection criteria for the patients as discussed above and their recommendation (Ash et al., 2000).

	RECOMMENDED	OPTIONAL	INVESTIGATIONAL
	Do well	Fair	Do poorly
PSA (ng/ml)	<10	10 -20	>20
Gleason score	5-6	7	8 -10
Stage	T1c -T2a	T2b - T2c	T3
IPSS	0 -8	9-19	>20
Prostate volume (cc)	<40	40-60	>60
Bone scan	Negative	-	-

2.4 International guidelines toward prostate cancer brachytherapy implant.

2.4.1: The European's ESTRO/EAU/EORTC guidelines

The Europeans have made the guidelines toward permanent I-125 seed implant for localised prostate cancer. Some of the parameters to be reported after the implant are (Ash et al., 2000) Prostate volume implanted (cc), Number of needles, Number of seeds, Prescribed dose (Gy), Total activity implanted (mCi), The dosimetric parameters D90 (Gy) , V100 % and V150 %. The European's also provides some restrictions when defining the target and organ at risk and some dosimetric parameters. The suggestions of the prescribed doses for pre-implant dosimetry for the clinical target volume (CTV) are as shown on Table 2.4 (Salembier et al, 2007).

Table 2.4: ESTRO/ EAU/EORTC recommendations of the prescription doses for pre-implant dosimetry (Karmar J., 2008).

Dose parameter	ESTRO/ EAU/EORTC
Prostate:	
D90 (%)	≥ 100 %
V100 (%)	≥ 95 %
V150 (%)	≤ 50 %
Urethra:	
UrD(10) %	< 150 %
UrD(30) %	< 130 %
Rectum:	
RD 2cc (Gy)	≤ 145 Gy
RD 0.1cc (Gy)	< 200Gy

The European guidelines recommends also CT-imaging for post - implant evaluation. The dosimetric parameters to be considered for CT- post implant are as follows; Prostate: D90 (%), V 100 (%), V150 (%), Urethra: UrD10 (Gy) and Rectum: RD2cc (Gy), V100% and V150% respectively (Salembier et al, 2007).

2.4.2 The American Brachytherapy Society (ABS) guidelines

The American Brachytherapy Society (ABS) has also issued various guidelines for seed implants. The guidelines for dosimetric parameters for pre-plan and implant to be considered are D100 (Gy), D90 (Gy) , V100(%) and to minimize the length of urethra receiving 200% of the prescribed dose (Nag et al., 1999). Likewise ABS recommends CT-imaging for post-implant evaluation (Nag et al., 2000). The dosimetric parameters to be reported for CT post -implant evaluation are; D100, D90, and D80 (Gy) for prescribed dose, V200, V150, V100 ,V90 and V80 (%) for volume coverage, Urethra and rectal doses, Post- implant prostate volume (cc) and number of days between implant and the date of imaging study. The recommendations from Europe and America do differ in the fact that ABS adds D

(80), V90, and V80 and recommends minimising the length of urethra receiving 200% of the prescribed dose.

2.5 Treatment modalities for Prostate cancer patients.

Treatment of prostate cancer involves the use of both high dose rate (HDR) and low dose rate (LDR) ionising radiation as well as other modalities. Some of the modalities are as described below,

2.5.1 Hormone therapy

Prostate cancer hormone therapy is the systemic ablation of the body's testosterone which, for a period of time, will slow or stop the growth and spread of prostate cancer. Hormone therapy may also be called androgen deprivation or androgen ablation. The male sex hormone, testosterone, causes the growth of the prostate gland and other sex organs in the developing male. Even as men pass through the age of puberty, testosterone continues to contribute to the growth of the organ. Testosterone will fuel the growth of any prostatic cell: the chemical cannot discriminate between the receptors of healthy tissue and cancerous tissue. Prostate cancer hormone therapy removes the chemical that "feeds" cells and can stop or slow the growth and spread of the tumour (Heidenreich et al.,2012).

2.5.2 Chemotherapy Treatment

Prostate cancer chemotherapy is usually used as salvage treatment during hormone refractory prostate cancer or for advanced prostate cancer with distant metastasis and has shown success in extending the life and quality of life in many patients. Most cases of prostatic adenocarcinoma usually grow very slowly, meaning the cells divide at a rate that is similar to that of healthy cells. Chemotherapy,

therefore, is usually not effective for early adenocarcinoma of the prostate as chemotherapeutic drugs are both toxic and systemic. Toxic because they damage cells so badly that upon division, the cell dies. Systemic because chemotherapy affects all the cells of the body as it circulates through the blood stream. Like radiation therapies, chemotherapy does not destroy the entire body because only cells that divide soon after being treated will die. Unfortunately, chemotherapy cannot be focused to any particular area of the body. All quickly-dividing cells of the body therefore are affected, including, those in the hair follicles, skin, gastrointestinal tract, and bone marrow. The severe and sometimes dangerous side effects of chemotherapy drugs have often outweighed their benefits as an early prostate cancer treatment. However, for patients with advanced disease, chemotherapy can be beneficial in both extending the life and decreasing pain. The earlier use of chemotherapy has been helpful in slowing the advancement of the disease (Heidenreich et al., 2012).

2.5.3 Cryotherapy Treatment

Also referred to as cryosurgery and cryoablation, prostate cryotherapy is a minimally invasive surgery capable of using controlled freeze and thaw cycles to destroy the disease. Because cryotherapy is relatively new, that is, lacking numerous long-term survival rate studies, cryotherapy is not used as often as radiation therapy for primary treatment. cryotherapy, however, is effective in treating cases of prostate cancer that are radio resistant and recur as a result. Some doctors believe that the use of freezing temperatures rather than stronger doses of radiation therapy is more effective for radio resistant prostate cancer. Prostate cryotherapy works because as cells freeze, ice crystals form inside and around them. The freezing and thawing processes destroy cells through dehydration, drastic changes in the pH levels, or

prevention of the flow of red blood cells. Subjecting the prostate gland to freezing temperatures, specifically negative 40 degrees Celsius, also activates an anti-tumour response in the body. An anti-tumour response begins with the production of anti-bodies that work to eradicate the tumour. Cryotherapy is an effective primary treatment for those who are in the early stages of prostate cancer with low risk for tumour extension. This treatment may also be an excellent alternative for those who are not good candidates for radical prostatectomy. Cryotherapy may be used if EBRT fails and the cancerous prostate cells are deemed radioresistant. Some advantages of include the one day in-hospital treatment, though some patients will stay overnight depending on their general health (Heidenreich et al., 2012).

2.5.4 External Radiation Treatment (Teletherapy)

External beam radiotherapy (EBT) is a type of radiation therapy that uses a machine to aim high energy rays at the prostate cancer from outside the body. During external beam radiation therapy, a beam of radiation is directed through the skin to the cancer and the immediate surrounding area in order to destroy the main tumour and any nearby cancerous cells. Usually the treatments are administered five days a week, Monday through Friday, for a number of weeks, where an average of 4500 cGy of radiation is given to each patient in number of fractionations. This allows the cancerous cells to be destroyed while repairing the healthy body cells. The radiation are generated by a cobalt-60 machine which produces gamma radiation or linear accelerator capable of producing high-energy X-rays and electrons for the treatment of prostate cancer. Using high-technique treatment planning software, the treatment team controls the size and shape of the beam, as well as how it is directed to the targeted area .The goal of treatment is to irradiate a targeted area with as much energy as possible while avoiding the neighbouring organs. Advanced radiotherapy

techniques include three-dimensional conformal radiotherapy (3D-CRT), intensity modulated beam radiation therapy (IMRT), image-guided radiation therapy (IGRT), intra-operative radiation therapy (IORT), proton beam radiation therapy (PBRT), tomotherapy, systemic radiation therapy, radio immunotherapy (RIT), and hypofractionated radiation therapy. Proton beam therapy is becoming a more widely accepted treatment for prostate cancer, while neutron beam therapy is still in the experimental stages (Heidenreich et al., 2012; khan, 2003; Podgorsak, 2005).

CHAPTER THREE

MATERIALS AND METHODS

The description of the methodology in this chapter forms the theoretical and experimental framework of the study. This section is divided into two parts; part one describes the real-time implant and part two describes the pre-plan process.

Part one: Real-time implant

This section describes the whole prostate implant procedure as it was done in the theatre. As a researcher, I was given permission to the theatre to observe and learn the role of a medical physicist during the interstitial implant. I also observed seven prostate implants between November 2012 and March 2013. Besides medical physicist, other personnel in the panel were; oncologist, urologist, anaesthetists, and nurses.

3.1 Description of real-time implant at KBTH.

Usually the real-time implant was done in the surgical theatre. This research was done for the purpose of quality assurance of the patients who were treated earlier (from August, 2008 to April, 2013), and for those patients who will undergo prostate brachytherapy treatment at KBTH in the future. The following section describes in brief, the real time implant in the theatre. Some of the equipment used during real time -implant were : Iodine -125 radionuclide (radioactive seeds), seed planning software (Variseed 7.2 model), mick compatible needles ,treatment planning software , ultrasound unit and rectal probe, stepper or probe carrier , B &K -

template (the perineum template), stabilization device / attachment, gel, mick applicator , anaesthesia machine and survey meter.

3.1.1 Description and application of each of the material mentioned above during real-time implant in the theatre at KBTH.

3.1.1.1 The implant needles

During real time implant procedure the needles (17 or 18 gauges) were inserted based on the ultrasound image guidance. The needles used in this study were supplied from BARD- COMPANY USA. Each needle was fixed on template grid with holes on either side, to allow the seeds to be deposited in patient's body. In general, patients under prostate brachytherapy can be implanted with needles between 15-20 and with seeds ranging from 45 - 90 (Khan, 2003). However, in this research, the number of needles and seeds for both real-time implant and pre-planning will be shown in the next section (chapter 4) in which results will be tabulated and analysed. Plate 3.1 is an example of needles mounted to Template which are used for the implant.

Plate 3.1 The picture shows a needles/obturator system which are used during real-time implant procedure at Korle-Bu Teaching Hospital.

3.1.1.2 Ultrasound unit, rectal probe and Gel

Ultrasound imaging (sonography) involves the use of a small transducer to expose the body to high-frequency sound waves. Ultrasound is safe and painless, and produces pictures of the inside of the body using sound waves. An ultrasound examination does not use ionising radiation . Because ultrasound images are captured in real-time, they can show the structure and movement of internal organs, as well as blood flow through blood vessels.

When LDR prostate brachytherapy (seed implantation) was done, an ultrasound probe was inserted into the rectum, and images from this probe were used to assess the size and shape of the prostate gland. This was done so that the doctor could identify how best to deliver the right radiation dose for each patient. The seeds were inserted in the exact locations as identified at the beginning of the procedure. This usually took 1–3 hours, no surgical incision was needed instead, the radioactive seeds were inserted into the prostate gland using needles which pass through the skin between the scrotum and the rectum and an ultrasound probe was used to accurately guide them to their final position.

The ultrasound machine had a seed implant software package such that a grid pattern could be displayed on the screen, similarly it could display the sagittal as well as transverse planes of the prostate volume. This feature has been found to be helpful in identifying the superior prostate capsule to guide individual needle insertion, in visualizing the movement of the prostate volume as needles were inserted and in confirming that the seeds were deposited correctly at the cephalad-most portion of the prostate. Ultrasound gel is a type of conductive medium that is used in ultrasound diagnostic techniques and treatment therapies. It was placed on the patient's skin at the beginning of the ultrasound examination or therapy. The transducer, was the device used to send and receive sound waves and was then placed on top of the skin.

The gel served to prevent air bubbles from forming and helped conduct sound waves from the transducer into the patient's body. Plate 3.2 shows the ultrasound unit and rectal probe used during real-time implant.

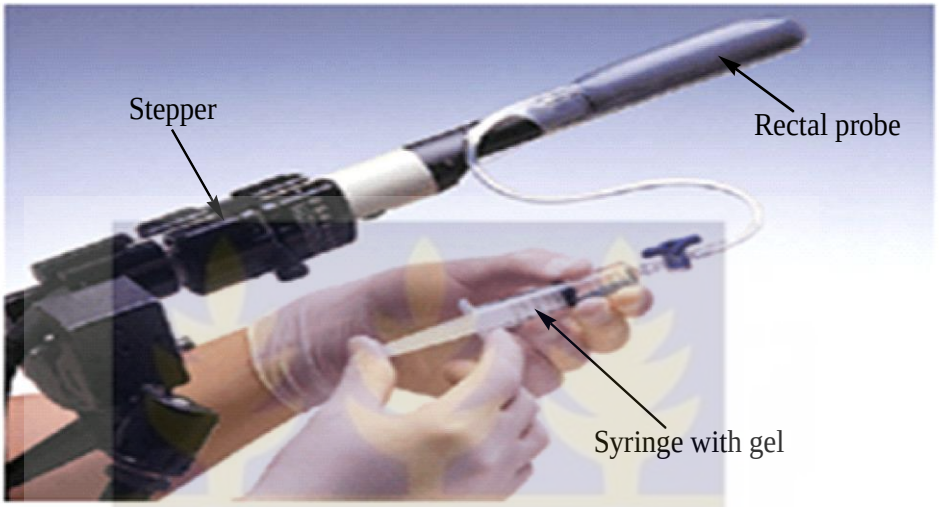

Plate 3.2: Ultrasound probe with contrast used during volume study

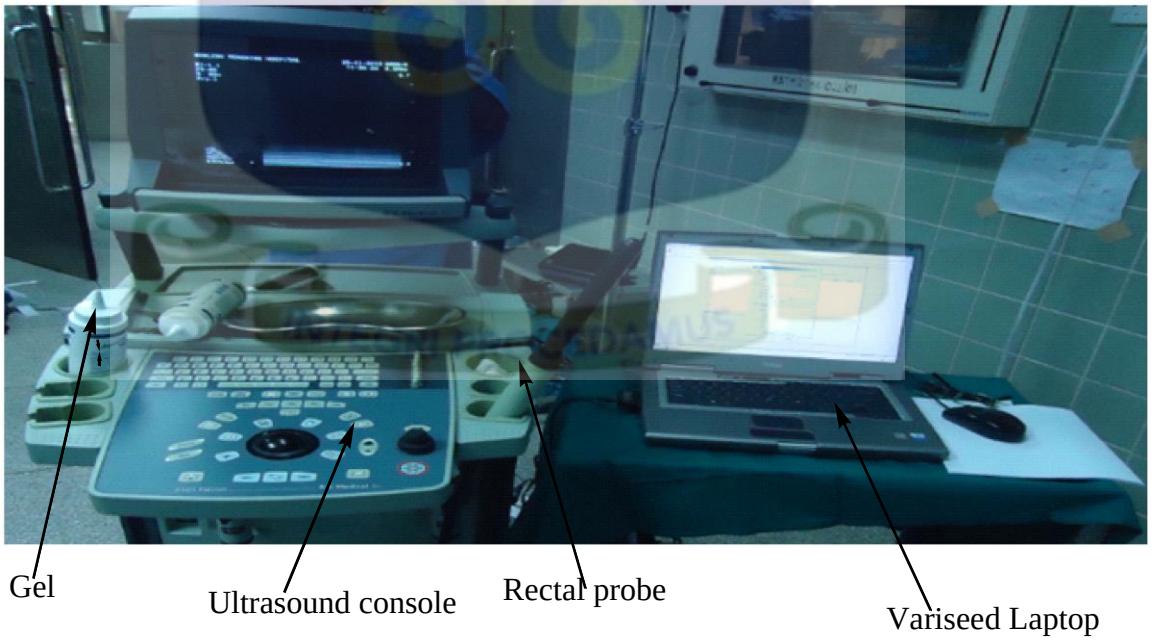

Plate 3.3: A pictorial view of ultrasound unit, rectal probe, Gel and a Variseed computer used at the theatre of Korle-Bu Teaching Hospital during real-time implant.

3.1.1.3 The Stepper and Template Grid

The needle template has holes which can accept 17 gauge or 18 gauge needles, arranged typically in a 13X13 matrix, at 5mm spacing. The template may be designed to mount directly to the rectal probe in some systems, in which case it moves together with the probe, or it may be mounted on the probe carrier, in which it remains stationary with respect to the perineum as the probe is moved. In either case, the holes on the needle template correspond to the grid points displayed on the TRUS monitor screen. The stabilizing mechanism immobilizes the entire rectal probe/carrier/ template system against the operating table or floor, to prevent unintentional motion of the probe and needle template during the implant procedure. The template was placed at close proximity to the perineum to minimize needle splaying in the target volume. (AAPM, 1999).

The template grid corresponds precisely with the electronic grid of the ultrasound machine, the grid was used to guide the needles into the perineal area, the co-ordinates or 'map references' on this grid or template were used to pinpoint the exact positions in the prostate where the seeds could be placed. At the time of volume study / implant, both the ultrasound probe and the template were fixed on the stepper, this device had a scale and a knob which was adjusted at 5mm intervals when studying both sagittal and transverse sections of the prostate through the rectum.

The stepping device allowed the rectal probe to be attached to the stabilizing mechanism while permitting movement in and out of the patient's rectum in precise steps. The square lightweight stepper template had a universal grid array and could be sutured to the patient. The stepper holder was available for various ultrasound stepper devices. The advanced needle fixation design uses a plate that locks all needles in a single action.

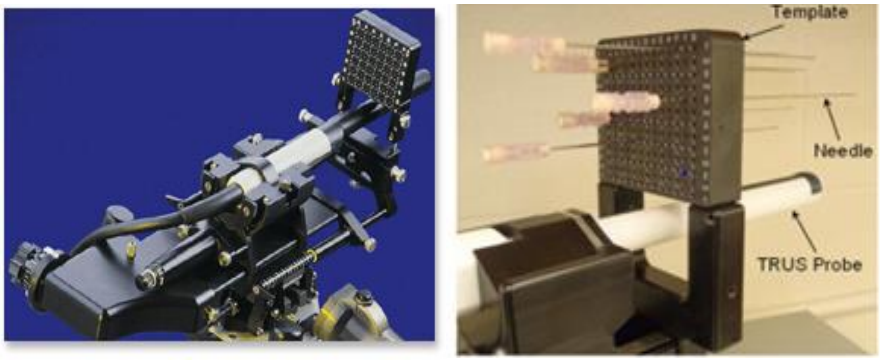

Plate 3.4: A pictorial views of stepper with ultrasound probe and template grid mounted on it, the probe was then connected to the Ultrasound machine for imaging and guidance during implant.

3.1.1.4 Mick applicator

During real time implant procedure, iodine -125 radioactive seeds in a magazine were attached to the Mick applicator, afterwards the needles were fixed to the applicator. The whole arrangement was inserted to the prostate gland through ultrasound imaging guidance. The oncologist then started shooting the seeds from the magazine to the prostate volume through needles, usually each magazine had 15 radioactive seeds. The applicator works like a gun by shooting the seeds to all needles until the whole prostate volume was effectively implanted. Plate 3.5 shows a Mick-applicator and the magazine which were used during real-time implant at Korle-Bu Teaching Hospital.

Mick applicator Magazine

Plate 3.5: Mick applicator used to hold and shoot seeds from a magazine containing seeds of I-125 during implants

3.1.1.5 Survey meter

This device was basically used for safety purposes, at the time of implant an accident may occur in which seeds might drop on the floor therefore at the end of the procedure, the theatre room must be thoroughly checked to confirm if any of the radioactive seeds have dropped. This task was done by a medical physicist with the aid of a survey meter. Plate 3.6 shows a survey meter which was used in the theatre during real time implant.

Plate 3.6: A Pictorial view of a survey metre which were used during real - time implant at KBTH.

3.1.1.6 Anaesthesia

Anaesthesia is derived from Greek meaning “loss of sensation” and it is a reversible condition meaning after a while the patient will come out of the “loss of sensation” state. It is a medical speciality related to providing patients with anaesthetic drugs in appropriate dosage in special scenarios such as surgeries. Anaesthesia deals with taking the patients to a state of amnesia temporarily during which painful procedures such as surgery could be done without the patients experiencing pain. The dosage in anaesthesia depends on several factors such as the patient's age, type of surgery to be performed, patients body state, cause of pain, patient’s medical history and surgery time .The dose was administered by anaesthetists.

There are several classes of anaesthesia which could be offered to a patient, this includes local anaesthesia in which the loss of sensation is needed in a part of the body for say a minor operation during this, mostly, the patient will be awake. The second classification is a general anaesthesia in which the loss of sensation of the total body is required in case of a major operation. In this case both the brain and the body are affected and the patient will be sleeping. There is also a regional anaesthesia in which the loss of sensation is needed in a wider area compared with that of the local anaesthesia. For regional anaesthesia the patient will be awake (Beecher et al., 1954). The anaesthetist stays with the patient throughout the procedure, and will make sure that the patient continues to receive the anaesthetic drugs and stays asleep, in a controlled state of unconsciousness. After the procedure, the anaesthetist then reverses the anaesthetic effects and the patient gradually wakes up (Hewer., 1937). In this study the patients were given general anaesthesia during the real time implant and the

anaesthetic machine was used to monitor the patient throughout the procedure. Plate 3.7 shows one of the anaesthetic equipment which was used.

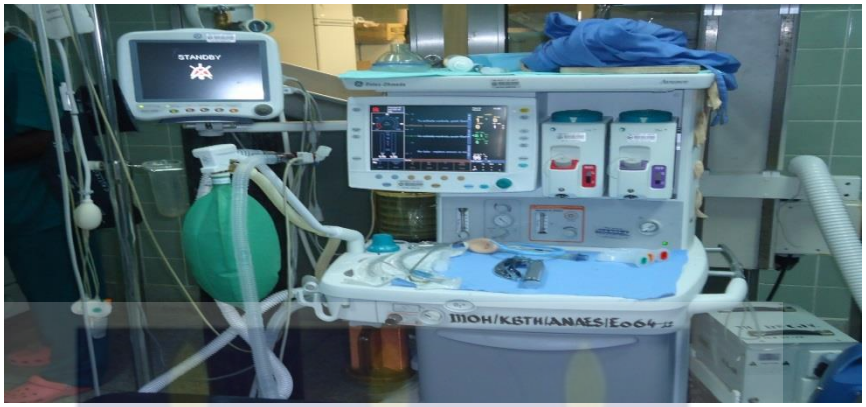

Plate 3.7: Anaesthesia machine - used to monitor the patient during the real-time prostate implant at theatre of KBTH.

