



# Abstract Booklet

9<sup>th</sup> ZEISS INTRABEAM System User Meeting, Mannheim  
July 9<sup>th</sup> and July 10<sup>th</sup> 2015

## Index

Intraoperative radiotherapy as a boost after neoadjuvant chemotherapy - DFS after a median follow-up of 4 years. ...	1
Effects of Pre-operative Imaging Modality on Patient Selection for Intraoperative Radiotherapy.....	3
The Impact of IORT on Breast Cancer Awareness in developing countries.....	5
Early complications following the breast conserving surgery with intraoperative radiotherapy using low energy photons for breast carcinoma.....	6
INTRAOPERATIVE RADIOTHERAPY GIVEN AS A BOOST FOR BREAST CANCER .....	7
Intraoperative Radiotherapy Using Intrabeam in an Oncoplastic Breast Conservation Procedure .....	8
First safety analysis after 80 treated patients with early breast cancer within the TARGIT-E trial.....	9
Breast related quality of life outcomes from the TARGIT-A Study in Western Australia .....	10
Quality of Life and Toxicity Outcomes for Patients with Early Stage Breast Cancer Treated with Intraoperative Radiation Therapy: A Prospective Analysis.....	11
Late toxicity and cosmetic outcome following Intraoperative Radiotherapy as a boost or as accelerated partial breast irradiation: a monocenter experience .....	13
Cosmetic outcomes from the TARGIT-A Study in Western Australia .....	14
Lessons From Initiating And Implementing Intraoperative Radioation Therapy For Breast Cancer At A Public Hospital In Israel: Multidisciplinary Care In The Operating Theatre .....	15
Introducing Intrabeam into New Zealand. Our experience and things we learnt along the way.....	16
The challenges and advantages of starting a service for delivery of TARgeted Intraoperative radioTherapy (TARGIT - IORT), for early stage breast cancer, in a UK District General Hospital, with no Radiation Centre .....	17
Investigation of Field Shaping in low-kV Intra-Operative Radiotherapy (IORT).....	18
Patient Preferences for Adjuvant Radiotherapy - outcomes from the TARGIT-A Study in Western Australia.....	19
The Challenge of Implementing a New Intrabeam Program: Initial Experience At Our Hospital .....	21
TREATMENT OF SKIN CANCER WITH INTRABEAM .....	23
IORT Spherical Applicator Gauges (poster presentation).....	24
Feasibility of the treatment of eyelid skin basal-cell carcinomas with superficial X-rays with flat applicators of an INTRABEAM device.....	25
INTRABEAM therapy for breast cancer: Comparative Cost Analysis.....	26
Experience of 47 cases using INTRABEAM for intracranial malignant tumors.....	27
IORT OF PRIMARY BRAIN TUMORS AND BRAIN METASTASES .....	28

High dose-low energy intraoperative radiotherapy in treatment of malignant parotid tumors.....	29
Our limited experience in abdominal INTRABEAM IORT: a report on 4 cases .....	30
First experience of intraoperative radiotherapy in pancreatic cancer and liver colorectal metastasis combine treatment .....	31
<b>I</b> ntraoperative radiotherapy in locally-advanced and recurrent rectal cancer: retrospective review of 68 cases .....	32
Preliminary outcome of intraoperative radiotherapy for High-risk patients with differentiated thyroid cancer T4 primary tumors or recurrent lesions: A single-institute experience .....	33
Monte Carlo Modeling of IORT Dose Distributions in a Commercial Treatment Planning System .....	34
An in-air and in-water investigation of the INTRABEAM system dosimetry using a Monte Carlo source model.....	35
Liquid Scintillation Dosimetry of an Intraoperative X-ray Source .....	37
Optimized Monte-Carlo based dose computation for low energy X-rays IORT implemented in Radiance TPS. ....	38
Practical aspects to calibration, commissioning and using a breast IORT system.....	40
Micro-Commissioning of an INTRABEAM Intraoperative Radiotherapy (IORT) X-ray Source (XRS) using EBT3	
Gafchromic film in conjunction with multichannel film dosimetry and Matlab analysis.....	41
Proposal for a quality assurance programme and measurement of skin dose in breast treatments with radiochromic film.....	43
Dosimetric characterization of INTRABEAM® flat and surface applicators for dermatologic applications .....	45