3.1.2 Real-time implant procedure

The implant of seeds to the patients should be done very carefully so as to avoid unnecessary radiation to the patients, for this case, firstly, the volume of prostate for each patient are studied and the imports of the seeds are done while the second visit is usually between two to three weeks for the real-time implant.

3.1.2.1 Volume study

The ultrasound volume study used to plan the prostate implant was done within 2-3 weeks before implantation, so as to limit changes in the prostate volume particularly, if the patient was under hormonal therapy. This was done by the urologist and the oncologist at KBTH. Afterward the seeds were ordered from the manufacturer (BARD COMPANY -USA) based on the prostate volume estimated.

The prostate volume study consists of consecutive axial images which were obtained at 5mm intervals from the base of prostate to the apex, with the template hole pattern superimposed on each image. A sagittal ultrasound image was often

obtained for base-apex length measurement to ensure that the proper number of slices was obtained. The patient was positioned in a way as it will be done during implant time, a dorsal lithotomy position (Plate 3.8). A urinary catheter with contrast was inserted to outline the bladder and urethra. No anaesthesia was used during the volume study. To align the patient correctly lasers were used. The ultrasound probe was attached in a stepper which was fixed to the table (Plate 3.3). On the ultrasound screen there was an electronic grid which corresponded precisely to the template grid that will be used at the time of the implant. The prostate was studied through the rectum, both in the axial and the longitudinal directions. An appropriate amount of water was inserted in a "balloon" attached to the probe, in order to lift the prostate to the first grid. The stepper has a system that allows the probe to move in and out of the rectum so that 4-9 axial pictures were taken from the base of the gland to the apex at 5 mm intervals. The images were transferred during the study to the treatment planning software, following the order, stepper - ultrasound machine - computer – printer (Plate 3.3) shows the arrangement. The urologist and oncologist outlined the target volume, prostate gland and the targets at risk, rectum and urethra, for each slice section. A physicist plans the seeds positions, the dose distribution with information from the ultrasound images and the template co-ordinates that appeared on each section. Based on the plans the estimated amount of sources were ordered as indicated in appendix M.

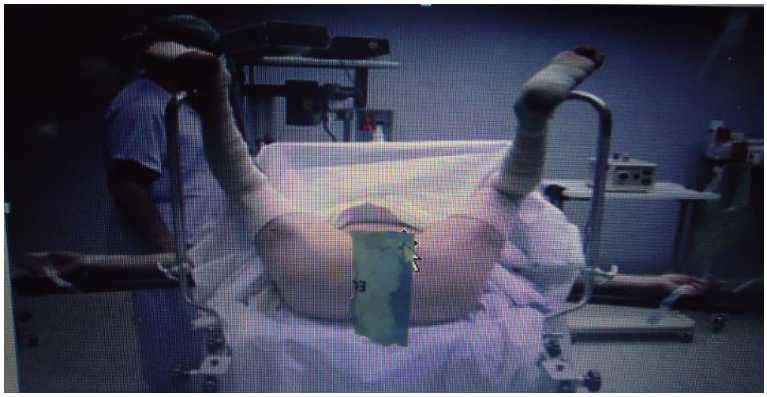

Plate 3.8: The picture shows the dorsal lithotomy position for the patient during volume study and real-time seed implant respectively.

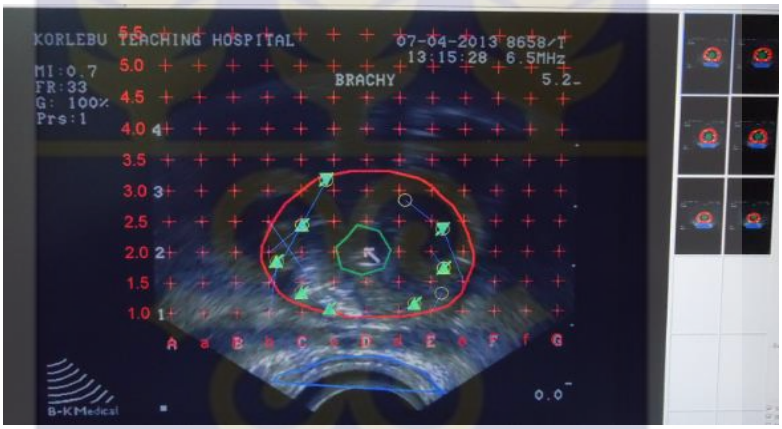

Plate 3.9: The Ultrasound image, indicates the number of slices which was summed up to get the prostate volume.

A medical physicist was present to ascertain that the patient was set up in such a manner that a satisfactory plan was developed from the volume study. The specific parameters that were checked included;

(i) The angle of elevation of the patient's legs in the stirrups.

(ii) The alignment of the ultrasound probe with respect to the prostate in all of the ultrasound images.

(iii) The implant needles, which were inserted parallel to the probe, did not traverse the rectal wall and the superposition of the template hole pattern on the contours of the prostate.

The planning volume study ideally included adequate localization of the prostatic urethra on each axial slice. The seed configuration was then designed to avoid implantation at or near the location of the prostatic urethra (AAPM, 1999).

3.1.2.2 Needle identification

At the treatment theatre the patient was placed supine on the bed with his feet in lithotomy stirrups. The B and K template attached to the interplant stepper were brought to the perineum of the patient and the ultrasound probe was inserted into the rectum while connected to the ultrasound machine (Plate 3.3). The urologist, oncologist and physicist were able to identify each needle planted around the peripheral of the prostate around the template. Both physical and electronic template matched. At the time the urologist was planting the needle the oncologist and physicist were identifying the position of each needle on the screen of the ultrasound. After all experts have agreed on the process the image was then printed out before the implant begun.

3.1.2.3 Needle placement

In the operation room the nurses positioned the patients in the same manner that it was during the ultrasound volume study. They cleaned the perineum with anti-septic solutions and instilled 150-200cc's sterile water into the bladder. They inserted a lubricated catheter into the urethra and injected a solution of air, lubricant and water through the urethra. This solution allowed the oncologist to see the urethra during the procedure and avoid traumatizing it. The largest prostate cross section seen on

ultrasound was used as the reference view for needle distribution. Starting at the anterior aspect, off of the midsagittal plane, needles were inserted approximately 1 cm apart around the periphery within the prostate capsule by approximately 5mm. Depending on the prostate size, either two or four interior needles were placed equidistant between the urethra and the peripheral needles. Plate 3.10 shows the ideal implant needle/catheter distribution. The template offers a 5-mm needle grid and mounts on a B&K ultrasound probe stabilizer (B&KMedical,BARD COMPANY - USA). A physicist was present in the operation room to document needle placement and to confirm adequate implant coverage for planning.

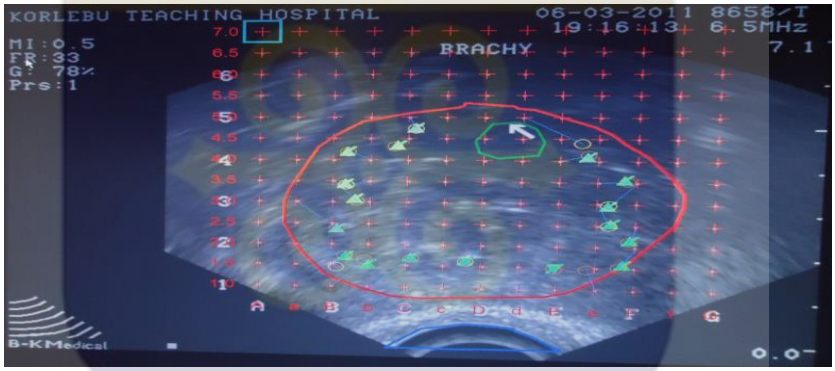

Plate 3.10: The figure shows the ideal implant needle/catheter distribution.

3.1.2.4 Delivery of seeds.

The plan of the implant was based on either ultrasound or CT cross-sectional (axial) images. The intended treatment volume generally was the whole prostate gland with a small margin of periprostatic tissue (usually 0.2 cm). The number of seeds required and their geometric placement in the target volume was determined through optimized computer dose planning or pre-calculated nomograms. The recommended total dose to the periphery of the target volume was 150–160 Gy for ^{125}I and 115–120

Gy for ^{103}Pd when a brachytherapy implant was the sole modality of radiation treatment (Podgorsak, 2005). Within 14-21 days the implant was performed in the operating room under general anaesthesia. Bladder was catheterized and the patient was placed in the dorsal lithotomy position. B&K template and ultrasound probe with offset cover was inserted into the rectum and attached to the stepper. Image registration was calibrated by identification of the base plane as the vesico/prostatic junction by the operator and entering this as the Z axis. The template was attached and stabilizer needles were placed in the lateral prostate. Transverse ultrasound images were obtained at 5mm increments and digitally entered into the interplant treatment planning computer. Contours of the prostate, urethra and rectum were drawn digitally and entered into the planning computer. Treatment plan was generated and optimized electronically. Generally, a peripheral loading pattern was used. Adjunct template guide holes were seldom used, with diagonal positions being preferentially loaded. More centrally located needles contained seeds loaded only at the base and apex. The interplant system provides straightforward tools for the operator to set these parameters. Anatomical boundaries from the contoured structures were automatically integrated and applied to set the limits of the pattern.

The prostate and rectum dose coverage obtained by overlaying the planned dose clouds onto the intra-operatively measured prostate and rectum contours was calculated (Plate 3.12). An analysis of the differences in prostate and rectum dose coverage due to the use of pre-plan dose clouds with prostate and rectum contours obtained intra-operatively was prepared. A significant decrease in prostate volume dose coverage was seen with the use of the pre-plan measured contours during the implant procedure instead of using intra-operatively obtained contours. A significant increase in rectal volume dose coverage was seen with the use of the plan measured

contours during the implant procedure instead of using intra-operatively obtained contours. The Plate 3.11 shows how the needles were implanted along the perineum of the patient.

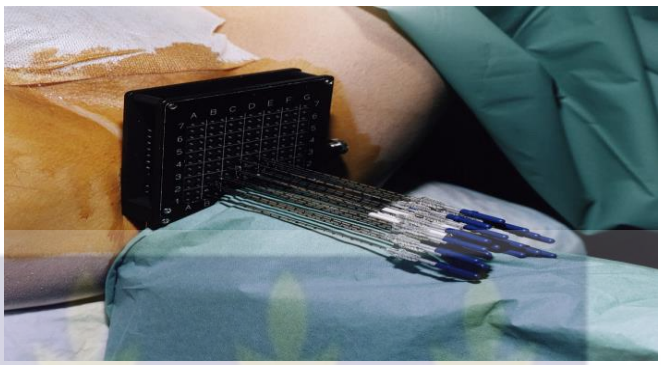

Plate 3.11: Shows the way needles were implanted in a template grid (Roeloffzen)

Plate 3.12: A demonstration of manual positioning of seeds Red colour indicates the Clinical target volume (CTV) and the pale blue colour indicates the 160Gy isodose coverage.

3.1.2.5 Dose planning.

The dose planning software used to perform real-time dose computation at KBTH was variseed 7.2 version, with online connection to the ultrasound system which also contains screen volume calculations. In this study the prescribed doses were 110 Gray for the partial implant and 160 Gray for the fully implant respectively. Eight (8) patients' were implanted with110 Gray and twenty three (23) patients were

implanted with 160 Gray respectively. The most important observation for the dose planning were to ensure that large areas with high doses were to be avoided, moderate dose to urethra and as low as possible dose to the rectum .

Table 3.1: Dose limits for prostate brachytherapy at KBTH.

Dose Parameter	Dose limit (KBTH)
Prostate:	
V200 [%]	< 50%
V150 [%]	< 70%
V100 [%]	> 95%
Urethra:	
UrD(90) [%]	< 90%
UrD(30) [%]	< 130 %
UrD(10) [%]	< 140 %
Rectum:	
V100 [%]	< 1%

These dose limits correspond with international guideline limits for Europe and American.

3.1.2.6 Radiation protection (restrictions to treated patients)

The low energies of both Iodine- 125 and Palladium -103 seeds were such that the dose rate at the skin surface was extremely small. Patients may therefore sleep in the same bed with their partner and be in the same room as children. It is advised that children should not sit on the patient's knee for any length of time for the first two

months after implantation. It is theoretically possible for a seed to be expelled in the semen on ejaculation. In the very rare event that this happens it is usually in the first one or two ejaculations. Some centres advise the use of a condom for the first two to three occasions of intercourse following implantation. Patients should be warned that prostate brachytherapy does not guarantee infertility and that pregnancy remains possible (Ash et al., 2000)

Part two: Pre-planning.

3.2 Materials

The equipment and facilities used to carry out this research work were as follows;

(i)Transparent A4-sheets and marker pens

(ii) Film scanner / Canon scanner

(ii) Treatment planning software-prowess (4.5 prowess panther)

(iv) Pre-evaluation ultrasound images

(v) Patient information (31 patients were involved)

3.2.1 Transparent A4-sheets and Pre-evaluated ultrasound images

The transparent A4-sheets used in this study were made up of materials whose chemical composition consists of 70% organic and 30% inorganic. The organic portion consists of cellulose, hemi-cellulose, lignin and or various compounds of lignin (Na-lignate) and inorganic portion consists of mainly filling and loading materials such as calcium carbonate, clay and titanium oxide. The A-4 transparent material was used to re-draw the ultrasound images. All the slices which were printed

from the ultrasound machine were traced on the A-4 sheets. The prostate, urethra and rectum were marked in the A-4 transparent sheets. Since the images traced from the ultrasound papers were smaller in size, a scaling factor of 5cm was assigned to each of the slice before scanning procedure. Plate 3.13 is a picture of A- 4 sheet, together with marked urethra, prostate and rectum.

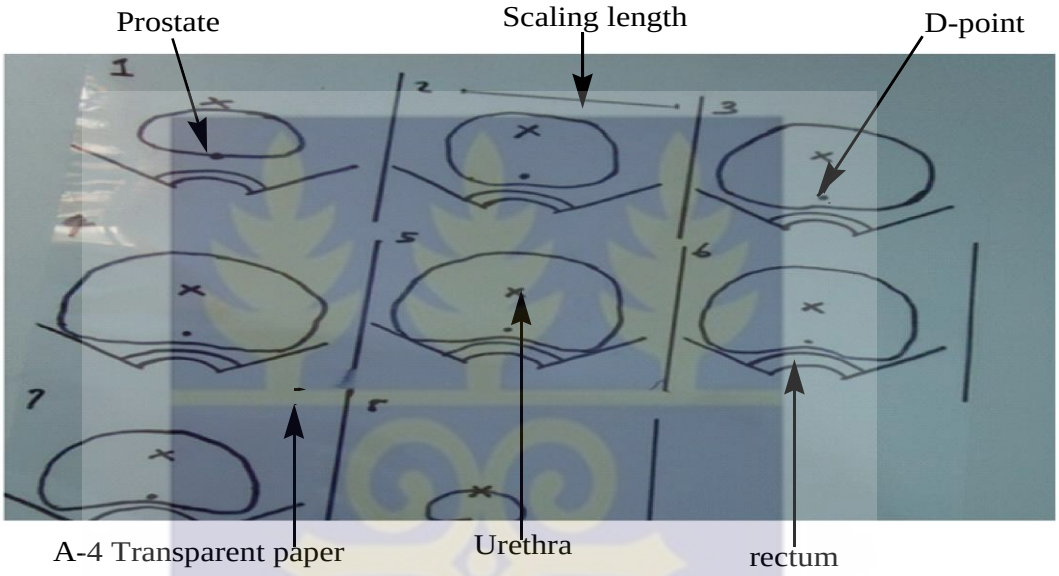

Plate 3.13: A picture of A4-sheet with ultrasound slices as numbered from 1 to 8.The D-points are there to outline the urethra in the straight line.

3.2.2 Marker-pen

The ACCU LINER permanent marker -pen was used to trace the ultrasound images to A4 transparent sheets in this study. It is waterproof and smear proof, alcohol based ink, and is non -toxic and conforms to ASTM D-4236. It was made from South Korea by Mon-Ami co. Limited. The marker-pen is shown in plate 3.14.

Plate 3.14: Pictures of ACCU-LINER marker-pen used in this study

3.2.3 Treatment planning software-Prowess (4.5 prowess panther)

For pre-planning the treatment planning system (TPS) used for this work was Prowess Panther 4.5 supplied by Prowess Company. It comprises a computer with 150 GB hard disc space, 2.00GB of RAM and a Pentium (R) D CPU of 3.00 GHz. A Vidar Systems Corporation film scanner and a film digitiser were the main image acquisition tools for the system. The Prowess Panther 4.5 brachytherapy dose calculation programme calculates the dose rate to any point for seed and line sources. It calculates the dose distribution in a plane from an array of sources by summing the dose-rates from each source at a point over an evenly spaced grid. The array size can be set between 10 x 10 and 128 x 128 calculation points. In this study the array used was 128 x 128. The window of calculation can be changed as necessary. After the system's calculation, isodose lines were plotted by interpolating the calculated matrix. Therefore, the larger the matrix points, the more accurate the isodose curves (Doughan, 2010). Plate 3.15 gives the pictorial view of the Prowess Panther 4.5 model.

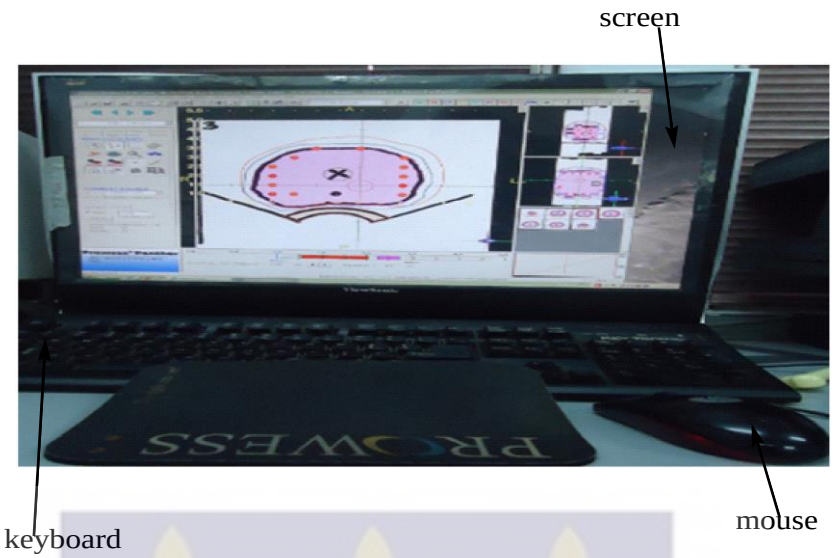

Plate 3.15 : A pictorial view of screen and keyboard of Prowess Panther 4.5 model .

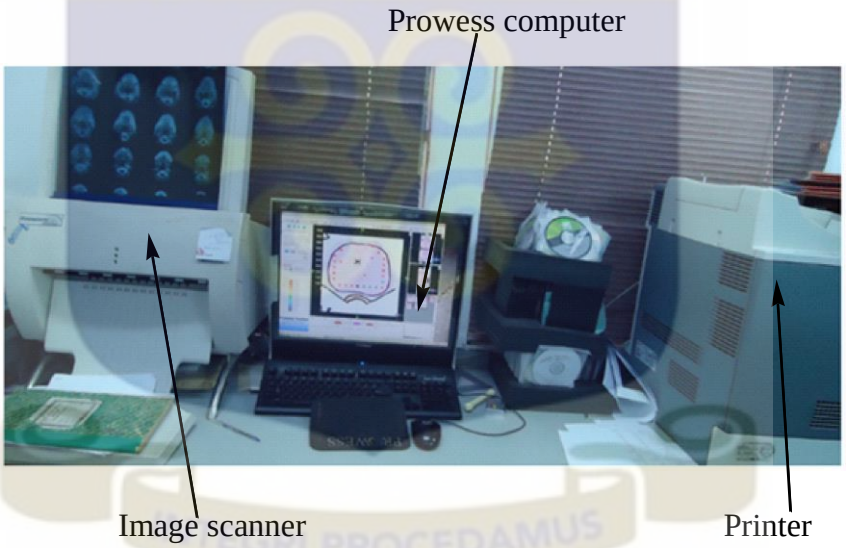

Plate 3.16: A pictorial view of image scanner connected to computer and printer.

3.2.4 Patient characteristics

3.2.4.1 Profile of patients treated with brachytherapy (Prostate seed implants).

The transrectal permanent prostate brachytherapy implant at KBTH was established in August, 2008. According to available statistics up to April, 2013 about

83 patients were implanted with the radioisotope (Record unit KBTH, 2013). The median age of treated patients was 64 years, (range 47-71). Normally for the patient to qualify for prostate brachytherapy implant, he must meet several criteria as stated in chapter one (section 1.1). Table 3.2 shows the characteristics of patients who were implanted at KBTH.

Table 3.2: Characteristics of 31 selected patients which were treated under permanent I-125 prostate brachytherapy implant at KBTH from 2008 to 2013.

Patient characteristics	Category	Number of patients	Percentage [%]
T-stage:	T1	8	25.81
	T2	18	58.06
	T3	5	16.13
Gleason score	5	5	16.13
	6	20	64.52
	7	6	19.34
Pre-treatment PSA :[ng/ml]	< 5	2	6.45
	5-9	16	51.61
	10-20	13	41.93
Bone scan	Negative	31	100.00
IPSS	≤ 12	31	100.00
Prostate volume: [cc]	< 20	5	16.13
	20-50	24	77.42
	> 50	2	6.44

Some of the patients attended the hospital at the late stages, as result they do not comply for the treatment criteria. As can be seen from the table 3.2, two treated patients had prostate volumes greater than 50cc (57.55 and 75.82cc) respectively and

five patients had T3 staged disease. The responses toward the criteria are as summarized in table 2.3.

Both appendices A and B show the patient information which were recorded during real-time implant and pre-plan implant for permanent prostate brachytherapy at KBTH. These included patient ID, year of treatment, prostate volume, prescribed dose, number of needles, number of seeds (source) and the source activity in millcurie.

3.2.4.2 Profile of patients according to the year of treatment.

The radiotherapy department at the centre was established in 1996 in which various cancer cases were reported. Statistically about seventeen (17) patients averagely are implanted with ^{125}I radionuclide every year for brachytherapy while one hundred ten (110) men are treated with external beam radiation (EBRT) per annum. Figure 3.1 shows the statistics.

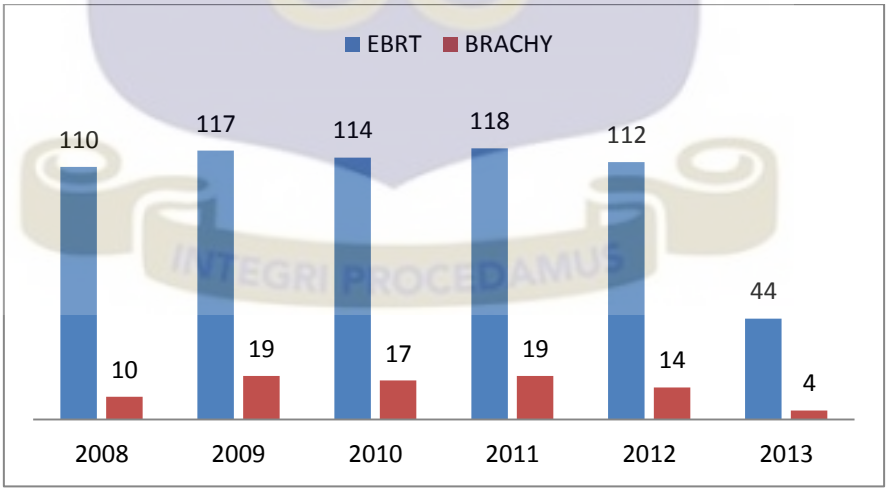

Figure 3.1: The distribution of prostate patients who were treated with EBRT and Brachytherapy for prostate cancer.

From figure 3.1, the number of patients treated with brachytherapy were much less compared to those patients treated with external beam radiotherapy. This was due to the cost affordability of the patient. The cost for prostate implant arises because all of the materials are imported from abroad (Needles, Seeds, Templates and other accessories. Currently the price for the implant is about Us $ 9,000 to Us $ 10,000. For external beam radiotherapy the cost is about Us $ 500 dollars only, for this case most patients opt to be treated with EBRT despite the side effects.

3.2.4.3 Patients distribution according to their ages.

The group age with the highest record was in the range of 65-69 years representing 31.33% of the total number. This means that prostate cancer is commonly at the age of 50 years and above and this age distribution agreed with the international guideline which describes the age risk with prostate cancer (Bostwick et al., 2004). Figure 3.2 shows the distribution of prostate cancer patients at KBTH.

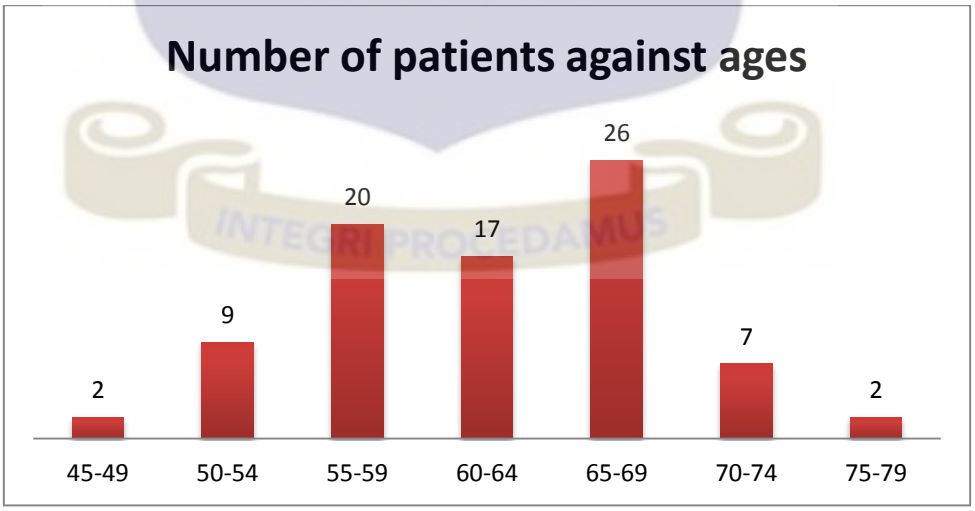

Figure 3.2: The distribution of patients according to their ages.

3.3. Planning procedure.

3.3.1 Drawing and contouring the prostate volume slices

The prostate volume slices were drawn using a marker pen and transparent material A-4 sheet sized, this was done by following the sliced images of ultrasound which were printed during real time - implant procedure. During the process the markings were made to the prostate volume, urethra, rectum and the D point. The D point is just above the rectum (the reference point to all slices which was fixed as identified in the template and it outlines the position of urethra which should be in the same line). The distance from the top of the rectum to D point was about 10 mm which represents the separation between the rectal probe and the rectum respectively during the real time implant procedure. Plate 3.1 represents the drawn ultrasound slices in the transparent paper to be scanned.

The next step was scanning the drawn image using a scanner connected to the treatment planning system, the magnification scale of the image was 5cm. After registration of the scanned image, the prostate, urethra and rectum were outlined (contoured) and registered so as to be recognised by the system (TPS). Plates 3.17, 3.18 and 3.19 show the scanner used in this study and some of the scanned and contoured images.

Plate 3.17: A scanner (Canon 5600 F) used to scan ultrasound images used in this study.

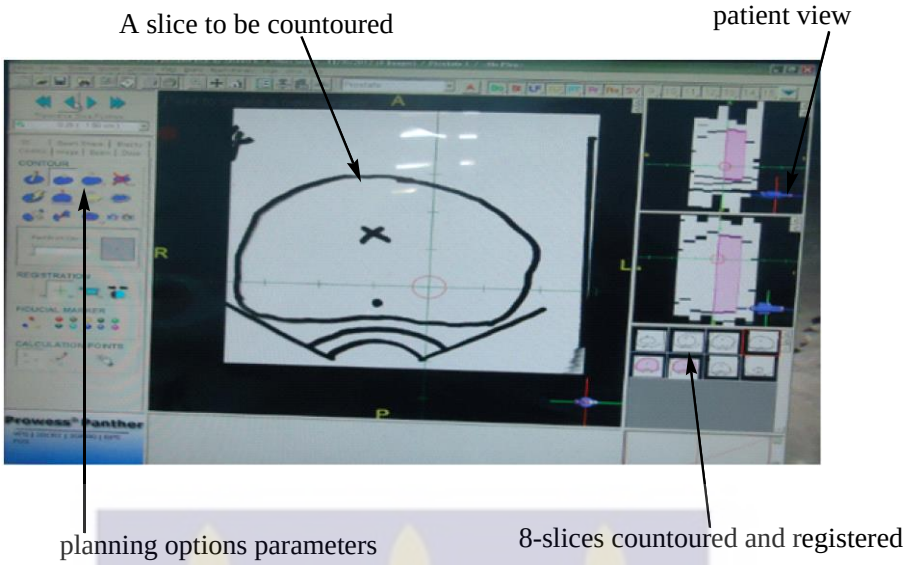

Plate 3.18: One of the sliced image which has been scanned and registered in the TPS.

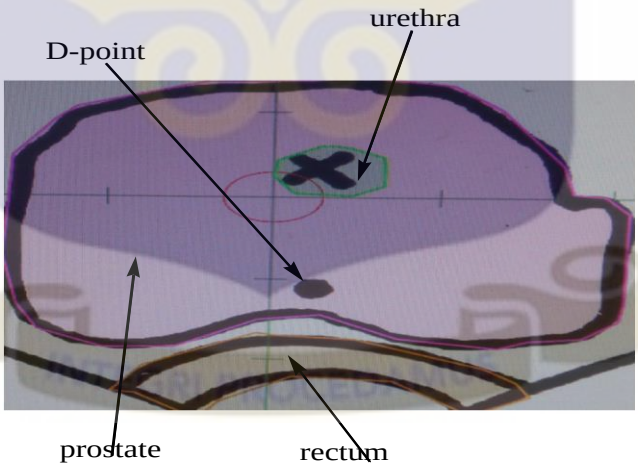

Plate 3.19: The picture shows the scanned and registered (contoured) image in the TPS. Purple colour-prostate volume, Green colour-Urethra, Yellow colour-Rectum and the Black point above the rectum is the D point.

3.3.2 Selection of parameters in the TPS

The Prowess treatment planning system has different types of treatment options for external beam and brachytherapy. In this study, the brachytherapy option was selected for the pre- planning procedure. The type of planning was named as pre-plan, the templates used in this case were B and K templates. The radioisotope used was STM125 ^{125}I and the activity of the source was entered in the TPS (in its respective unit U or mCi), which describes the air kerma strength for every patient. The selection of templates and isotopes mimic exactly the material which will be used during real-time implant procedure.

3.3.3 Pubic arch

The first consideration in the planning process was to determine the degree of pubic arch interference. The pubic bones grow together to form a "V" shape, which is in front of the prostate gland. A narrow pubic arch can make prostate seed implantation difficult. Patients with pubic arch interference may want to consider other prostate cancer treatments .The pubic arch may 'shadow' the anterior and lateral portions of the prostate, making it difficult or impossible to implant seeds in these locations. If this restriction exists, the brachytherapy's may angle the template and ultrasound probe assembly to achieve better needle access. In this work the pubic arch study was done with the TPS, in which the target volume was selected as the prostate and the study organ as urethra. The TPS was allowed to run for a few seconds while calculating the possible volume to be implanted while blocking the urethra (plate 3.20). Since it is known that the urethra lies within the prostate volume, then during implant only the prostate gland should receive seeds and not the organ at risk (urethra). It is not necessary to block the rectum because it is located outside the prostate volume, what is important is to observe that the dose tolerance to the rectum does not exceed the limit.

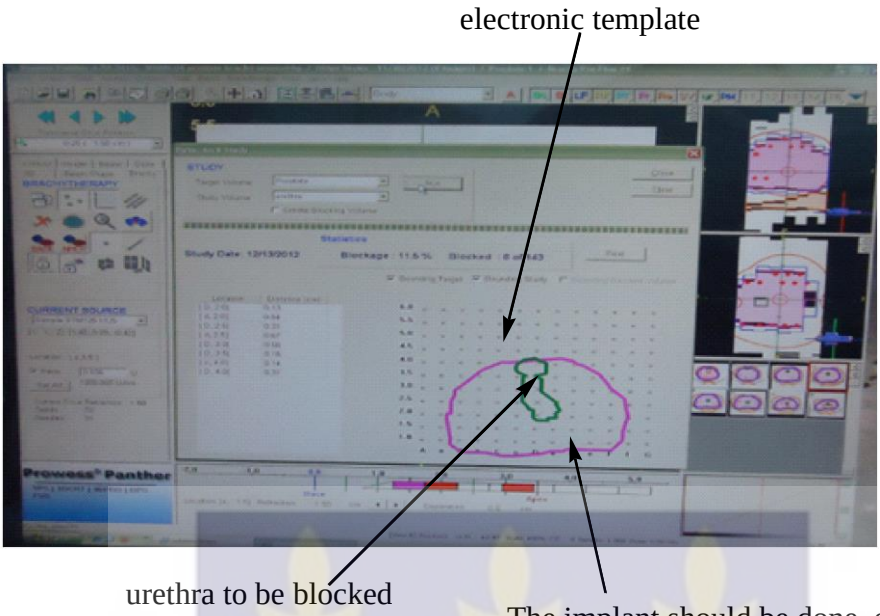

Plate 3.20: A pictorial view of TPS showing the Target volume (prostate) in purple and Study volume (Urethra) in Green colour respectively as defined in a template grid.

Each slice was given a margin of 2mm, which mimics the same margin that will be given to the slices during real time - implant procedure. When needles are inserted into the prostate volume, there is a temporal enlargement of the prostate. The margin of 2mm will therefore account for the swelling of the prostate. Plate 3.9 defines the prostate volume and its margin.

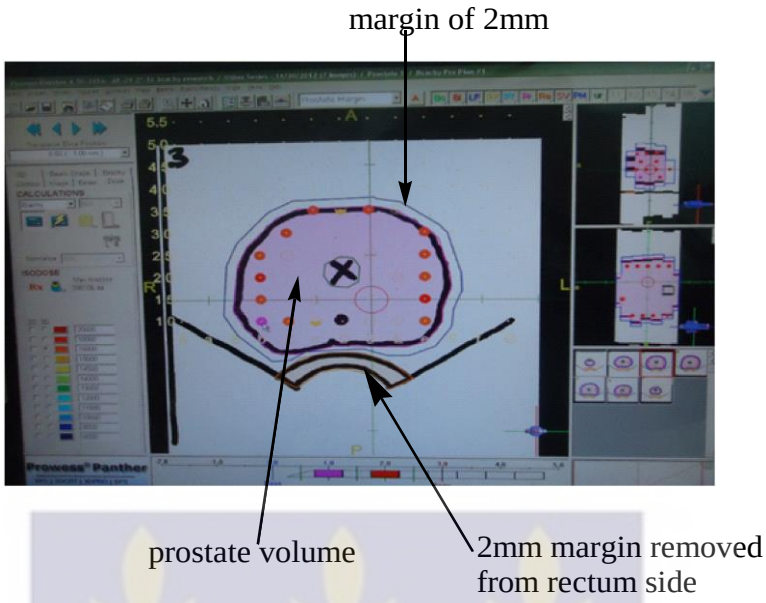

Plate 3.21: A pictorial view of prostate volume (Purple) and its margin (2mm)-blue colour.

3.3.4 Seed distribution

Different types of seed distributions are in current use, the classic approach is to space the seeds 10 mm apart, centre to centre, throughout the prostate. This approach, referred to as *uniform loading* which needs a higher number of lower strength seeds (typically 0.4 U to 0.5 U seeds for ^{125}I and 1.2 U to 1.5 U seed for ^{103}Pd) and is characterized by relatively high doses in the centre of the prostate. In *modified peripheral loading*, some seeds in the central portion of a uniformly loaded implant are removed to reduce the central dose. This may require increasing the strength of the remaining seeds or decreasing the needle to needle or seed to seed spacing in the periphery. *Peripheral loading* is an alternative approach in which the seeds are preferentially limited to the periphery of the prostate. This requires a substantial increase in seed strength (typically 0.75 to 1.0 U/seed for 125I, 2.0 U/seed or higher for ^{103}Pd). The end result is to produce a dose minimum, instead of a dose maximum, at the location of the urethra (AAPM, 1999).

In this study, the slices for every patient were displayed, the base and the apex slices were defined and registered in the TPS. A slice which was closer to the bladder was named as a base and the last slice at the other end was identified as an Apex (Plate 3.10). Twenty eight patients had 6-8 slices, two patients had 11 slices and one patient had 14 slices.

The electronic template selected from the TPS displays the dose calculation points (numbers in the ordinate and letters in the abscissa). The abscissa was moved such that the D point was aligned to match the point which was drawn in the slices just above the rectum and this served as a reference in which no seed was implanted along this line. Point D is usually marked to outline the urethra to be almost in the straight line for all slices. Similar arrangement is expected to be achieved during real-time implant with physical template.

The size of the matrix used was 128 x128. The largest slice was selected for every patient and the implant was done. The choice of the largest slice was based on the fact that the smaller slices were superimposed on the largest and hence will also receive dose coverage. Needles were filled with seeds from the base to apex at intervals of 5mm along the periphery of the target volume. Depending on the size of the prostate the equivalent number of needles and seeds were implanted (Plate 3.22).

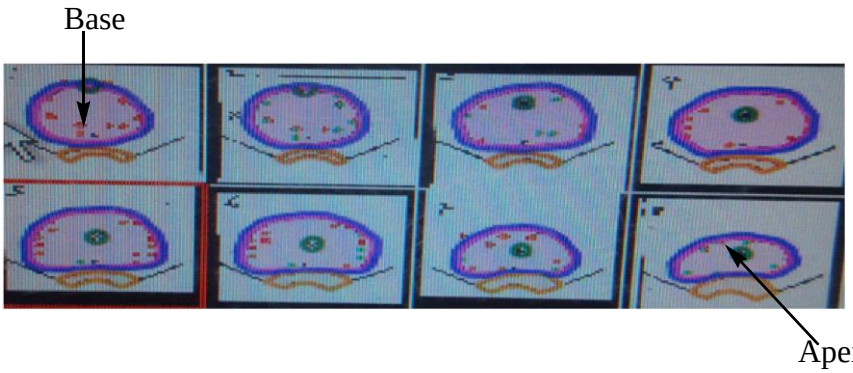

Plate 3.22: A pictorial view of slices arranged from a Base (No 1) which is closer to the bladder up to the Apex (No 8) which is nearby the rectum. The arrangement is according to human anatomy and it is the same way the TPS will recognise it.

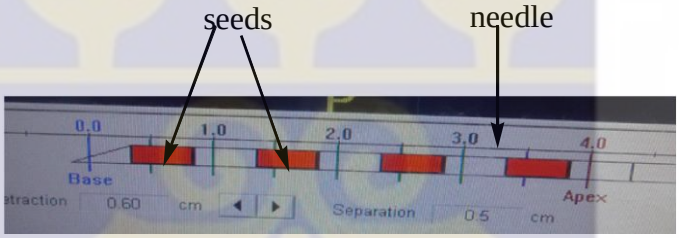

Plate 3.23. The view in which seeds were implanted through needles to the prostate glands from the Base to Apex at the interval of 5mm.

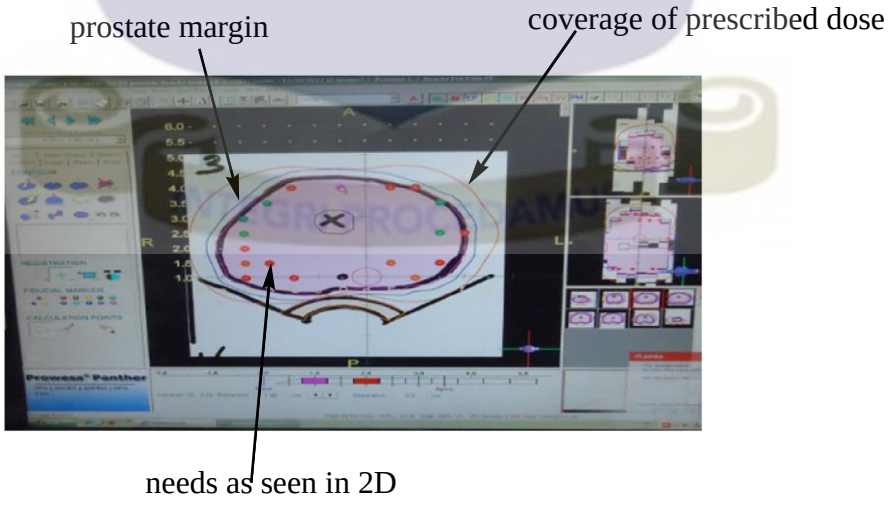

Plate 3.24: A pictorial view of one of the slices which had been implanted with seeds as guided by the TPS parameters. The blue isodose is a prostate margin and the dose coverage is shown with orange colour.

3.3.5 Dose margin

Due to seed placement uncertainties that are inherent to the implant procedure, the percentage of the prostate volume that is covered by the prescribed dose was always less than planned. Thus, if the prescribed dose and coverage are to be achieved it may be necessary to ‘‘over plan’’ the implant. This is achieved in a variety of ways:

(a) By using a planning volume that is larger than the prostate volume (which is also justified by the known incidence of extracapsular extension of disease).

(b) By increasing the total activity implanted by about 15%.

(c) By increasing the number of seeds or seed strength until the prescribed isodose line lies several millimetres outside the prostate.

All of these methods effectively constitute a planning integral dose escalation. Thus, the decision to plan a dose margin is tied to the prescribed dose itself (AAPM 1999). The prescribed doses in centigray (cGy) were entered, afterward the TPS was allowed to run. At times the allocation of seeds to slices was observed and varied so as to meet the dosimetric constraints as directed by the isodose lines and the dose volume histogram (DVH) displayed the dosimetric parameters to be assessed.

The dosimetric parameters to be assessed were V150%, V100%, V95%, D90 Gy and D50 Gy for prostate, for which the dose coverage for a particular volume should be above V95% of the prescribed dose. Similarly for urethra the dosimetric parameters were D90 Gy, D30 Gy and D10 Gy with the focus much on D30 Gy which should receive not more than 130% of the prescribed dose. For the rectum the dosimetric parameters were V100%, D100 Gy and D30 Gy, the focus was mainly on V100%, which should receive less than 1% of the prescribed dose. All of these dosimetric parameters were achieved with the guidance of dose volume histogram (DVH. Plate 3.25 shows the dosimetric parameters as recorded from DVH.

Dose Volume Histogram — Prowess Panther v 4.50

Patient Name: *YS-06 prostate Brachy-research^^^^*
Patient ID:
Physician: *Dr. Vanderpuye / Yarney*
Institution: *Oncology Department, Korle Bu Teaching Hospital*

Plan Name: *Brachy Pre Plan #1*
Anatomical Site: *Anatomical Site*
Dosimetrist: *Kalolo Tegemea*
Date: *1/23/2013*

Volume Name	Prostate	Rectum	Prostate Margin	urethra
Volume Total (cc)	50.2	5.8	60.4	1.6
DLV at 100.0 cGy	50.2 cc 100.0 %	5.8 cc 100.0 %	60.4 cc 100.1 %	1.6 cc 100.0 %
D100	14280.0 cGy 89.3 %	5640.0 cGy 35.3 %	11520.0 cGy 72.0 %	14040.0 cGy 87.8 %
D90	19423.8 cGy 121.4 %	7864.5 cGy 49.2 %	18418.9 cGy 115.1 %	15111.0 cGy 94.4 %
D30	38272.8 cGy 239.2 %	12146.1 cGy 75.9 %	36536.8 cGy 228.4 %	20758.5 cGy 129.7 %
V150	31.1 cc 61.9 %	0.0 cc 0.0 %	35.9 cc 59.4 %	0.0 cc 2.3 %
V100	49.4 cc 98.3 %	0.0 cc 0.7 %	58.4 cc 96.8 %	1.4 cc 83.3 %
V95	50.0 cc 99.5 %	0.1 cc 2.4 %	59.5 cc 98.6 %	1.4 cc 88.4 %
Min Dose	14271.8 cGy 89.2 %	5589.7 cGy 34.9 %	11432.6 cGy 71.5 %	13966.5 cGy 87.3 %
Max Dose	316918.2 cGy 1980.7 %	19213.3 cGy 120.1 %	316918.2 cGy 1980.7 %	29756.7 cGy 186.0 %
Mean Dose	37760.7 cGy 236.0 %	10873.0 cGy 68.0 %	36241.2 cGy 226.5 %	19392.3 cGy 121.2 %
EUD (cGy)	-	-	-	-

Plate 3.25: A pictorial view of DVH with dosimetric parameters. The orange colour shows the coverage of prescribed dose (160Gy in this case), Green is the Urethra coverage, Blue is the prostate margin and Purple is the Prostate coverage.