# Intraoperative radiotherapy as a boost after neoadjuvant chemotherapy - DFS after a median follow-up of 4 years.

Hans-Christian Kolberg<sup>1 2</sup>, György Lövey<sup>2 3</sup>, Leyla Akpolat-Basci<sup>1 2</sup>, Miltiades Stephanou<sup>1 2</sup>, Michael Untch<sup>4</sup>

<sup>1</sup>Marienhospital Bottrop, Bottrop, Germany; <sup>2</sup>Uni-Brustzentrum Essen – ubze; <sup>3</sup>BORAD, Bottrop, Germany; <sup>4</sup>Helios Klinikum Berlin-Buch, Berlin, Germany

## Background

The concept of breast conserving therapy in breast cancer consists of a segmental resection followed by whole breast irradiation with a dose of 50 Gray. The expected local recurrence rate in 5 year follow-up is 7,6%. In the majority of the cases the whole breast irradiation is followed by a boost irradiation of the index region with a dose of 10 to 16 Gray, resulting in a reduced recurrence rate of 4,3% in 5 years according to the EORTC data. The boost irradiation as an intraoperative procedure using a 50kV X-ray source showed a further decrease of local recurrence rates down to 1,75% in the 5 year follow up and therefore results in better local control. Because the high risk group of patients who are receiving neoadjuvant chemotherapy would benefit especially from a better local control, we adapted this approach to patients after neoadjuvant chemotherapy and are reporting the DFS after a median of 4 years of follow up. To our knowledge this is the first time that data concerning intraoperative radiotherapy after neoadjuvant chemotherapy are presented.

## Methods

Between April 2010 and November 2011 we treated 61 patients after neoadjuvant chemotherapy (+/- Trastuzumab according to HER2-status) with an intraoperative boost of 20 Gy with a 50 kV Y-ray source followed by an external radiation with 50 Gy. The patient characteristics were as follows and represent the high risk cohort typical for a cohort of patients treated with neoadjuvant chemotherapy: median age 54,9 years, 24 pts premenopausal / 37 pts postmenopausal, 31 pts G2 / 30 pts G3, 39 pts ER positive / 22 pts ER negative, 29 pts PR positive / 32 pts PR negative, 24 pts HER2 positive / 37 pts HER2 negative, 36 pts T1 / 24 pts T2 / 1 pt T3, 28 pts node negative / 33 pts node positive. 19 patients reached a pathologic complete remission. 17 patients needed more than one operation. No patient was lost to follow up and at the time of data closure the median follow up was 49,56 months.

## Results

At a median follow up of 49,55 months 53 of 61 patients were free of tumor (DFS 86,89%), 57 of 61 patients were free of metastases (DDFS 93,44%). 18 of the 19 patients were disease free in the group of patients who reached a pCR (DFS 94,74%). In the group of 42 patients who had residual tumor after neoadjuvant chemotherapy, 35 were disease free (DFS 83,33%).

## Conclusions

An overall DFS of 86,89% compares favorably to the DFS expected for patients after neoadjuvant chemotherapy. The higher DFS in the pCR-group was expected due to the fact that a pCR after neoadjuvant chemotherapy +/-

Trastuzumab is predictive for DFS. Still the DFS in the non pCR-group compares favorably to the known data for patients not reaching a pCR after neoadjuvant chemotherapy. Our data show are the first on IORT as a boost after neoadjuvant chemotherapy and show a favorable outcome of the patients in this high risk group. They strongly encourage the design of prospective trials in this indication.