If all of the above described parameters are achieved then the planning was successful. The dose for patients was prescribed by the oncologist, in this study the prescribed dose was 110 Gy for partial implant and 160 Gy for full implant

respectively as recommended by the guidelines. Plates 3.26 & 3.27 show some of the three dimensional views of the seeds implanted within target volume.

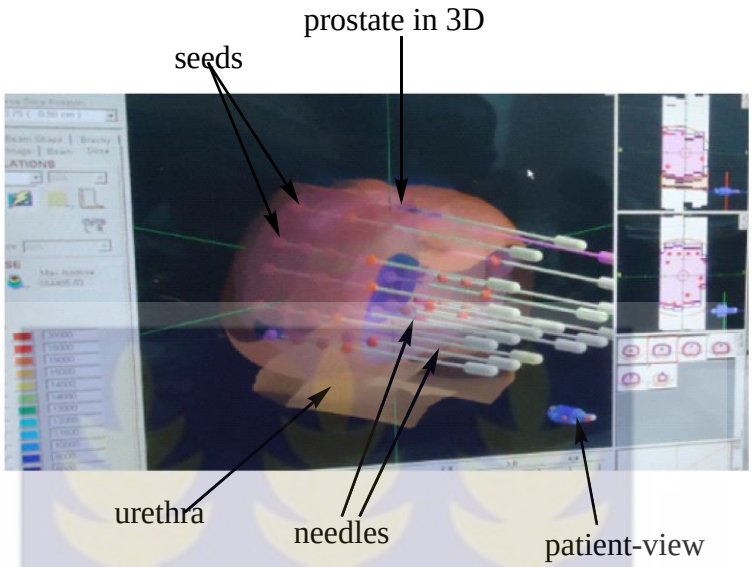

Plate 3.26: A pictorial view of 3D needle implanted with TPS .

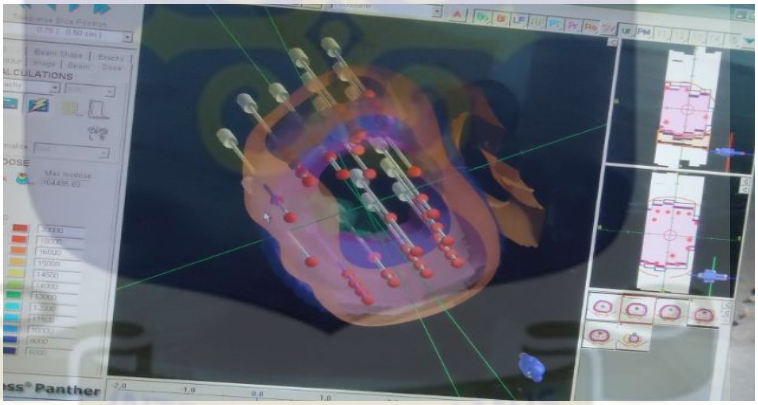

Plate 3.27: A pictorial view of 3D needle implanted with TPS.

CHAPTER FOUR

RESULTS AND DISCUSSION

In this chapter the results from the study are presented and discussed. The results are divided into two parts real-time implant and Pre-plan implant.

4.1 Comparison of prostate volume, number of needles and amount of seeds implanted.

From the results obtained a comparison of prostate volume, number of needles and the amount of seeds implanted were made which is as follows:

4.1.1 Prostate volume.

For effective seed implantation it was important to study the size of the prostate such that the number of needles to be inserted and the seeds to be implanted were proportional to the prostate volume. Appendix C indicates the comparison of the prostate volume during real-time implant (variseed summary report) and pre-plan implant (contoured using prowess 4.5 panther). Both the ultrasound machine and the TPS were calibrated such that the volumes displayed were the actual ones. The average volume error was 3.19 % which was within the tolerance limit of variation of ±5%. The agreement in prostate volumes indicated that the calibration of both prowess 4.5 version software and Variseed 7.2 version were accurate. This signifies that using Prowess 4.5 software to re-estimate the volume was the same as using Ultrasound variseed 7.2 software.

4.1.2 Number of needles

The assessment of number of needles was important so that the patient could neither be overdosed nor under dosed, Appendix D indicates the comparison between number of needles during real-time implant (Variseed) and pre-plan implant (Prowess

Panther). There was a slight difference in number of needles in some plans, this might have been caused possibly by overestimated prostate volume at the time of tracing it from the ultrasound images. This meant that the pre-plan validates the accuracy of real-time implant.

4.1.3 Number of Seeds

The dose delivered to the patient was necessary for assessment so as ensure that it corresponded to the tumour diagnosed. Appendix E displays the comparison between number of seeds implanted during real-time implant (Variseed) and pre-plan implant (Prowess Panther). The differences in the amount of seeds provided the percentage error of 4.07% which was within the tolerance limit.

Based on the slight variations in prostate volume, number of needles and amount of seeds to be implanted, it is important to do pre-plan implant (simulation implant) so as to speed up the real time implant as some patients cannot stay under anaesthesia for long.

4.2 Dosimetric parameters.

4.2.1 Pre-plan Implant Data using Prowess 4.5 panther.

Table 4.1 shows the median dosimetric values obtained from pre-plan implant using prowess 4.5 panther for the prostate, urethra and rectum with their corresponding ranges.

Table 4.1: The median dose values for prostate, urethra and rectum from DVH

Prostate:	Median (%)	Range (%)
V95 (%)	97.17	95.8 - 99.50
V100 (%)	97.12	94.6 - 98.30
V150 (%)	59.73	55.0 - 68.00
D90 (Gy)	177.15 Gy (110.70) %	120.55 - 196.19 Gy
Urethra		
UrD(90) Gy	128.35 Gy (84.50) %	79.04 - 156.39 Gy
UrD(30) Gy	205.47 Gy(129.08) %	139.67 - 209.12 Gy
Rectum		
V100 (%)	0.30	0.2 - 0.9
V150 (%)	61.01	-
D30 (Gy)	89.76 Gy (68.50) %	69.73 - 124.58 Gy

- **The median was computed by using excel**.

The dose volume histogram (DVH) guided the planner to compromise with the isodose by changing the location of needles in the template while observing the amount of dose coverage displayed. The dosimetric parameters for prostate, V95% should be greater than 95 for the good coverage of dose around the prostate. This was achieved by compromising with the isodose line during planning. For urethra, the prescribed dose for the full implant patients was 160 Gy which meant that the 130% of the prescribed dose was 208Gy. The median of 205.47 Gy agreed with the recommended limit (Table 2.4). The UrD30 Gy was the reference dose for urethra which was not required to exceed 130% of the prescribed dose. In the case of the rectum, the V100 should be less than 1% for a successful planning. As seen from the table 4.1, the median was 0.3% which agreed with the American Brachytherapy Society (ABS) and European recommendations.

4.2.2: Real-time Implant Data Using Variseed 7.2 Software

The median dose values obtained from real-time implant using Variseed 7.2 software for the prostate, urethra and rectum shown in Table 4.2 with their corresponding ranges.

Table 4.2: The median dosimetric values from variseed 7.2 software

Prostate:	Median (%)	Range (%)
V100 (%)	96.05	90.92 - 99.77
V150 (%)	61.01	55.07 - 72.98
D90 (Gy)	176.72Gy (115.55)	115.65 - 221.98 Gy
Urethra		
UrD(90) Gy	130.21 Gy (81.98)	86.10 - 194.90
UrD(30) Gy	204.73 Gy (128.12)	134.48 - 245.94
UrD(10) Gy	215.81 Gy	139.19 - 265.39 Gy
Rectum		
V100 (%)	0.395	0.00 - 1.01
D30 (Gy)	75.53 Gy	41.56 - 113.18 Gy

The median was computed by using excel.

From Table 4.2, the V100 % dose around the prostate was achieved by compromising with the isodose line during planning using the treatment planning software (Variseed 7.2 version) and the dose volume histogram (DVH) respectively. For urethra, 130% of the prescribed dose of 160 Gy was 208 Gy, and the median dose was 204.73 Gy. This meant that the dose to the urethra was achieved as recommended by ABS. The UrD (30) which is a reference dose should not exceed 130% of the prescribed dose was achieved. Similarly, the V100% for rectum was less than 1% for the planning. The median was 0.395% which agreed with the ABS (1995) and Europeans recommendations of 2012.

4.3 Comparison of Dosimetric Parameters.

The median values for dosimetric parameters for all thirty one patients was calculated for prostate, urethra and rectum respectively. Table 4.3 shows the comparison of dosimetric parameters with their corresponding ranges.

Table 4.3: The comparison of prostate, urethra and rectum dosimetric parameters.

Prostate:	Median: Real-time implant	Median: Pre-plan implant	Differences (%)
V95 (%)	-	97.17 %	-
V100 (%)	96.05 %	97. 12 %	1.11 %
V150 (%)	61.01 %	59. 73 %	-2.00 %
D90 (Gy)	176.72 Gy	177.87 Gy	0.65 Gy
Urethra			
UrD(90) Gy	130.21 Gy (81.98)%	128.35Gy (84.5)%	-1.43Gy
UrD(30) Gy	204.73 Gy (128.12)%	205.47 Gy(129.08)%	0.36Gy
UrD(10) Gy	216.62	-	-
Rectum			
V100 (%)	0.395 %	0.30 %	2.43%
V150 (%)	-	0.00	-
D30 (Gy)	92.01 Gy (75.53) %	89.76 Gy (68.50) %	-2.44 Gy

❖ **The median was computed by using excel**

The dosimetric parameters reported are mainly based on international guidelines such as the America Brachytherapy Society (ABS), Europeans Association of Urology (EAU), European Organisation for the Research and Treatment of Cancer (EORTC) and European Society for Therapeutic Radiology and Oncology (ESTRO) guidelines. Comparison was made for dosimetric parameters which were recorded from the dose volume histogram (DVH) for each patient. In brachytherapy dosimetry, dose is referred to a calculation point, which is presented by a median values.

Table 4.3 shows the dosimetric parameters reported for prostate, urethra and rectum respectively. The dosimetric parameters for prostate include V100 (%), V150 (%) and D90 (Gy). The percentage deviations for V100% was 1.11%, V150% was

2.0% and D90 was 0.65% respectively, confirming that doing pre-plan is important as stated in the objectives. The errors in all of the three cases are within the acceptable limit of ±5% (Hanson et al., 1991).

The dosimetric parameters for urethra, included UrD90 (Gy) and UrD30 (Gy). The percentage deviations for UrD90 was 1.43% and 0.36% for UrD30. The implication of this is that pre-plan is beneficial to the patient since the deviation is so small to perturb the dose.

For the rectum the dosimetric parameters were V100 (%) and D30 (Gy). The differences between real-time implant and pre-plan implant were 2.43% for V100 (%) and 2.44% for D30 Gy respectively. According to Hanson et al., 1995, the acceptable error in dosimetry should be less than ±5%. Thus the pre-plan implant should be carried out, as it is beneficial to the patients since the deviation is within the acceptable limit of ±5%.

4.4. Comparison of Graphs

4.4.1 Number of seeds Vs. prostate volume (cc).

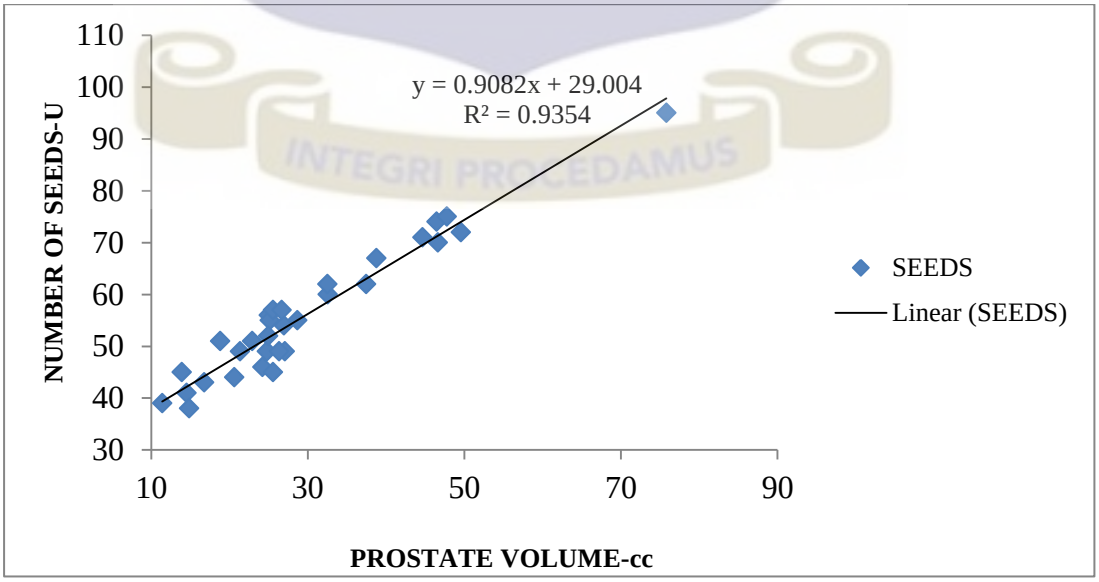

Figure 4.1: Real-time implant: Number of seeds Vs. Prostate volume (cc).

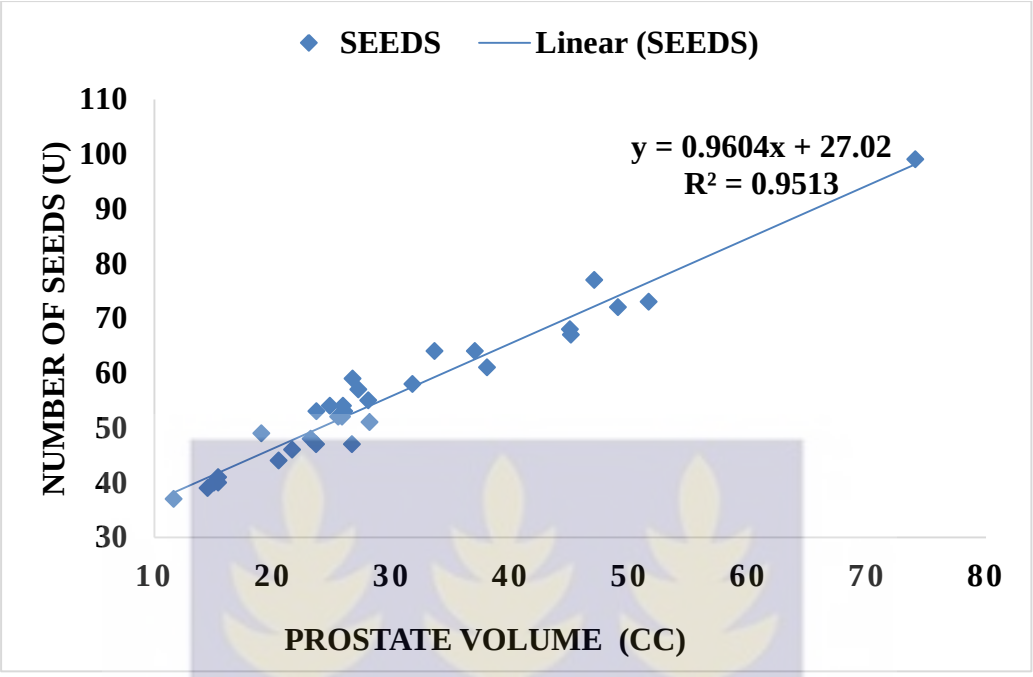

Figure 4. 2: pre-plan implant: Number of seeds Vs. Prostate volume (cc)

Figures 4.1 and 4.2 indicate that the number of seeds implanted was linearly proportional to the prostate volume. In this research one of the objectives was to find out whether there was a correlation between real-time implant and pre-plan implant. Clearly there was correlation, implying that there is a need to perform pre-plan prior to real -time implant as the dosimetry will not be altered. Pre-plan enhances the duration of implant hence reduces the time for patient to be under anaesthesia. However, aside the cost of brachytherapy, the amount of seeds to be ordered from the manufacturer will be proportional to the prostate size.

4.4.2 Total activity (mCi) Vs. Prostate volume (cc).

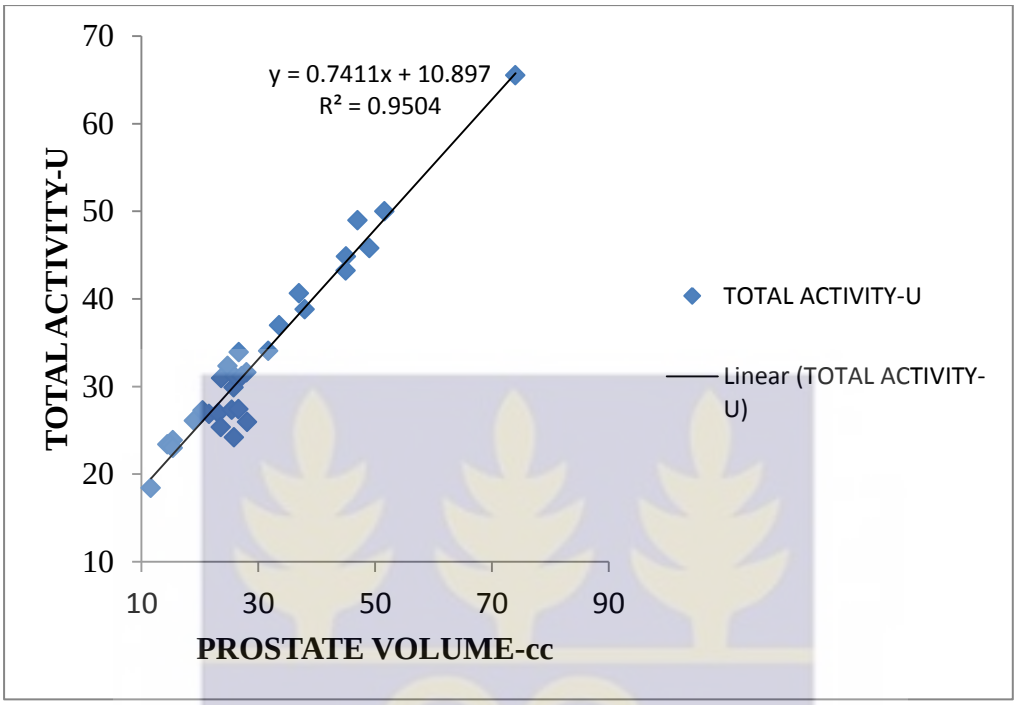

Figure 4.3: Real-time implant: Total activity (U= mCi) Vs. Prostate volume (cc)

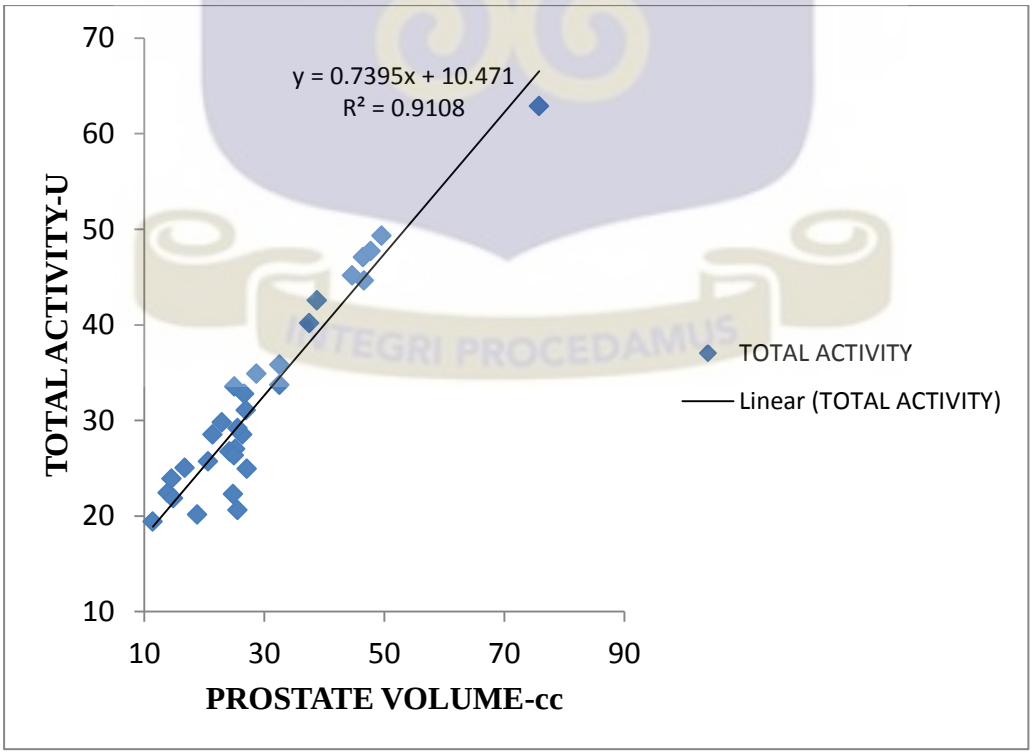

Figure 4.4 Pre-plan implant: Total activity (U= mCi) Vs. Prostate volume (cc)

Figures 4.3 and 4.4 also indicate that there is a linear relationship between the total activity to be implanted and the prostate volume. There was a correlation between the difference in total activity and prostate volume contoured using different softwares. This was within the limit of < ± 5% as recommended by ICRU (2001). This shows that pre-plan and the real-time implant is beneficial to patients.

4.5 Clinical Data Results compared with International Guidelines.

4.5.1 Data Comparison with European Recommendations

The dosimetric parameters recorded from dose volume histogram (DVH) at KBTH were compared with that of European recommendations as shown in Table 4.4 and Figures 4.5, 4.6 and 4.7 for Prostate, Rectum and Urethra respectively.