# Effects of Pre-operative Imaging Modality on Patient Selection for Intraoperative Radiotherapy

Bansil H<sup>1</sup>, Feldman S, Borden B, Chen M, Ananthakrishnan P, Taback B, Connolly E.<sup>1</sup>

<sup>1</sup>Columbia University Medical Center, New York, USA

## Introduction

Following the update of the Targit-A trial there has been increased uptake of intraoperative radiotherapy (IORT). Appropriate patient selection for IORT is challenging and tumor size on imaging is a key selection criteria. The ELIOT trial showed increased 5 year ipsilateral breast tumor recurrence in patients with pathologic tumor size >2cm. The accuracy of imaging modalities; MRI, mammogram and ultrasound; in predicting pathologic size is variable and can therefore strongly influence the inclusion or exclusion of patients from IORT.

## Methods

Using a prospectively consented cohort of 73 consecutive women referred for IORT at CUMC from September 2013 to January 2015, we retrospectively reviewed charts for clinical characteristics, and treatment outcomes. Demographic, pre-operative staging, pre and post-operative pathology, surgical and radiation data were collected. We evaluated need for re-excision, post-operative external beam radiation therapy (EBRT) and variations between pre-operative staging by imaging modalities and final tumor size at surgical excision.

## Results

Patient characteristics include median age 67 (range 45-91), 93% post-menopausal. Final pathologic type: 24 DCIS, 40 IDC, 2 mixed type and 7 ILC. Median pre-operative tumor size by imaging was 1.2cm (range 0.3-7.6cm). Mean tumor size at surgical excision was 1.0cm (range 0-3.0cm). Nine patients required re-excision for positive margins (12.3%). 4/9 re-excised patients had DCIS (44%). Fourteen patients received post-operative EBRT after IORT (19%). Choice of pre-operative imaging modality was at the breast surgeons' discretion. The mean difference in size between pre-operative imaging and final pathologic size for invasive cancers was -0.05 cm±0.76 for mammogram, -0.17 cm±0.55 for ultrasound and 0.58 cm±1.56 for MRI with mammogram and US underestimating final size and MRI overestimating. The mean difference for DCIS was 0.15 cm±0.88 for mammogram (n 72), -0.15 cm±0.75 for ultrasound (n 56) and 1.18±2.22 cm for MRI (n 35) with positive values indicating an overestimate of size and negative value indicating underestimate. MRI was used in 35/73 patients and in 5/9 patients requiring re-excision. Indications for EBRT included; 9 patients with positive margins requiring re-excision, two with positive sentinel lymph node biopsy, one with focally positive margin who refused further excision, one with pleomorphic lobular carcinoma, one with triple negative breast cancer, one HER2 amplified and one with age < 50 years old. No patients requiring re-excision or EBRT had significant pre-operative underestimation of tumor size on MRI, mammogram or ultrasound.

## Conclusion

Accuracy of imaging modality can strongly influence patient's eligibility for IORT. Both mammogram and ultrasound showed acceptable accuracy in predicting size. MRI showed significant variability in accuracy with occasional large overestimates of size, most notably in patients with DCIS. Variations in imaging modality did not appear to affect

rates of re-excision or EBRT. MRI may occasionally inappropriately exclude patients from IORT. Our data set includes only patients referred for IORT and may not reflect appropriate exclusion of patients based on MRI results prior to referral. No single imaging modality is accurate or appropriate for all patients and ongoing follow up for local recurrence and survival will further clarify appropriateness of patient selection.

# The Impact of IORT on Breast Cancer Awareness in developing countries

Maha Abdel Hadi. MD. FRCSI. FACS. MSc (Healthcare Mg.)<sup>1</sup>

<sup>1</sup>Department of Surgery University of Dammam, Kingdom of Saudi Arabia

## Background

In developing countries, patients present at a young age with locally advanced disease. This problem is mainly due the lack of structured Breast cancer awareness programs and further compounded by the scarcity of Radiation Oncology Centers in the Region limiting the surgical options to liberal mastectomies.

We aim to our present our four years' experience with IORT and assess the benefit of such modality in our current setup.

## Materials and methods

All breast cancer patients presenting at King Fahad Hospital of the university between January 2012 –April 2015 were included. Strictly adhering selection criteria and intraoperative radiotherapy (IORT) guidelines cases were carefully selected. Special emphasis was focused on patients' age at presentation, sizes of the applicators used

## Results

The total number of patients referred with breast cancer are 219. Eligible patients for IORT were 57patients (26 %). Age ranged between 31-74 years, with (mean age 42years ). Larger applicator sizes were used in the first and second years. Average and smaller sizes followed in subsequent years. The applicator size mostly used ranged between 3.0-3.5 in 27(47%) cases in the second half of the period indicating smaller lesions at presentation.

## Conclusion

IORT is an appealing treatment method propagating breast conserving therapy (BCT) in our communities. The reduction in the applicator sizes used indicates the improvement in the surgical techniques, confidence in choosing appropriate sizes, promoting early detection and providing BCT as available surgical option.

However, thus far due to the young age at presentation IORT is of more benefit when used as boost therapy.

# Early complications following the breast conserving surgery with intraoperative radiotherapy using low energy photons for breast carcinoma

Małgorzata Jankiewicz<sup>1 2</sup>, Andrzej Kurylcio<sup>1</sup>, Bogumiła Ciseł<sup>1</sup>, Monika Lewicka<sup>1</sup>, Jerzy Mielko<sup>1</sup>, Wojciech P. Polkowski<sup>1</sup>

<sup>1</sup>Department of Surgical Oncology, Medical University of Lublin, Poland, <sup>2</sup>St. John's Cancer Center Lublin, Poland

## Background

Intraoperative radiotherapy (IORT) is an attractive and increasingly used option of the boost delivery during breast conserving surgery (BCS) for early breast carcinoma.

The aim of this study was to assess early complications of the BCS and IORT with low energy photons.

## Methods

Eighty five consecutive patients with early-stage breast cancer were qualified to the BCS (sentinel node biopsy and wide local excision (WLE) and IORT between 2005 and 2008. They underwent BCS along with 50 kV IORT of the tumour bed using Intrabeam PRS 500, that was used either alone or as a boost prior to the external beam radiation therapy (EBRT) of the whole breast. The acute toxicities were assessed based on the RTOG/EORTC CTC v.3 criteria and taking into account the process of healing and other post-surgical complications.

## Results

Eighty percent of patients did not develop any complications following the BCS with IORT. The most frequent early complications included mastitis (n=7; 8,2%), and haematoma (n=4; 4.7%). Delayed wound healing occurred in 9 (10,6%) patients. Erythema grade 1-2 observed in 10 (11,8%) patients, whereas acute toxicity grade 3 in two (2,4%) women. No grade 4 acute toxicity.

## Conclusions

IORT with low energy photons applied into tumour bed after the BCS is well tolerated and it does not lead to marked toxicity in early observation after the treatment.

# **INTRAOPERATIVE RADIOTHERAPY GIVEN AS A BOOST FOR BREAST CANCER**

Natalia Jankarashvili<sup>1</sup>, Maia Topeshashvili<sup>1</sup>, Irakli Sikharulidze<sup>1</sup>; Mikheil Janjalia<sup>1</sup>;

<sup>1</sup>Tbilisi Cancer Center Ltd, Tbilise, Georgia

## **Purpose**

The standard radiotherapy (RT) of breast cancer consists of 50 Gy external beam RT (EBRT) to the whole breast followed by a photon or electron boost of 10–16 Gy (5-8 fraction) to the tumor bed in breast-conserving therapy (BCT). Intraoperative radiotherapy (IORT) could be an alternative to EBRT boost in 1 fraction with better cosmetic results.