Table 4.4: Comparison of dosimetric parameters between KBTH and other centres (Salembier et al., 2007)

Dose parameter	Korle-Bu Teaching Hospital (Ghana)		Karolinska Hospital (Sweden)		European Recommendations *
	Median values	Dose limits	Median values *	Dose limits *	
Prostate:					
V95 (%)	97.2 (95.8 - 99.50)	>95	-	-	-
V100 (%)	97.12 (95.6 - 98.30)	>95	97 (93 - 100)	>99	≥95
V150 (%)	60.5 (55.0 - 67.80)	<65	57 (40 - 74)	<60	≤50
D90 (%)	110 (104.6 - 122.6)	≥100	120 (105 - 134)	-	≥100
Urethra:					
UrD10 (%)	-	-	130 (112 - 147)	<130	<150
UrD30 (%)	129.45 (124 -130.70)	≤130	124 (107 - 142)	<125	<130
Rectum:					
D30 (Gy)	108.13 (71.84 - 124.58)	<130	98 (73 - 128)	-	≤145
V100 (%)	0.4 (0.2 - 0.9)	<1.00	-	<1.0	<1.00

*** (Kramar, 2008)**

❖ **Median was computed by using excel.**

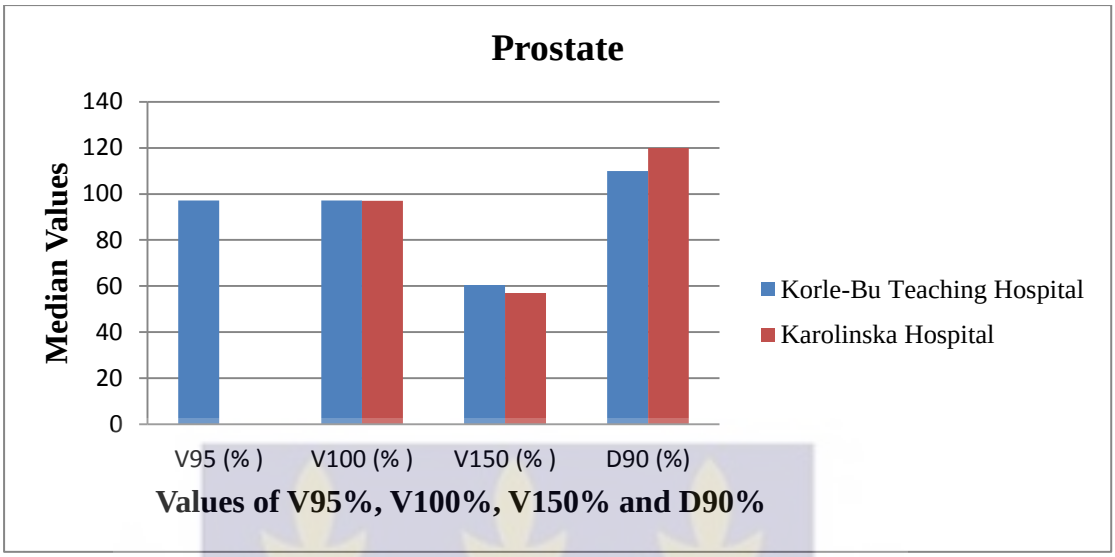

Figure 4.5: Comparison of dosimetric parameters between KBTH and Sweden on Prostate doses.

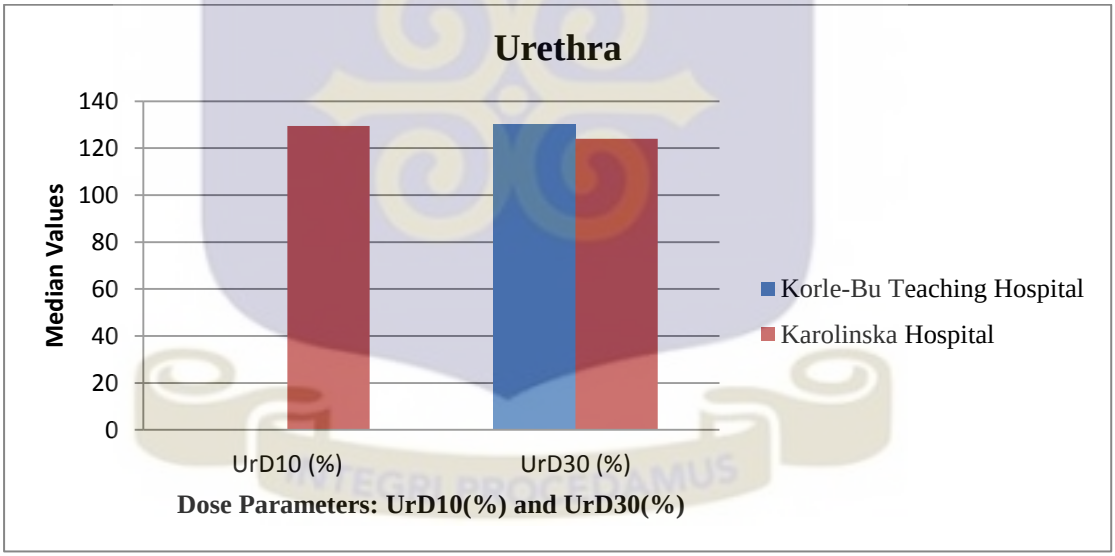

Figure 4.6: Comparison of dosimetric parameters between KBTH and Sweden on Urethra doses.

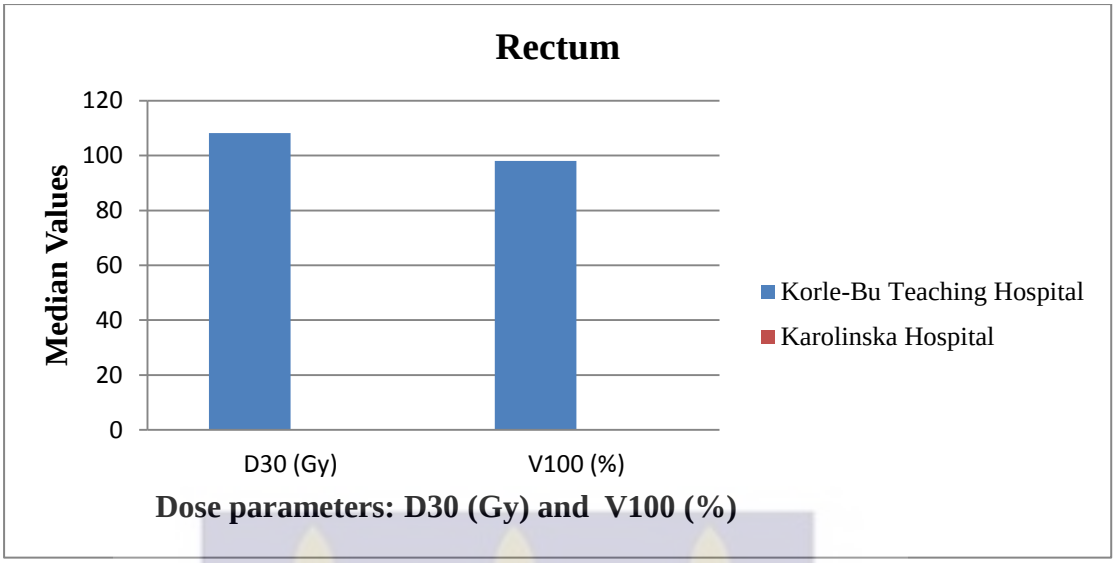

Figure 4.7: Comparison of dosimetric parameters between KBTH and Sweden on Rectum doses.

Table 4.4, the data for dosimetric parameters at KBTH is in good agreement with that from Sodersjukhuset, Karolinska University Hospital (Sweden) as well as the European recommendations, are within the range and the dose limit required. In both centres (KBTH and Karolinska) V150 (%) is the only dosimetric parameter which is above the limit and it exceeded 50 indicating the presence of hot spots in the prostate. With Prowess Panther 4.5 version at KBTH to achieve planning, the prostate had to receive above 95% of the prescribed dose (V95 > 95%). Consequently, when V95 goes beyond 99%, it increases V150%. Due to this, if V150% is to be lowered, it will be presumably necessary to lower V95% and this reduces the dose received by the prostate hence leading to cold spot. From Table 4.4 above, the brachytherapy of prostate implant done at KBTH are in good agreement with that of Sweden and European recommendations and histograms (Figures 4.5, 4.6 and 4.7) clearly compare the values with respect to doses on prostate, rectum and urethra.

4.5.2 Data Comparison with Other Published Work

Comparison of data from different authors is important when evaluating the dosimetric parameters during planning, however due to lack of uniformity in defining and calculating the dose to the target and organ at risk is very difficult at present. The target volume and organ at risk are evaluated differently in different places. The prescribed dose also varies. In Europe the prescription is 145 Gy while in United States is 144 Gy when using ^{125}I (AAPM TG-43(6) 1995). There are also different methods of outlining the treatment. Some centres recommend the use of CT while other centres recommend MRI. In addition different softwares are used for planning.

Table 4.5 shows the comparison for median values treated with permanent seed implants in Ghana and Sweden

Parameter	This Work		Reference	
	KBTH (Ghana)		Karolinska university Hospital (Sweden)*	
	Median	Range	Median	Range
Prostate volume (cc)	30.07	13.81 - 75.82	30.00	14.00 - 58.00
Number of Needles	23.00	15.00 - 38.00	23.00	15.00 - 30.00
Number of Seeds	59.00	37.00 - 114.00	61.00	42.00 - 90.00
Number of seeds/ cc	1.995	1.23 - 3.26	2.00	1.50 - 3.30
Total activity U(mCi)	35.54	21.57 - 76.17	34.37	20.04 - 69.17

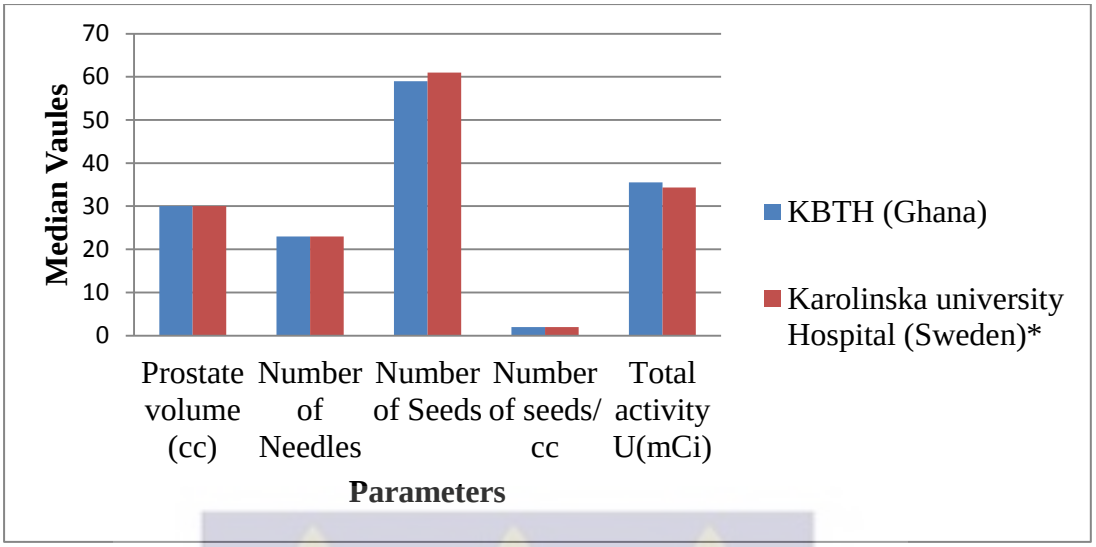

Figure 4.8: Comparison for median values treated with permanent seed implants in Ghana and Sweden hospitals.

*** (Kramar, 2008)**

- **Median was computed by using excel.**

Table 4.5 as illustrated on Figure 4.8 shows the values obtained at KBTH (Ghana) and Sodersjukhuset, Karolinska university Hospital, Sweden. The median for prostate volume was 30.07 cc at KBTH (Ghana) and 30.00 cc (Sweden) with the variation of ± 0.23 %. In the case of number of needles both centres have median of 23. Similarly the median for number of seeds was 59 at KBTH (Ghana) and 61 (Sweden). For the number of seeds per unit volume the median value was 2.0 at both centres. However the median values for the total activity was 35.54 U at KBTH (Ghana) and 34.37 U (Sweden) respectively. These results compared favourably well, as all of the values compared for both centres fall within the acceptable limit of deviation.

Hoskin and Venselaar (2007) have published an overview of 57 centres in Europe practicing permanent seed implant. The clinical target volume (CTV) was defined by the prostate contour at all the centres. However an important observation

was the variation in the definition of the planning target volume, PTV. The margin of the prostate varied from 0 to 10mm. All centres used ^{125}I with a standard prescribed dose of 145 Gy. As ESTRO recommended all of the centres undertook post plan evaluation with the majority using CT. The dosimetric parameters used for prostate volume included D (90), V (100) and V (150) for all centres. D (90) and V (100) values reported by different authors are compared in Table 4.6

Table 4.6: shows the comparison of dosimetric parameters D90 (Gy) and D100 (Gy) for prostate as reported by different authors.

Authors	D90(Gy)	V100 (%)	Dose (Gy)	Prostate volume (cc)	Number of patients	Remark
KBTH,Ghana, 2013 (this work)	176.72 (Median)	97.12 (Median)	160	30.07 (Median)	31	Prowess Panther 4.5 software, 2mm margin.
Karolinska, Sweden,2007*	177 (Median)	97 (Median)	145	30 (Median)	198	US-based Variseed software, no margin.
Zelefsky et al ,2007 *	176 (Median)	96 (Median)	144	32 (Median)	555	CT-Scan 3hours after implant
Chauveinc et al,2004 * (Paris-France)	177.03 (Median)	97.70 (Median)	145	31 (Median)	450	US-based, variseed software, Loose seed
Potters et al, 2003 *	175.67 (Median)	96 (Median)	144	32 (Median)	26	Us-based, Variseed Software, 2mm margin

*** (Kramar, 2008)**

- **Median was computed by using excel.**

KBTH, Ghana, 2013:

The values from KBTH (Ghana) are from pre-plan implant. The prescribed dose was 110 Gy for partial implant with 2mm margin in which 45 Gy followed in

external beam therapy to boost up the dose. As seen from table 4.6, during full implant the prescribed dose was 160 Gy with 2 mm prostate margin. The dosimetric parameters reported were V100 (%), V150 (%) and D90 (Gy) for prostate. For Urethra UrD90 (Gy), UrD30 (Gy) and UrD10 (Gy) were reported and V100 (%), D100 (Gy) and D30 (Gy) were also reported for the rectum. Despite different technique and software used, the median parameters for prostate, D90 Gy and V100% reported from KBTH were in good agreement with other centres as indicated in table 4.6. The use of 160 Gy was as recommended by ESTRO and the internal protocol of the instution.

In their study Zelefsky et al., (2007) described the dosimetric constraints which was taken from CT scan three hours after the implant. Although there was a difference in contouring the volume of slices when using CT and Ultrasound, comparison can still be made on the dosimetric parameters. The prescribed dose was 144 Gy as recommended by AAPM and the constraints for dosimetric planning were V100% > 95, UrD10 < 120% (173 Gy). The average rectal dose was < 80%. Other dosimetric data reported were V100%, V150%, V200%, D90Gy for prostate, UrD30 (Gy), UrD10 (Gy) for urethra, RD 30(Gy) and RD10 (Gy) for rectum with their mean doses respectively. As seen from table 4.6 the values reported in this work (KBTH) and Zelefsky et al., 2007 are in good agreement despite the difference in number of patients treated and the technique used. The CT scans in Zelefsky's work was used for post implant as recommended by ABS.

Potters et al., (2003) reported implant done with both pre-plan and real-time implantation approach. The dose planning software used was variseed with online connection to the ultrasound. The D90 with 175.67 Gy was less compared to 176.72 Gy at KBTH. This agreed with European (ESTRO) which recommends that D90

should be ≥ 100% of the prescribed dose. The implant was done with the margin of 2 mm around the prostate with 114 Gy partial implant. As seen from table 4.6, the values for D90 Gy and V100% are in good agreement.

Chauveinc et al., (2004) also presented the results from ultrasound based with variseed software with loose seeds technique, with 145Gy prescribed dose. The dosimetric values reported were D90 with 177.03 Gy and V100 with 97.7 % respectively. As shown from the table 4.6, Chauveinc values were higher than values reported from KBTH as D90 was 176.72 Gy and V100 was 97.12%. When compared to the guideline (ESRTO) for which D90 ≥ 100 Gy and V100 ≥ 95%, it can be concluded that both values reported by Chauveinc and at KBTH agreed with the international guidelines.

Table 4.7: The mean values of the selected thirty-one (31) patients treated with permanent seed implant at KBTH.

	Real-time implant		Pre-plan implant		Deviation
	Mean	Range	Mean	Range	(%)
Prostate volume (cc)	29.54	11.40 - 75.82	29.47	11.61 - 74.06	-0.24
Number of Needles	16.83	10.00 - 20.00	16.85	10.00 - 21.00	0.12
Number of Seeds	55.16	38.00 - 95.00	54.96	37.00 - 99.00	-0.20
Number of seeds/ cc	2.03	1.25 - 3.42	2.04	1.33 - 3.25	0.49
Total activity U(Gym^2/hr)	32.67	19.42 - 62.89	32.69	18.42 - 65.53	0.06

The mean values for all of the parameters for real-time implant and pre-plan implant are in good agreement, as the deviation is below ± 1% (Table 4.7). This indicates that the pre-plan should be done so as to speed up the implant procedure in the theatre and thereby increase the accuracy and maintain the good dose coverage.

CHAPTER FIVE.

CONCLUSIONS AND RECOMMENDATIONS

In this study, comparative studies on permanent prostate brachytherapy: pre-plan and real-time Transrectal ultrasound guided iodine-125 seed implants were carried out. The results obtained were compared with some international guidelines and published works.

5.1 Conclusions

The study sample in this research was 31 out of 83 patients who were treated under brachytherapy between August, 2008 and April, 2013. The selection of 31 patients was based on available ultrasound images. Despite the small sample available for the study, it was possible to compare the dosimetric parameters reported at KBTH with the international guideline and values reported from other centres. The results reported at KBTH were in good agreement with other centres from different hospitals. Comparisons were made between the real-time implant and pre-plan implant prostate brachytherapy. The total of 31 patients were pre-planned using prowess 4.5 panther software and the variation of dosimetric parameters were within the acceptable error of ±5%. For contoured volume the variation was 3.19% which is within the limit. The number of seeds varied by 4.07% .The number of needles were alternating. However the differences ranged between one to two needles only. These results showed that since the differences are within the limits, then it is adviseable to start doing pre-plan implant procedures so as to speed up the process during real time implant.

5.2 Recommendations

From the results of pre-plan implant and real-time plan there is slight variation in prostate volumes for some patients. These were caused possibly by drawing

manually the prostate, urethra and rectum volumes during pre-plan. It is recommended that the patient should bring either CT or MRI images in future to be used for pre -plan implant so that results in the volume contoured will be compared with that of ultrasound images used currently. For CT / MRI images the process of digitizing the image will increase the accuracy in the size of the contoured and registered volumes. According to American Brachytherapy Society (ABS) every patient should undergo CT -post implant. This is necessary to outline the prostate plus critical organs and seed position in the prostate.

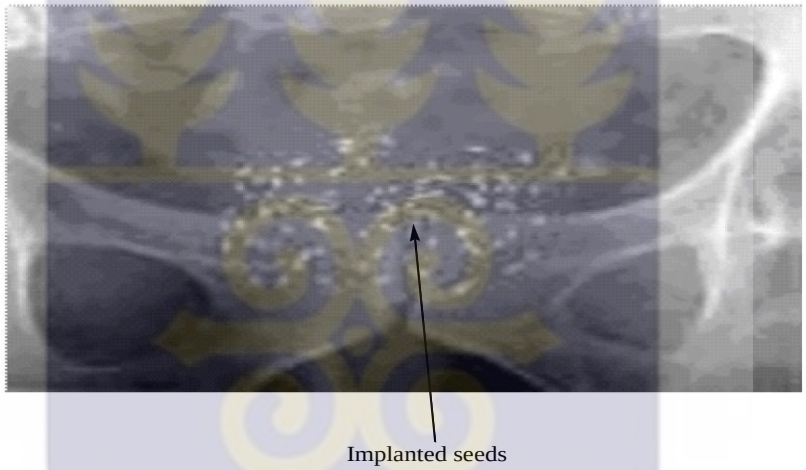

Plate 5.1: CT image after I-125 seeds implant, this is done four weeks after the procedure.

It is also recommended that more observation time should be spent (at least ten years) Kollmeier et al, (2005) for correct reporting of morbidity since prostate cancer is a relatively slow growing disease. Comparison of clinical data is very difficult at present. A uniform method of defining the target and organ at risk, to decide which dosimetric parameters should be given is needed. A necessary prerequisite is a uniform method of keeping patient data records.

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APPENDIX A

Patient information obtained after real-time (online ultrasound guided) implant using variseed software 7.2 at KBTH.

Patient ID	Age	Year of treatment	Country	Prostate volume (cc)	Prescribed dose(Gy)	No. of needles	No. of seeds (sources)	Source Activity (U) AirKerma
P1	47	2009	Ghana	20.61	160	15	44	0.584
P2	65	2010	Ghana	21.43	160	20	45	0.599
P3	70	2011	Nigeria	46.61	160	18	70	0.729
P4	72	2010	Ghana	44.64	160	20	71	0.636
P5	58	2012	Ghana	13.91	160	16	45	0.498
P6	58	2012	Togo	46.46	160	19	74	0.636
P7	61	2011	Ghana	27.07	110	15	49	0.509
P8	58	2011	Nigeria	25.01	160	17	40	0.582
P9	61	2010	Ghana	22.91	160	20	51	0.584
P10	65	2010	Ghana	11.40	160	13	39	0.498
P11	57	2012	Ghana	37.48	160	18	59	0.681
P12	60	2010	Nigeria	26.93	160	17	54	0.575
P13	69	2010	DRC	14.53	160	14	41	0.583

P14	56	2009	Ghana	32.55	160	20	60	0.635
P15	68	2010	Ghana	47.75	160	18	75	0.636
P16	70	2008	Ghana	75.82	160	22	95	0.662
P17	68	2010	Togo	24.22	110	15	46	0.452
P18	57	2011	Benin	25.17	110	17	55	0.455
P19	63	2011	Nigeria	24.78	110	18	49	0.455
P20	66	2009	Ghana	32.52	160	20	62	0.69
P21	59	2009	Burkina Faso	26.33	160	20	49	0.582
P22	65	2009	Ghana	49.55	160	19	72	0.685
P23	66	2010	Ghana	38.75	110	16	67	0.635
P24	51	2012	Burkina Faso	18.81	110	13	51	0.395
P25	49	2008	Ghana	21.36	160	15	46	0.62
P26	51	2011	Burkina Faso	24.94	110	17	52	0.448
P27	70	2009	Benin	25.54	160	20	62	0.575
P28	71	2013	Ghana	14.83	160	10	38	0.575
P29	64	2013	Ghana	26.67	160	17	57	0.575
P30	71	2013	Ghana	28.68	160	14	55	0.634
P31	67	2013	Ghana	16.27	110	16	42	0.458

APPENDIX B

Patients information obtained during pre-plan using prowess 4.5 panther at KBTH.

Patient ID	Age	Year of treatment	Prostate volume (cc)	Prescribed dose(Gy)	No. of needles	No. of seeds (sources)	Source Activity (U) AirKerma
P1	47	2009	21.58	160	17	46	0.584
P2	65	2010	20.50	160	18	43	0.599
P3	70	2011	45.06	160	18	67	0.729
P4	72	2010	44.97	160	21	68	0.636
P5	58	2012	14.47	160	18	39	0.498
P6	58	2012	47.03	160	19	77	0.636
P7	61	2011	28.11	110	17	51	0.509
P8	58	2011	24.40	160	18	38	0.582
P9	61	2010	23.64	160	19	53	0.584
P10	65	2010	11.61	160	14	37	0.498
P11	57	2012	37.99	160	17	61	0.681
P12	60	2010	25.79	160	16	52	0.575

P13	69	2010	15.01	160	15	40	0.583
P14	56	2009	31.73	160	19	58	0.635
P15	68	2010	49.02	160	17	72	0.636
P16	70	2008	74.06	160	22	99	0.662
P17	68	2010	23.16	110	16	48	0.452
P18	57	2011	25.99	110	18	53	0.455
P19	63	2011	23.61	110	17	47	0.455
P20	66	2009	33.59	160	18	64	0.69
P21	59	2009	25.47	160	19	52	0.582
P22	65	2009	51.61	160	19	73	0.685
P23	66	2010	36.98	110	16	64	0.635
P24	51	2012	19.02	110	16	49	0.395
P25	49	2008	20.47	160	14	44	0.62
P26	51	2011	25.87	110	18	54	0.448
P27	70	2009	26.68	160	19	59	0.575
P28	71	2013	15.36	160	12	40	0.575
P29	64	2013	28.01	160	17	55	0.575
P30	71	2013	27.17	160	15	57	0.634
P31	67	2013	15.80	110	17	40	0.458

APPENDIX C

Comparison of patients Prostate volume between real- time implant and pre-plan implant.

P. ID	Age	Year	P. dose(Gy)	Source Activity (U) AirKerma	P. volume (cc)Pre-plan	P. volume (cc)-Real time	Difference (%)
P1	47	2009	160	0.584	21.58	20.61	4.70
P2	65	2010	160	0.599	20.50	21.43	-4.34
P3	70	2011	160	0.729	45.06	46.61	3.32
P4	72	2010	160	0.636	44.97	44.64	-0.81
P5	58	2012	160	0.498	14.47	13.91	-4.02
P6	58	2012	160	0.636	47.03	46.46	-1.23
P7	61	2011	110	0.509	28.11	27.07	-3.84
P8	58	2011	160	0.582	24.40	25.01	-2.43
P9	61	2010	160	0.584	23.64	22.91	-3.19
P10	65	2010	160	0.498	11.61	11.40	-1.84
P11	57	2012	160	0.681	37.99	37.48	-1.36
P12	60	2010	160	0.575	25.79	26.93	4.23
P13	69	2010	160	0.583	15.01	14.53	-3.30
P14	56	2009	160	0.635	31.73	32.55	2.52
P15	68	2010	160	0.636	49.02	47.75	-2.69
P16	70	2008	160	0.662	74.06	75.82	2.32

P17	68	2010	110	0.452	23.16	24.22	4.38
P18	57	2011	110	0.455	25.99	25.17	-0.82
P19	63	2011	110	0.455	23.61	24.78	4.72
P20	66	2009	160	0.69	33.59	32.52	1.17
P21	59	2009	160	0.582	25.47	26.33	3.27
P22	65	2009	160	0.685	51.61	49.55	-4.16
P23	66	2010	110	0.635	36.98	38.75	4.57
P24	51	2012	110	0.395	19.02	18.81	-1.12
P25	49	2008	160	0.62	20.47	21.36	4.17
P26	51	2011	110	0.448	25.87	24.94	-3.73
P27	70	2009	160	0.575	26.68	25.54	-4.46
P28	71	2013	160	0.575	15.36	14.83	-3.58
P29	64	2013	160	0.575	28.01	26.67	-5.01
P30	71	2013	160	0.634	27.17	28.68	4.98
P31	67	2013	110	0.458	15.80	16.27	-2.88
						AVERAGE	3.19

P: patient

ID: Identification

APPENDIX D

Comparison of number of needles between the real-time implant and pre-plan implant.

P. ID	Age	Year	Prescribed dose(Gy)	Source Activity (U) AirKerma	Number of needles Real—time	Number of needles Pre-plan	Difference in number of needles
P1	47	2009	160	0.584	17	16	1
P2	65	2010	160	0.599	20	18	-2
P3	70	2011	160	0.729	18	18	0
P4	72	2010	160	0.636	20	21	1
P5	58	2012	160	0.498	16	18	2
P6	58	2012	160	0.636	19	19	0
P7	61	2011	110	0.509	15	17	2
P8	58	2011	160	0.582	17	18	1
P9	61	2010	160	0.584	20	19	-1
P10	65	2010	160	0.498	14	14	0
P11	57	2012	160	0.681	18	17	-1
P12	60	2010	160	0.575	17	16	-1
P13	69	2010	160	0.583	15	15	0
P14	56	2009	160	0.635	20	19	-1
P15	68	2010	160	0.636	18	17	-1

P16	70	2008	160	0.662	22	20	-2
P17	68	2010	110	0.452	15	16	1
P18	57	2011	110	0.455	17	18	1
P19	63	2011	110	0.455	18	17	-1
P20	66	2009	160	0.69	20	18	-2
P21	59	2009	160	0.582	20	19	-1
P22	65	2009	160	0.685	19	19	0
P23	66	2010	110	0.635	16	16	0
P24	51	2012	110	0.395	15	16	1
P25	49	2008	160	0.62	15	14	-1
P26	51	2011	110	0.448	17	18	1
P27	70	2009	160	0.575	20	19	-1
P28	71	2013	160	0.575	10	12	2
P29	64	2013	160	0.575	17	17	0
P30	71	2013	160	0.634	14	15	1
P31	67	2013	110	0.458	16	17	1

P: Patient

APPENDIX E

Comparison of number of seeds between the real-time implant and pre-plan implant.

P. ID	Age	Year	Prescribed dose (Gy)	Source Activity (U) AirKerma	Number of seeds Real-time	Number of seeds Pre-plan	Difference (%)
P1	47	2009	160	0.584	44	46	-4.54
P2	65	2010	160	0.599	45	43	-4.44
P3	70	2011	160	0.729	70	67	4.28
P4	72	2010	160	0.636	71	68	4.23
P5	58	2012	160	0.498	45	47	4.44
P6	58	2012	160	0.636	74	77	4.05
P7	61	2011	110	0.509	49	51	4.08
P8	58	2011	160	0.582	40	38	5.00
P9	61	2010	160	0.584	51	53	3.92
P10	65	2010	160	0.498	39	37	5.12
P11	57	2012	160	0.681	59	57	3.39
P12	60	2010	160	0.575	54	52	3.70
P13	69	2010	160	0.583	41	40	2.44
P14	56	2009	160	0.635	60	63	5.0
P15	68	2010	160	0.636	75	72	4.0
P16	70	2008	160	0.662	95	99	4.21

P17	68	2010	110	0.452	46	48	4.35
P18	57	2011	110	0.455	55	53	3.63
P19	63	2011	110	0.455	49	47	4.08
P20	66	2009	160	0.69	62	64	3.22
P21	59	2009	160	0.582	49	47	4.08
P22	65	2009	160	0.685	72	73	1.39
P23	66	2010	110	0.635	67	64	4.48
P24	51	2012	110	0.395	51	49	3.92
P25	49	2008	160	0.62	46	44	4.35
P26	51	2011	110	0.448	52	54	3.84
P27	70	2009	160	0.575	62	59	4.84
P28	71	2013	160	0.575	38	40	5.26
P29	64	2013	160	0.575	57	55	3.51
P30	71	2013	160	0.634	55	57	3.64
P31	67	2013	110	0.458	42	40	4.76
						Average	4.07

P: Patient

APPENDIX F

International Prostate Symptoms Score- IPSS

International Prostate Symptom Score (I-PSS)

Patient Name: _____ **Date of birth:** _____ **Date completed** _____

In the past month:	Not at All	Less than 1 in 5 Times	Less than Half the Time	About Half the Time	More than Half the Time	Almost Always	Your score
1. Incomplete Emptying How often have you had the sensation of not emptying your bladder?	0	1	2	3	4	5	
2. Frequency How often have you had to urinate less than every two hours?	0	1	2	3	4	5	
3. Intermittency How often have you found you stopped and started again several times when you urinated?	0	1	2	3	4	5	
4. Urgency How often have you found it difficult to postpone urination?	0	1	2	3	4	5	
5. Weak Stream How often have you had a weak urinary stream?	0	1	2	3	4	5	
6. Straining How often have you had to strain to start urination?	0	1	2	3	4	5	
	None	**1 Time**	**2 Times**	**3 Times**	**4 Times**	**5 Times**	
7. Nocturia How many times did you typically get up at night to urinate?	0	1	2	3	4	5	
Total I-PSS Score							

Score: 1-7: *Mild* 8-19: *Moderate* 20-35: *Severe*

Quality of Life Due to Urinary Symptoms	Delighted	Pleased	Mostly Satisfied	Mixed	Mostly Dissatisfied	Unhappy	Terrible
If you were to spend the rest of your life with your urinary condition just the way it is now, how would you feel about that?	**0**	**1**	**2**	**3**	**4**	**5**	**6**

About the I-PSS

The International Prostate Symptom Score (I-PSS) is based on the answers to seven questions concerning urinary symptoms and one question concerning quality of life. Each question concerning urinary symptoms allows the patient to choose one out of six answers indicating increasing severity of the particular symptom. The answers are assigned points from 0 to 5. The total score can therefore range from 0 to 35 (asymptomatic to very symptomatic).

The questions refer to the following urinary symptoms:

Questions	Symptom
1	Incomplete emptying
2	Frequency
3	Intermittency
4	Urgency
5	Weak Stream
6	Straining
7	Nocturia

Question eight refers to the patient's perceived quality of life.

The first seven questions of the I-PSS are identical to the questions appearing on the American Urological Association (AUA) Symptom Index which currently categorizes symptoms as follows:

Mild (symptom score less than of equal to 7)
Moderate (symptom score range 8-19)
Severe (symptom score range 20-35)

The International Scientific Committee (SCI), under the patronage of the World Health Organization (WHO) and the International Union Against Cancer (UICC), recommends the use of only a single question to assess the quality of life. The answers to this question range from "delighted" to "terrible" or 0 to 6. Although this single question may or may not capture the global impact of benign prostatic hyperplasia (BPH) Symptoms or quality of life, it may serve as a valuable starting point for a doctor-patient conversation.

The SCI has agreed to use the symptom index for BPH, which has been developed by the AUA Measurement Committee, as the official worldwide symptoms assessment tool for patients suffering from prostatism.

The SCI recommends that physicians consider the following components for a basic diagnostic workup: history; physical exam; appropriate labs, such as U/A, creatine, etc.; and DRE or other evaluation to rule out prostate cancer.

APPENDIX G

THE VOLUME STUDY LETTER

Korle-Bu Teaching Hospital, P.O.Box 77, Accra -Ghana

Dear Mr. _____:

Your volume study is scheduled for _____ at _____AM/PM.

This procedure measures the size of your prostate to determine the number of seeds needed for your brachytherapy (seed implant). In addition, the volume study is done to make sure your anatomy is suitable for brachytherapy. Please report to Radiation Oncology on first floor of the Urology department, Korle -bu teaching hospital.

Early on the day of your appointment, use two **Fleet's enemas** as directed on the bottle. These can be purchased at any pharmacy. If you have a long travel time, it may be best to use the enemas the night before the procedure.

Do not eat any solid food after midnight prior to your procedure. You may drink clear liquids and take your usual morning medicines on the day of the procedure.

Please **bring a driver** with you for this appointment, as you will be taking a medication to relax you, making it unsafe for you to drive home. Take Ativan 0.5mg tabs 1-2 at 30 minutes prior to volume study (prescription is enclosed in this packet).

When you arrive in Radiation Oncology building, inform the receptionist at the desk near the elevator that you are here for a prostate volume study. A staff member will greet you and bring you to an exam room, where you will change into a gown. To visualize your urethra on ultrasound, a urinary catheter is placed into your bladder.

You will then be escorted to the volume study suite. To perform the volume study, you will lie on your back with your legs in stirrups. An ultrasonic probe is inserted into the rectum to visualize the prostate gland.

Once all pictures and measurements are completed, the urinary catheter and rectal probe are removed. The procedure takes about 35-45 minutes.

After the volume study, you may experience some burning and blood-tinged urine related to the urinary catheter placement but this resolves in 24 hours.

You will be asked to void (pass your urine) before you go home.

If you have any questions, please call 00233244271843 between 8 AM and 4:30PM and ask for Ahsante or J .E Mensah.

APPENDIX H: Dose limits for some critical organs

Quantitative Analyses of Normal Tissue Effects in the Clinic (QUANTEC)

Critical structure	Volume	Dose per volume	Max. dose	Toxicity Rate	Toxicity end point
Rectum	V50	< 50%		< 10%	Grade 3 + toxicity
Rectum	V60	<35%		<10%	Grade 3+ toxicity
Rectum	V65	<25%		<10%	Grade 3+ toxicity
Rectum	V70	<20%		<10%	Grade 3+ toxicity
Rectum	V75	<15%		<10%	Grade 3+ toxicity
Bladder (bladder cancer)			<65	<6%	Grade 3+ toxicity
Bladder (prostate cancer)	V65	<50%			Grade 3+ toxicity
Bladder (prostate cancer)	V70	<35%			Grade 3+ toxicity
Bladder (prostate cancer)	V75	<25%			Grade 3+ toxicity
Bladder (prostate cancer)	V80	<15%			Grade 3+ toxicity
Penile bulb	Mean dose to 95% gland	<50 Gy		<35%	Severe erectile dysfunction
Penile bulb	D90	<50 Gy		<35%	Severe erectile dysfunction
Penile bulb	D60-70	<70 Gy		<55%	Severe erectile dysfunction

Marks LB, (2010) Int J Radiat Oncol Biol Phys,76(3 Suppl):S10-9.)

APPENDIX I

Real-time: The median values for Prostate volume, Number of needles, Number of seeds, Source activity, Total activity, Seeds per volume.

P. ID	Age (yrs)	Volume (cc)	Number of needles	Number of seeds	Seeds per volume	Activity (U) Gym^2/hr	Total activity-Air kerma (U-Gym^2/hr)
P1	47	20.61	15	44	2.134886	0.584	25.696
P2	65	21.43	20	45	2.142857	0.599	33.544
P3	70	46.61	18	70	1.501824	0.729	51.03
P4	72	44.64	20	71	1.590502	0.636	45.156
P5	58	13.91	16	45	3.235083	0.498	22.41
P6	58	46.46	19	74	1.592768	0.636	47.064
P7	61	27.07	15	49	1.810122	0.509	24.941
P8	58	25.01	17	40	1.599360	0.582	25.026
P9	61	22.91	20	51	2.226102	0.584	29.784
P10	65	11.4	13	39	3.421053	0.498	19.422
P11	57	37.48	18	59	1.574173	0.681	40.179
P12	60	26.93	17	54	2.005199	0.575	31.05
P13	69	14.53	14	41	2.821748	0.583	23.903
P14	56	32.55	20	60	1.843318	0.635	38.1
P15	68	47.75	18	75	1.570681	0.636	47.7
P16	70	75.82	13	95	1.252968	0.662	62.89
P17	68	24.22	15	46	1.899257	0.452	20.792
P18	57	25.17	17	55	2.185141	0.455	25.025

P19	63	24.78	18	49	1.977401	0.455	22.295
P20	66	32.52	20	62	1.906519	0.69	42.78
P21	59	26.33	20	49	1.860995	0.582	28.518
P22	65	49.55	19	72	1.453078	0.685	49.32
P23	66	38.75	16	67	1.729032	0.635	42.545
P24	51	18.81	13	51	2.711324	0.395	20.145
P25	49	21.36	15	46	2.153558	0.62	28.52
P26	51	24.94	17	52	2.085004	0.448	23.296
P27	70	25.54	20	62	2.427565	0.575	35.65
P28	71	14.83	10	38	2.562374	0.575	21.85
P29	64	26.67	17	57	2.137233	0.575	32.775
P30	71	28.68	14	55	1.917713	0.634	34.87
P31	67	16.27	16	42	2.5814382	0.458	20.61
Median	64	25.54	17	52	1.977401	0.583	29.784

P: patients

APPENDIX J

Pre-plan : The median values for Prostate volume, Number of needles, Number of seeds, Source activity, Total activity, Seeds per volume .

P. ID	Age (yrs)	Volume (cc)	Number of needles	Number of seeds	Seeds per volume	Activity (U) Gym^2/hr	Total activity-Air kerma (U-Gym^2/hr)
P1	47	21.58	17	46	2.131603	0.584	26.864
P2	65	20.50	18	43	2.0975609	0.599	32.346
P3	70	45.06	18	67	1.486906	0.729	48.843
P4	72	44.97	21	68	1.512119	0.636	43.248
P5	58	14.47	15	47	3.2481	0.498	23.406
P6	58	47.03	20	77	1.637253	0.636	48.972
P7	61	28.11	16	51	1.814301	0.509	25.959
P8	58	24.40	18	38	1.557377	0.582	23.862
P9	61	23.64	19	53	2.241963	0.584	30.952
P10	65	11.61	14	37	3.186908	0.498	18.426
P11	57	37.99	17	57	1.500395	0.681	38.817
P12	60	25.79	16	52	2.016285	0.575	29.9
P13	69	15.01	15	40	2.66489	0.583	23.32
P14	56	31.73	19	63	1.985503	0.635	40.005
P15	68	49.02	17	72	1.468788	0.636	45.792
P16	70	74.06	14	99	1.336754	0.662	65.538

P17	68	23.16	14	48	2.072539	0.452	21.696
P18	57	25.99	18	53	2.039246	0.455	24.115
P19	63	23.61	17	47	1.990682	0.455	21.385
P20	66	33.59	19	64	1.905329	0.69	44.16
P21	59	25.47	19	47	1.845308	0.582	27.354
P22	65	51.61	20	73	1.414455	0.685	50.005
P23	66	36.98	17	64	1.730665	0.635	40.64
P24	51	19.02	14	49	2.576236	0.395	19.355
P25	49	20.47	14	44	2.149487	0.62	27.28
P26	51	25.87	18	54	2.08736	0.448	24.192
P27	70	26.68	19	59	2.211394	0.575	33.925
P28	71	15.36	10	40	2.604167	0.575	23
P29	64	28.01	18	55	1.963584	0.575	31.625
P30	71	27.17	14	57	2.097902	0.634	36.138
P31	67	15.80	17	40	2.531645	0.458	21.526
Median	64	25.87	17	53	2.01	0.583	29.9

APPENDIX K

Real-time: The median for dosimetric parameters

	Prostate					Urethra					Rectum		
P. Id	V100%	V150%	D90Gy	D90%		D90Gy	D90%	D30Gy	D30%		D30Gy	D30%	V100%
P1	98.6	56.81	172.5	138.74		155.45	121.81	245.94	127.99		115.32	72.02	0.41
P2	91.95	62.91	168.01	113.88		114.22	67.64	206.64	121.89		84.11	52.57	0.07
P3	97.11	66.5	192.85	112.33		141.36	80.65	134.48	123.61		94.97	86.34	0.82
P4	95.13	56.18	184.36	113.18		133.22	67.92	203.83	127.96		124.5	77.82	0.71
P5	95.6	63.23	181.59	102.11		141.44	87.29	210.77	128.62		98.49	61.56	0.25
P6	95.68	57.25	184.89	105.14		125.98	87.89	143.02	116.52		71.13	64.66	0.45
P7	98.91	61.01	183.72	111.84		130.42	78.27	135.31	129		101.45	92.23	0.5
P8	96.18	66.79	190.09	110.45		93.91	82.87	207.96	128.37		80.6	50.37	0.6
P9	96.12	55.13	187.98	109.29		131.17	70.69	205.56	129.4		131.67	82.29	0.35
P10	96.12	68.1	164.9	113.15		130.21	66.92	190.58	132.86		81.39	52.3	0.15
P11	96.16	57.48	165.62	121.42		134.88	62.57	220.85	122.09		103.61	64.88	0.25
P12	95.6	56.91	181.05	119.04		100.1	84.3	195.34	138.03		113.48	70.93	0
P13	99.6	60.3	174.86	117.49		107.07	81.38	212.58	119.11		120.85	75.53	0.11
P14	94.08	59.62	176.72	118.81		113.11	81.98	207.05	128.47		105.68	66.05	0.11
P15	96.36	66.49	123.02	114.82		132.6	58.69	205.39	129.97		92.01	80.23	0.15
P16	92.21	64.32	115.65	115.55		86.1	81.51	206.41	123.01		82.34	85.45	0.25
P17	90.92	56.03	163.38	113.49		96.68	67.16	186.44	130.02		112.32	70.24	0.86
P18	95.67	69.75	181.09	115.23		139.67	88.4	205.79	131.73		75.42	47.14	0.1
P19	95.83	72.98	123.56	120.53		108.67	83.26	204.73	127.39		77.14	85.25	1.01
P20	96.05	68.85	169.7	105		88.71	88.35	197.78	122.25		96.8	113.18	0.45
P21	99.77	55.11	221.98	123.1		108.23	71.39	195.03	129.15		66.5	41.56	0.43
P22	94.45	67.73	185.84	116.15		194.9	97.15	204.79	153.71		75.79	94.25	1.01
P23	95.73	68.72	178.885	114.35		128.09	81.45	205.09	128.42		76.19	99.06	0.38
P24	98.67	56.72	167.4	167.4		108.92	67.26	139.48	122.41		73.37	66.7	0.53
P25	96.02	63.14	173.4	190.12		134.76	86.92	195.97	118.72		113.58	70.97	0.46

P26	95.08	55.07	181.79	181.79		98.63	88.96	144.19	114.96		98.01	89.21	0.27
P27	98.7	61.23	124.52	124.52		141.09	72.63	202.83	137.71		76.82	95.8	0.57
P28	97.61	56.12	187.8	117.32		167.16	104.48	204.99	128.12		89.6	81.29	O.74
P29	98	60.21	190.17	118.85		171.7	107.31	207.94	129.96		87.91	101.39	0.32
P30	93.41	58.24	174.9	109.31		133.11	83.19	182.61	114.13		109.2	93.86	0.02
P31	97.13	61.64	128.6	116.91		114.25	103.87	140.48	127.71		72.82	71.33	0.81
Median	96.05	61.01	176.72	115.55		130.21	121.81	204.73	153.71		92.01	75.53	0.395

- **P: patient**
- **Median were computed by using Excel programme**

APPENDIX L

Pre-plan : The median for dosimetric parameters

	Prostate						Urethra					Rectum		
P. Id	V95%	V100%	V150%	D90Gy	D90%		D90Gy	D90%	D30Gy	D30%		D30Gy	D30%	V100%
P1	97.9	96.5	59.1	179	111.9		131.17	82	207.11	129.8		108.56	68.5	0.4
P2	97.4	96	63.1	176.95	110.6		143.13	89.5	206.77	129.2		124.34	77.7	0.9
P3	97	95.5	61.6	175.46	109.7		142.86	89.3	207.98	130		107.09	66.9	0.4
P4	96.9	95.5	63.3	180	112.5		128.35	80.2	208.56	130.2		96.58	60.4	0.4
P5	99.1	98.3	63	196.19	122.6		117.12	73.2	204.36	127.7		71.84	65.3	0.3
P6	97	95.9	60.1	122.17	106.01		88.77	80.7	141.24	128.4		112.27	70.2	0.8
P7	97.6	95.8	58.2	179.6	112.4		122.01	76.3	208.32	130.2		108.69	66.9	0.9
P8	96.6	95.1	61.7	175.96	110		110.94	69.3	190.12	118.8		97.13	60.7	0.3
P9	98.3	95.5	59.9	175.44	109.7		152.82	95.5	208.15	130.1		109.04	68.1	0.4
P10	96.8	95.9	58.2	170.47	106.5		156.39	97.7	208.1	130.1		118.5	74	0.5
P11	95.8	97.1	55.2	167.39	104.6		141.85	88.7	204.81	128		101.17	63.2	0.6
P12	96.2	94.7	60.8	176.43	110.3		135.15	84.5	186.62	116.6		80.53	73.2	0.8
P13	98.9	96.6	60.5	125.85	114.4		100.9	91.7	139.67	127		108.13	67.6	0.9
P14	97	97.9	60.5	174.89	109.3		146.86	91.8	198.41	124		109.51	68.4	0.2
P15	97.2	96.1	67.1	186.76	116.7		102.09	63.8	196.81	123		90.73	56.7	0.6
P16	97.6	95.2	55	177.19	110.7		115.7	68.9	209.12	129.08		124.58	77.9	0.3
P17	96.9	94.6	64.3	179.17	112		137.24	85.5	207.45	129.7		76.68	69.7	0.4
P18	96.5	96.9	59.9	186.11	116.3		90.86	82.6	143.25	130.2		108.66	67.9	0.3
P19	97.9	97.4	65.3	177.35	110.8		106.08	66.3	205.47	128.4		119.85	74.9	0.4
P20	98.6	94.9	67.8	189.7	121.4		123.12	77	208.17	130.1		100.69	76.8	0.5
P21	96.7	98.3	55.2	120.55	109.6		146.06	92.3	208.07	128.91		121.46	75.6	0.7
P22	99.5	96.4	61.9	179.17	112.2		151.11	94.4	207.56	129.7		86.72	69.56	0.7
P23	98.3	96.7	62.3	170.63	112.01		138.19	89.19	207.19	119.98		106.91	62.9	0.3
P24	97.6	97.3	56.7	178.19	108.09		153.8	95.7	205.82	128.6		97.24	76.41	0.4

P25	96.9	95.9	55.7	125.96	106.09		112.96	78.43	199.13	129.71		116.12	69.54	0.3
P26	97.2	98.3	58.4	187.12	102.9		109.92	92.72	205.35	120.76		108.86	68	0.5
P27	98.4	95.9	58.7	179.05	113.01		137.64	86	200.09	125.1		119.01	76.03	0.7
P28	96.6	98.3	60	177.54	112		115.69	72.3	209.11	130.7		98.65	61.7	0.9
P29	97.3	95.3	68	129.55	117.8		83.7	76.3	149.35	135.8		69.73	63.4	0.4
P30	98.32	97.4	62.1	181.92	108.1		135.92	85	204.21	127.6		98.76	75.91	0.8
P31	96.78	96.73	57.9	179.42	104.92		79.04	71.9	143.87	130.8		109.27	69.81	0.6
Median	97.17	97.12	59.73	177.35	110.7		128.35	84.5	205.47	135.8		89.76	68.5	0.3

- **P: Patient**
- **Median were computed by using Excel programme**

APENDIX M

Brachytherapy seeds ordered after volume study and seeds implanted (Bard sheet record-KBTH-2013)

P.Id	Estimated volume	Estimated number of seeds	Actual volume	Seeds implanted	Remark (Seeds-remained)
P1	23	59	20.61	44	15
P2	25	60	21.43	45	15
P3	47	85	46.61	70	15
P4	46	85	44.64	71	14
P5	15	60	13.91	45	15
P6	50	95	46.46	74	21
P7	30	60	27.07	49	11
P8	29	60	25.01	40	20
P9	26	70	22.91	51	19
P10	15	55	11.40	39	16
P11	41	75	37.48	59	16
P12	29	70	26.93	54	16
P13	15	55	14.53	41	14
P14	35	75	32.55	60	15
P15	51	75	47.75	75	0.0
P16	79	120	75.82	95	25
P17	28	60	24.22	46	14
P18	28	70	25.17	55	15
P19	29	60	24.78	49	11
P20	35	75	32.52	62	13
P21	30	60	26.33	49	11
P22	50	85	49.55	72	13
P23	41	85	38.75	67	18
P24	23	65	18.81	51	14
P25	25	60	21.36	46	14
P26	29	70	24.94	52	18
P27	30	75	25.54	62	13
P28	19	50	14.83	38	12
P29	29	75	26.67	57	18
P30	32	65	28.68	55	10
P31	19	45	16.27	42	03

P: patient , Id: Identification

APPENDIX N

The range of prostate volume (cc) and the source activity as guided by the manufacturer (BARD COMPANY)

BARD BRACHYTHERAPY

Your Total Resource

Seed Activity for I - 125

PROSTATE VOLUME	SEED STRENGTH mCi	COMBINATION THERAPY
< 20	0.393	0.305
20 – 40	0.46	0.36
40 – 50	0.498	0.393
50 – 60	0.543	0.46
60 – 80	0.585	0.498
80 +	0.638	0.543

VariSeed 7.1 ProSeed Nomogram Tables DOC VS 7.1 PSNomo 071604

ProSeed I-125 (STM 1251) [NIST 99]

Prostate Volume (cc)	Total Activity mCi	Prostate Volume (cc)	Total Activity mCi
7	13.60	54	46.2
8	14.20	56	47.5
9	14.80	58	48.7
10	15.30	60	49.9
12	16.30	62	51.2
14	17.20	64	52.4
16	19.00	66	53.6
18	20.70	68	54.7
20	22.30	70	55.9
22	24.00	72	57.1
24	25.50	74	58.3
26	27.00	76	59.5
28	28.60	78	60.7
30	30.00	80	61.9
32	31.50	82	63.0
34	32.90	84	64.2
36	34.30	86	65.4
38	35.80	88	66.6
40	37.10	90	67.8
42	38.40	92	69.0
44	39.80	94	70.2
46	41.10	96	71.4
48	42.30	98	72.6
50	43.60	100	73.8
52	44.90		

For further information please contact either:
Griet van Gorp or Marijke Lammens by email: brachytherapy@crbard.com
Telephone: 003214285916

BBI Nomogram

APPENDIX O

Clinical information(Criteria for prostate brachytherapy) for 83 prostate cancer patients treated under real-time brachytherapy between 2008 to April, 2013 KBTH - Ghana.

P.Id	Year	Age (Yrs)	DRE	Gleason Score	Stage (TNM)	Volume (cc)	PSA ng/Ml	Bone scan	IPSS
P1	2008	47	Normal	3+4=7	T2a	20.61	16.34	Negative	11
P2	2008	65	Normal	3+3=6	T2a	25.02	8.41	Negative	10
P3	2011	70	Normal	3+4=7	T2a	46.61	10.91	Negative	11
P4	2012	72	Normal	4+4=8	T2b	44.64	12.00	Negative	7
P5	2008	58	Normal	3+3=6	T1	13.91	6.11	Negative	10
P6	2012	58	Normal	3+4=7	T2	46.46	7.92	Negative	12
P7	2012	61	Normal	3+4=7	T3	27.07	13.31	Negative	6
P8	2012	58	Normal	3+3=6	T2a	16.75	8.91	Negative	8
P9	2008	61	Normal	3+3=6	T2a	22.91	23.01	Negative	-
P10	2008	65	Normal	3+4=7	T2	11.40	8.62	Negative	-
P11	2008	57	Normal	3+2=5	T2	37.48	5.93	Negative	-
P12	2009	60	Normal	3+3=6	T2a	26.93	11.19	Negative	7
P13	2009	69	Normal	3+2=5	T1	14.53	8.49	Negative	11
P14	2009	56	Normal	4+3=7	T1c	32.55	7.46	Negative	6
P15	2009	68	Normal	3+3=6	T2	47.75	14.57	Negative	8
P16	2009	70	Normal	3+3=6	T2	75.82	13.88	Negative	11
P17	2009	68	Normal	3+2=5	T2	24.22	10.82	Negative	12
P18	2009	57	Normal	3+3=6	T2	25.17	11.78	Negative	9
P19	2009	63	Normal	4+3=6	T2b	24.78	29.01	Negative	-
P20	2009	66	Normal	3+4=7	T1c	32.52	6.71	Negative	-

P21	2009	59	Normal	3+4=7	T2	26.33	2.07	Negative	-
P22	2009	65	Normal	3+3=6	T3	49.55	8.65	Negative	9
P23	2009	66	Normal	3+3=6	T3a	38.75	29.01	Negative	10
P24	2009	51	Normal	4+3=7	T2a	18.81	6.83	Negative	7
P25	2009	49	Normal	2+3=5	T1c	21.36	16.31	Negative	8
P26	2009	51	Normal	3+4=7	T2	24.94	18.01	Negative	11
P27	2009	70	Normal	3+4=7	T2	25.54	6.02	Negative	12
P28	2009	71	Normal	3+3=6	T1	14.83	8.94	Negative	8
P29	2009	64	Normal	4+3=7	T3	26.67	7.96	Negative	9
P30	2009	71	Normal	3+4=7	T1a	28.68	17.03	Negative	7
P31	2010	67	Normal	3+3=6	T1b	25.55	12.09	Negative	11
P32	2010	57	Normal	4+3=7	T1c	17.28	15.09	Negative	10
P33	2010	63	Normal	3+3=6	T2	26.93	8.93	Negative	12
P34	2010	68	Normal	3+3=6	T2b	21.62	9.80	Negative	9
P35	2010	70	Normal	3+4=7	T2	20.59	8.92	Negative	10
P36	2010	62	Normal	3+3=6	T3	32.76	10.01	Negative	8
P37	2010	65	Normal	2+3=5	T3a	38.75	12.01	Negative	11
P38	2010	63	Normal	3+4=7	T2c	17.83	9.03	Negative	12
P39	2010	69	Normal	3+3=6	T1c	21.25	8.97	Negative	-
P40	2010	70	Normal	3+4=7	T2	18.79	12.01	Negative	-
P41	2010	59	Normal	2+3=5	T2b	22.41	10.92	Negative	-
P42	2010	67	Normal	4+3=7	T3	44.64	8.98	Negative	-
P43	2010	72	Normal	3+3=6	T2	47.15	14.09	Negative	9
P44	2010	64	Normal	3+3=6	T2b	14.53	11.02	Negative	8
P45	2010	68	Normal	3+4=7	T3	22.66	9.04	Negative	10
P46	2011	66	Normal	3+4=7	T2b	24.22	8.93	Negative	10
P47	2011	65	Normal	3+3=6	T1c	18.20	9.67	Negative	11
P48	2011	69	Normal	3+4=7	T2a	37.48	10.04	Negative	8
P49	2011	59	Normal	4+4=8	T2a	57.34	9.02	Negative	9

P50	2011	71	Normal	3+3=6	T2a	54.25	16.34	Negative	10
P51	2011	62	Normal	3+4=7	T2b	17.04	8.41	Negative	10
P52	2011	67	Normal	3+4=7	T1	24.94	10.91	Negative	11
P53	2011	70	Normal	3+3=6	T2	31.80	12.00	Negative	9
P54	2011	59	Normal	3+3=6	T3	20.73	6.11	Negative	-
P55	2011	57	Normal	3+4=7	T2a	11.40	7.92	Negative	-
P56	2011	68	Normal	3+2=5	T2a	13.51	13.31	Negative	-
P57	2011	64	Normal	3+3=6	T2	18.81	8.91	Negative	-
P58	2011	69	Normal	3+2=5	T2	27.07	23.01	Negative	-
P59	2011	62	Normal	4+3=7	T2a	16.75	8.62	Negative	-
P60	2011	65	Normal	3+3=6	T1	64.66	5.93	Negative	9
P61	2011	68	Normal	3+3=6	T1c	46.46	11.19	Negative	10
P62	2011	69	Normal	3+2=5	T2	30.05	8.49	Negative	7
P63	2012	68	Normal	3+3=6	T2	28.45	7.46	Negative	8
P64	2011	67	Normal	4+3=6	T2	21.96	14.57	Negative	11
P65	2011	58	Normal	3+4=7	T2	34.71	13.88	Negative	12
P66	2012	72	Normal	3+4=7	T2b	32.79	10.82	Negative	8
P67	2012	68	Normal	3+3=6	T1c	20.39	11.78	Negative	9
P68	2012	71	Normal	4+3=7	T2	17.12	29.01	Negative	7
P69	2012	68	Normal	3+2=5	T3	33.47	6.71	Negative	11
P70	2012	69	Normal	3+3=6	T3a	21.32	2.07	Negative	10
P71	2012	64	Normal	4+3=7	T2a	60.77	8.65	Negative	12
P72	2012	69	Normal	2+3=5	T1c	23.09	29.01	Negative	9
P73	2012	63	Normal	3+4=7	T2	36.56	6.83	Negative	10
P74	2012	64	Normal	3+4=7	T2	17.26	16.31	Negative	8
P75	2012	79	Normal	3+3=6	T1	17.18	18.01	Negative	11
P76	2012	67	Normal	4+3=7	T3	22.45	6.02	Negative	12
P77	2012	58	Normal	3+4=7	T2b	28.68	8.94	Negative	-
P78	2012	59	Normal	3+3=6	T1c	25.55	7.96	Negative	-

P79	2012	67	Normal	4+3=7	T2	23.91	17.03	Negative	12
P80	2013	69	Normal	3+3=6	T2	14.83	18.09	Negative	11
P81	2013	72	Normal	3+3=6	T3	26.67	11.09	Negative	10
P82	2013	69	Normal	3+4=7	T3	28.68	10.20	Negative	9
P83	2013	71	Normal	3+3=6	T3	25.55	9.83	Negative	11

APPENDIX P

Clinical information for 83 prostate cancer patients treated under real-time brachytherapy between 2008 to April, 2013.

P.Id	Year	Age	Volume (cc)	n. slices	Needles	Seeds	Dose (Gy)	Activity (U=mCi)	Total activity-U
P1	2008	47	20.61	5	15	44	160	0.584	25.696
P2	2008	65	21.43	7	20	45	160	0.599	33.544
P3	2011	70	46.61	7	18	70	160	0.729	51.03
P4	2012	72	44.64	8	20	71	160	0.636	45.156
P5	2008	58	13.91	6	16	45	160	0.498	22.41
P6	2012	58	46.46	7	19	74	160	0.636	47.064
P7	2012	61	27.07	7	15	49	110	0.509	24.941
P8	2012	58	25.01	7	17	40	160	0.582	25.026
P9	2008	61	22.91	7	20	51	160	0.584	29.784
P10	2008	65	11.40	8	13	39	160	0.498	19.422
P11	2008	57	37.48	7	18	59	160	0.681	40.179
P12	2009	60	26.93	7	17	54	160	0.575	31.05
P13	2009	69	14.53	7	14	41	160	0.583	23.903
P14	2009	56	32.55	8	20	60	160	0.635	38.1
P15	2009	68	47.75	8	18	75	160	0.636	47.7
P16	2009	70	75.82	9	22	95	160	0.662	62.89
P17	2009	68	24.22	14	15	46	110	0.452	20.792
P18	2009	57	25.17	10	17	55	110	0.455	25.025
P19	2009	63	24.78	8	18	49	110	0.455	22.295
P20	2009	66	32.52	11	20	62	160	0.69	42.78
P21	2009	59	26.33	7	20	49	160	0.582	28.518
P22	2009	65	49.55	10	19	72	160	0.685	49.32
P23	2009	66	38.75	8	16	67	110	0.635	42.545
P24	2009	51	18.81	10	13	51	110	0.395	20.145
P25	2009	49	21.36	11	15	46	160	0.62	28.52
P26	2009	51	24.94	9	17	52	110	0.448	23.296

P27	2009	70	25.54	7	20	62	160	0.575	35.65
P28	2009	71	14.83	10	10	38	160	0.575	21.85
P29	2009	64	26.67	8	17	57	160	0.575	32.775
P30	2009	71	28.68	6	14	55	160	0.634	34.87
P31	2010	67	16.27	9	16	42	110	0.458	20.61
P32	2010	57	17.28	5	14	35	110	0.497	17.395
P33	2010	63	26.93	6	17	63	160	0.575	36.225
P34	2010	68	21.62	7	18	66	160	0.453	29.898
P35	2010	70	20.59	6	16	46	160	0.582	26.772
P36	2010	62	32.76	7	16	65	160	0.636	41.34
P37	2010	65	38.75	8	16	54	110	0.635	34.29
P38	2010	63	17.83	6	14	48	160	0.575	27.6
P39	2010	69	21.25	6	18	48	110	0.491	23.568
P40	2010	70	18.79	7	13	41	110	0.503	20.623
P41	2010	59	22.41	5	20	66	160	0.584	38.544
P42	2010	67	44.64	8	20	84	160	0.636	53.424
P43	2010	72	47.15	9	18	75	160	0.636	47.7
P44	2010	64	14.53	5	14	41	160	0.583	23.903
P45	2010	68	22.66	6	13	42	110	0.622	26.124
P46	2011	66	24.22	7	15	46	110	0.452	20.792
P47	2011	65	18.20	6	12	45	160	0.578	26.01
P48	2011	69	37.48	6	18	55	160	0.687	37.785
P49	2011	59	57.34	8	20	97	160	0.682	66.154
P50	2011	71	54.25	8	20	91	160	0.681	61.971
P51	2011	62	17.04	4	16	54	160	0.491	26.514
P52	2011	67	24.94	6	12	52	110	0.448	23.296
P53	2011	70	31.80	6	18	72	160	0.584	42.048
P54	2011	59	20.73	6	15	48	160	0.636	30.528
P55	2011	57	11.40	5	13	39	160	0.498	19.422
P56	2011	68	13.51	5	16	45	160	0.498	22.41
P57	2011	64	18.81	6	13	51	110	0.395	20.145
P58	2011	69	27.07	6	15	47	110	0.501	23.547

P59	2011	62	16.75	6	14	43	160	0.582	25.026
P60	2011	65	64.66	6	17	74	110	0.635	46.99
P61	2011	68	46.46	9	19	78	160	0.636	49.608
P62	2011	69	30.05	7	14	59	160	0.583	34.397
P63	2012	68	28.45	8	17	54	110	0.486	26.244
P64	2011	67	21.96	8	19	57	160	0.569	32.433
P65	2011	58	34.71	6	19	57	110	0.502	28.614
P66	2012	72	32.79	6	20	50	110	0.498	24.9
P67	2012	68	20.39	7	15	47	110	0.460	21.62
P68	2012	71	17.12	7	12	45	160	0.583	26.235
P69	2012	68	33.47	6	16	67	160	0.536	35.912
P70	2012	69	21.32	6	15	53	160	0.575	30.475
P71	2012	64	60.77	8	23	109	160	0.569	62.021
P72	2012	69	23.09	6	09	37	110	0.461	17.057
P73	2012	63	36.56	9	12	54	110	0.497	26.838
P74	2012	64	17.26	8	11	41	160	0.582	23.862
P75	2012	79	17.18	7	11	47	160	0.578	27.166
P76	2012	67	22.45	6	11	49	160	0.578	28.322
P77	2012	58	28.68	5	12	55	160	0.634	34.87
P78	2012	59	25.55	6	11	45	110	0.458	20.61
P79	2012	67	23.91	8	12	50	110	0.578	28.9
P80	2013	69	14.83	6	15	38	160	0.575	21.85
P81	2013	72	26.67	6	13	57	160	0.575	32.775
P82	2013	69	28.68	6	14	55	160	0.634	34.87
P83	2013	71	25.55	7	17	45	110	0.458	20.61

- **P: Patient**
- **Number of slices were drawn from Ultrasound images**
- **Total activity = number of seeds x Activity of the source**

APPENDIX Q

Some samples of pre-plan results from prowess 4.5 panther after pre-planning procedure.

The print showing the detailed information about number of needles and seeds

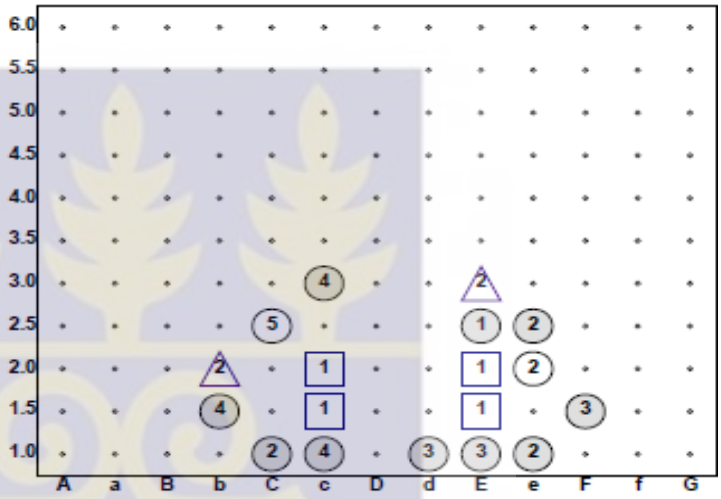
Patient ID:

Operating Room Report

Physician:	*Dr. Vanderpuye / Yarney*	Planned By:	*Kalolo Tegemea Lawrence*
Institution:	*Oncology Department, Korle Bu Teaching Hospital*	Creation Date:	*03/03/2013*
Prescription:	***16000.0 cGy to the 16000.0 isodose line***	Plan Name:	*Brachy Pre Plan #1*
Isotope:	*Sample I125-STM (Permanent)*	Template:	*B&K*
Activity:	*0.599 U (1232.133 U-hrs)*	Total Sources:	*43*
Vendor:	*SourceTech Medical*	Total Needles:	*18*

Needle Number	Hole Location	Retraction (cm)	Number Seeds
1	c3.0	0.30	4 (3)
2	E3.0	0.80	2 (2)
3	C2.5	0.10	5 (3)
4	E2.5	0.30	1
5	e2.5	0.60	2
6	b2.0	0.80	2 (2)
7	c2.0	2.20	1
8	E2.0	2.20	1
9	e2.0	0.20	2 (2)
10	b1.5	0.30	4 (3)
11	c1.5	2.00	1
12	E1.5	2.20	1
13	F1.5	0.60	3 (2)
14	C1.0	0.70	2 (2)
15	c1.0	0.30	4 (3)
16	d1.0	0.30	3 (3)
17	E1.0	0.40	3 (2)
18	e1.0	0.40	2

Indicates Overlapping Seeds
Indicates Special Loading
Indicates Single Seed Needle



Retraction Legend					
0.00 cm	0.60 cm	1.00 cm	1.60 cm	2.00 cm	2.60 cm
3.00 cm	3.60 cm	4.00 cm	4.60 cm	6.00 cm	All Others

Number of Needles	Seeds per Needle
6	1
8	2
3	3
3	4
1	5

Ordered	
Seeds Ordered	
Needles Ordered	
Seeds Implanted	
Needles Used	
Rapid Strand	
Total Activity	

Checked by : _____ Approved by : _____

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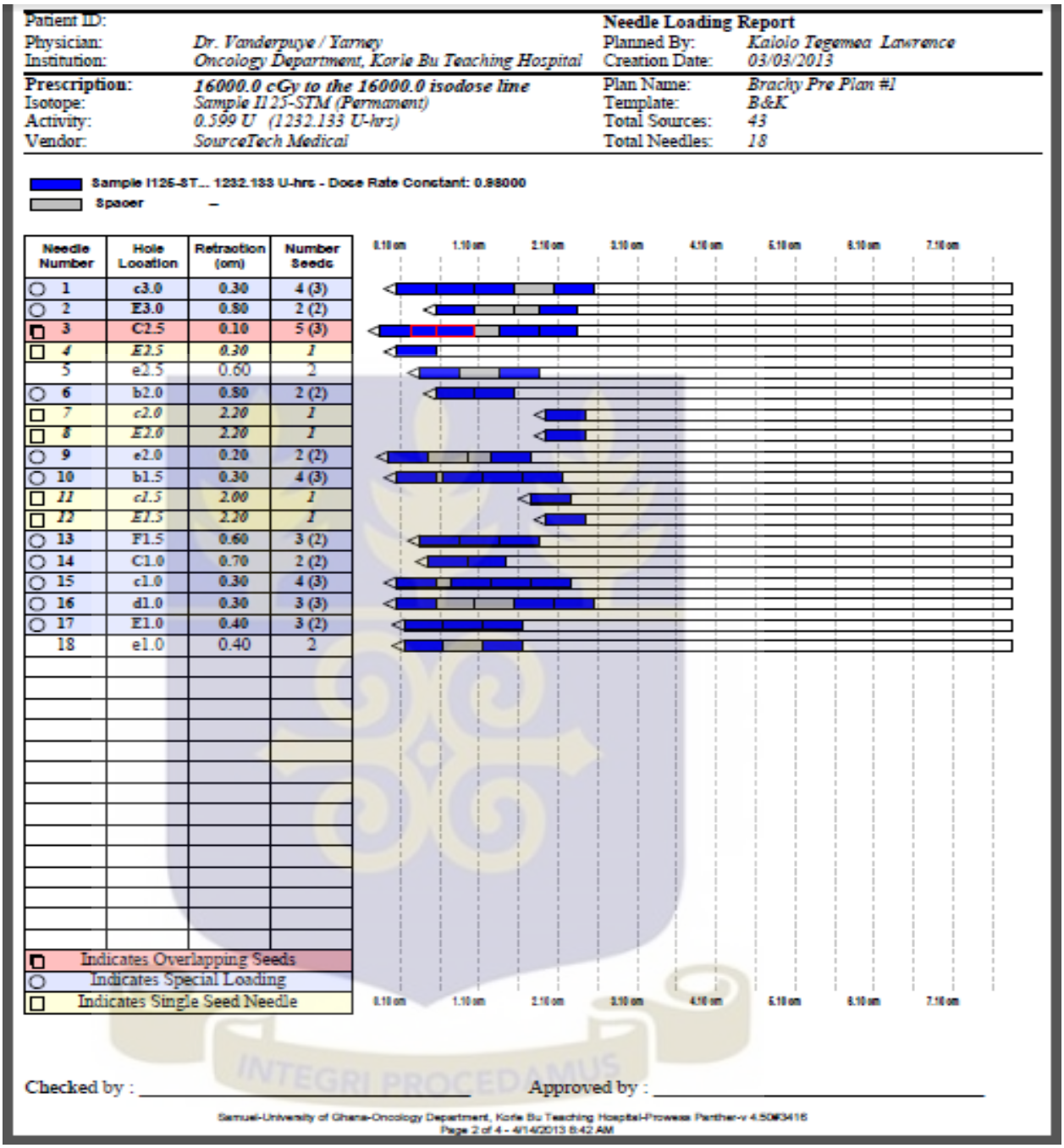
The print shows the amount of seeds to be implanted in each needle



Patient ID:

Physician: *Dr. Vanderpuye / Yarney*
Institution: *Oncology Department, Korle Bu Teaching Hospital*

Prescription: ***16000.0 cGy to the 16000.0 isodose line***
Isotope: *Sample I125-STM (Permanent)*
Activity: *0.599 U (1232.133 U-hrs)*
Vendor: *SourceTech Medical*

Needle Loading Report
Planned By: *Kalolo Tegemea Lawrence*
Creation Date: *03/03/2013*

Plan Name: *Brachy Pre Plan #1*
Template: *B&K*
Total Sources: *43*
Total Needles: *18*

Sample I125-ST... 1232.133 U-hrs - Dose Rate Constant: 0.88000
Spacer –

Needle Number	Hole Location	Retraction (cm)	Number Seeds
1	c3.0	0.30	4 (3)
2	E3.0	0.80	2 (2)
3	C2.5	0.10	5 (3)
4	E2.5	0.30	1
5	e2.5	0.60	2
6	b2.0	0.80	2 (2)
7	c2.0	2.20	1
8	E2.0	2.20	1
9	e2.0	0.20	2 (2)
10	b1.5	0.30	4 (3)
11	c1.5	2.00	1
12	E1.5	2.20	1
13	F1.5	0.60	3 (2)
14	C1.0	0.70	2 (2)
15	c1.0	0.30	4 (3)
16	d1.0	0.30	3 (3)
17	E1.0	0.40	3 (2)
18	e1.0	0.40	2

Indicates Overlapping Seeds
Indicates Special Loading
Indicates Single Seed Needle

0.10 cm 1.10 cm 2.10 cm 3.10 cm 4.10 cm 5.10 cm 6.10 cm 7.10 cm

Checked by : _____ Approved by : _____

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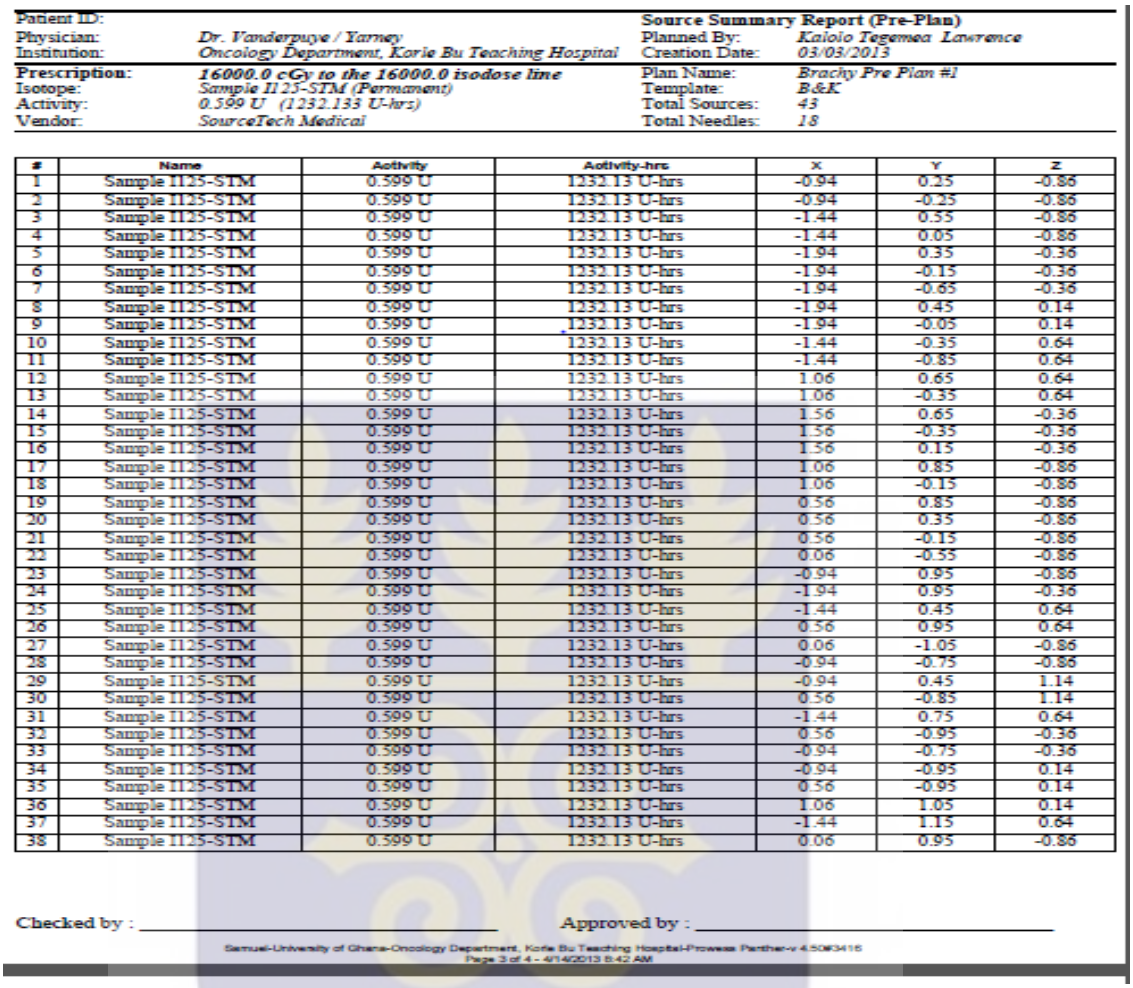
The print shows the number of needles, activity of the source and allocation of seeds in three dimension (XYZ) respectively.



Source Summary Report (Pre-Plan)

Patient ID:			
Physician:	*Dr. Vanderpuye / Yarney*	Planned By:	*Kalolo Tegemea Lawrence*
Institution:	*Oncology Department, Korle Bu Teaching Hospital*	Creation Date:	*03/03/2013*
Prescription:	***16000.0 cGy to the 16000.0 isodose line***	Plan Name:	*Brachy Pre Plan #1*
Isotope:	*Sample I125-STM (Permanent)*	Template:	*B&K*
Activity:	*0.599 U (1232.133 U-hrs)*	Total Sources:	*43*
Vendor:	*SourceTech Medical*	Total Needles:	*18*

#	Name	Activity	Activity-hrs	X	Y	Z
1	Sample I125-STM	0.599 U	1232.13 U-hrs	-0.94	0.25	-0.86
2	Sample I125-STM	0.599 U	1232.13 U-hrs	-0.94	-0.25	-0.86
3	Sample I125-STM	0.599 U	1232.13 U-hrs	-1.44	0.55	-0.86
4	Sample I125-STM	0.599 U	1232.13 U-hrs	-1.44	0.05	-0.86
5	Sample I125-STM	0.599 U	1232.13 U-hrs	-1.94	0.35	-0.36
6	Sample I125-STM	0.599 U	1232.13 U-hrs	-1.94	-0.15	-0.36
7	Sample I125-STM	0.599 U	1232.13 U-hrs	-1.94	-0.65	-0.36
8	Sample I125-STM	0.599 U	1232.13 U-hrs	-1.94	0.45	0.14
9	Sample I125-STM	0.599 U	1232.13 U-hrs	-1.94	-0.05	0.14
10	Sample I125-STM	0.599 U	1232.13 U-hrs	-1.44	-0.35	0.64
11	Sample I125-STM	0.599 U	1232.13 U-hrs	-1.44	-0.85	0.64
12	Sample I125-STM	0.599 U	1232.13 U-hrs	1.06	0.65	0.64
13	Sample I125-STM	0.599 U	1232.13 U-hrs	1.06	-0.35	0.64
14	Sample I125-STM	0.599 U	1232.13 U-hrs	1.56	0.65	-0.36
15	Sample I125-STM	0.599 U	1232.13 U-hrs	1.56	-0.35	-0.36
16	Sample I125-STM	0.599 U	1232.13 U-hrs	1.56	0.15	-0.36
17	Sample I125-STM	0.599 U	1232.13 U-hrs	1.06	0.85	-0.86
18	Sample I125-STM	0.599 U	1232.13 U-hrs	1.06	-0.15	-0.86
19	Sample I125-STM	0.599 U	1232.13 U-hrs	0.56	0.85	-0.86
20	Sample I125-STM	0.599 U	1232.13 U-hrs	0.56	0.35	-0.86
21	Sample I125-STM	0.599 U	1232.13 U-hrs	0.56	-0.15	-0.86
22	Sample I125-STM	0.599 U	1232.13 U-hrs	0.06	-0.55	-0.86
23	Sample I125-STM	0.599 U	1232.13 U-hrs	-0.94	0.95	-0.86
24	Sample I125-STM	0.599 U	1232.13 U-hrs	-1.94	0.95	-0.36
25	Sample I125-STM	0.599 U	1232.13 U-hrs	-1.44	0.45	0.64
26	Sample I125-STM	0.599 U	1232.13 U-hrs	0.56	0.95	0.64
27	Sample I125-STM	0.599 U	1232.13 U-hrs	0.06	-1.05	-0.86
28	Sample I125-STM	0.599 U	1232.13 U-hrs	-0.94	-0.75	-0.86
29	Sample I125-STM	0.599 U	1232.13 U-hrs	-0.94	0.45	1.14
30	Sample I125-STM	0.599 U	1232.13 U-hrs	0.56	-0.85	1.14
31	Sample I125-STM	0.599 U	1232.13 U-hrs	-1.44	0.75	0.64
32	Sample I125-STM	0.599 U	1232.13 U-hrs	0.56	-0.95	-0.36
33	Sample I125-STM	0.599 U	1232.13 U-hrs	-0.94	-0.75	-0.36
34	Sample I125-STM	0.599 U	1232.13 U-hrs	-0.94	-0.95	0.14
35	Sample I125-STM	0.599 U	1232.13 U-hrs	0.56	-0.95	0.14
36	Sample I125-STM	0.599 U	1232.13 U-hrs	1.06	1.05	0.14
37	Sample I125-STM	0.599 U	1232.13 U-hrs	-1.44	1.15	0.64
38	Sample I125-STM	0.599 U	1232.13 U-hrs	0.06	0.95	-0.86

Checked by : _____ **Approved by :** _____

Samuel-University of Ghana-Oncology Department, Korle Bu Teaching Hospital-Prowess Panther-v 4.50#3416
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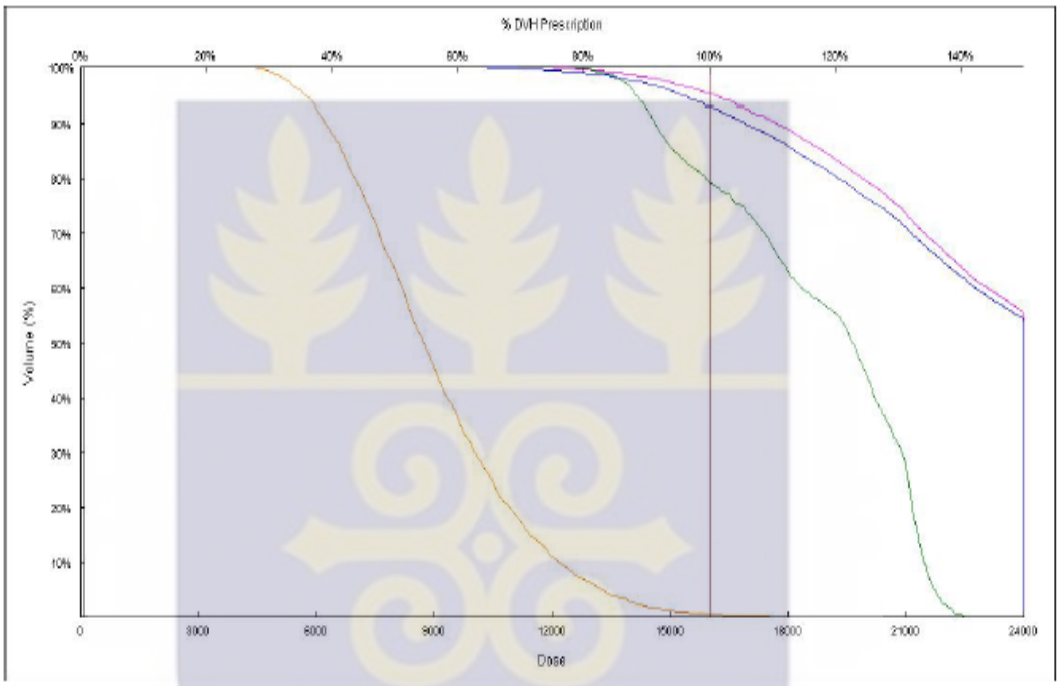
The print of dose volume histogram showing the 160 Gy coverage

Dose Volume Histogram — Prowess Panther v 4.50

Patient Name:	*WHAN-04 prostate brachy resesarchy^^^^*	Plan Name:	*Brachy Pre Plan #1*
Patient ID:		Anatomical Site:	*Anatomical Site*
Physician:	*Dr. Vanderpuye / Yarney*	Dosimetrist:	*Kalolo Tegemea*
Institution:	*Oncology Department, Korle Bu Teaching Hospital*	Date:	*1/23/2013*



Histogram Mode:	Integrated	**Isotope:**	Sample STM125 I-125 (Permanent)
DVH Prescription:	16000.0 cGy	**Activity:**	0.636 U (1308.06 U-hrs)
Dose Level:	100.0 cGy		

Checked by : _____ Approved by : _____

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The print of dosimetric parameters for prostate, urethra and rectum

Dose Volume Histogram — Prowess Panther v 4.50

Patient Name: *OTS-02-02^^^^*
Patient ID:
Physician: *Dr. Vanderpuye / Yarney*
Institution: *Oncology Department, Korle Bu Teaching Hospital*

Plan Name: *Brachy Pre Plan #1*
Anatomical Site: *Anatomical Site*
Dosimetrist: *Kalolo Tegemea Lawrence*
Date: *3/3/2013*

Volume Name	Prostate	Rectum	Prostate Margin	urethra
Volume Total (cc)	20.5	4.5	25.6	0.7
DLV at 100.0 cGy	20.5 cc 100.0 %	4.5 cc 100.0 %	25.6 cc 100.0 %	0.7 cc 100.0 %
D100	11880.0 cGy 74.3 %	4440.0 cGy 27.8 %	10200.0 cGy 63.8 %	12120.0 cGy 75.8 %
D90	18307.8 cGy 114.4 %	6021.2 cGy 37.6 %	16874.8 cGy 105.5 %	13764.0 cGy 86.0 %
D30	32456.5 cGy 202.9 %	10525.7 cGy 65.8 %	30994.1 cGy 193.7 %	20009.7 cGy 125.1 %
V150	12.2 cc 59.8 %	0.0 cc 0.0 %	13.9 cc 54.1 %	0.0 cc 0.0 %
V100	19.7 cc 96.2 %	0.0 cc 0.5 %	23.8 cc 92.8 %	0.5 cc 68.8 %
V95	20.0 cc 97.9 %	0.1 cc 1.5 %	24.4 cc 95.3 %	0.5 cc 77.5 %
Min Dose	11775.6 cGy 73.6 %	4348.9 cGy 27.2 %	10183.3 cGy 63.6 %	12082.9 cGy 75.5 %
Max Dose	149464.3 cGy 934.2 %	19678.5 cGy 123.0 %	149464.3 cGy 934.2 %	22156.8 cGy 138.5 %
Mean Dose	30489.6 cGy 190.6 %	9219.2 cGy 57.6 %	29148.4 cGy 182.2 %	18107.0 cGy 113.2 %
EUD (cGy)	-	-	-	-

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The print of isodose, showing the coverage of prescribed dose (160 Gy=16000 cGy) . The coverage is shown by the purple colour