## **Methods and Materials**

Between November 2012 till April 2015 we have evaluated 135 women with early breast cancer (youngest 35 years old), which were operated on followed by intraoperative applicators placed in the tumor bed. Prescribed dose was 20Gy on tissue surface. The skin was not in the radiation field. In all cases we have performed fast morphology study to evaluate postoperative margins and they were clear in 100% of patients. 110 patients received postoperative EBRT (46-50Gy in 2 Gy fractions). Late toxicity, cosmetic results and local control were assessed.

## **Results**

After a median follow-up of 29 month no local recurrences were observed within the primary tumor bed. All patients are alive without disease. Only G1 and G2 Adverse Events (AE) (late subcutaneous fibrosis within the boost area) were detected. A very good quality of life and cosmesis was good to excellent in the evaluated patients.

## **Conclusion**

Our results revealed, that IORT, given as a boost after breast-conserving surgery is a reliable alternative to conventional postoperative fractionated boost radiation and cosmetic effects is excellent in both cases, with only IORT and after IORT+EBRT.

# Intraoperative Radiotherapy Using Intrabeam in an Oncoplastic Breast Conservation Procedure

Pla M Jesus <sup>1</sup>, Eraso M Aranzazu <sup>2</sup>, Sancho Ismael <sup>3</sup>, Plana Maria <sup>2</sup>, Picon Cristina <sup>3</sup>, Ponce Jordi <sup>1</sup>, Guedea Ferran <sup>2</sup>

<sup>1</sup>Department of Gynaecology, Bellvitge University Hospital (HUB). <sup>2</sup>Department of Radiation Oncology, Institut Català d'Oncologia (ICO). <sup>3</sup>Medical physics Department ICO, L' Hospitalet de Llobregat, Barcelona, Spain

## Introduction

Oncoplastic techniques allow surgeons to prevent or minimize cosmetic breast deformity which can occur after breast conservation surgery due to the location or size of the resected tumour. Oncoplastic surgery is sometimes the best option due to preoperative breast ptosis and breast size. After the oncoplastic procedure, the surgical bed is closed and completely covered with glandular flaps. However, despite efforts by the surgeons to mark the tumour with metallic clips, it is often difficult to precisely locate the tumour when boost radiotherapy (RT) is needed. Previous studies have demonstrated that boost RT improves local control in breast cancer and the use of intraoperative radiotherapy (IORT) assures that the tumour bed is correctly located and, consequently, treated.

## Material and methods

We performed a reduction mammoplasty in a 67-year old woman with large ptotic breasts and a tumor located in the upper external quadrant. The resected tumour was a 25 mm infiltrating ductal carcinoma, luminal B. Wide local excision was performed with sentinel node biopsy using Tc 99. A 4.5 cm Intrabeam applicator was used to deliver boost RT delivered with IORT (20 Gy, Intrabeam). Irradiation time was 37 minutes, after which the oncoplastic procedure was completed by covering the tumour bed with glandular flaps.

The surgical outcome was acceptable, although a dehiscence at the vertical wound (currently improving) was observed. Based on our institutional criteria, the patient will be treated with external RT of the breast and adjuvant chemotherapy.

## Conclusion

IORT with Intrabeam allows for precise localization of the tumour bed in patients treated with an oncoplastic breast conservation procedure. The limiting factor is whether the Intrabeam applicator can be applied to the tumour bed while preserving a safe distance from the skin. A Phase II study has been designed to validate the feasibility of Intrabeam as a boost in oncoplastic procedures in patients whose RT treatment will be completed with hypofractionated whole breast RT.

# First safety analysis after 80 treated patients with early breast cancer within the TARGIT-E trial

Neumaier, Christian<sup>1</sup>, Welzel, Grit<sup>1</sup>, Keller, Anke<sup>1</sup>, Abo-Madyan<sup>1,2</sup>, Yasser, Sperk, Elena<sup>1</sup>, Gerhardt, Axel<sup>3</sup>, Sütterlin, Marc<sup>3</sup>; Wenz, Frederik<sup>1</sup>

<sup>1</sup>Department of Radiation Oncology, University Medical Centre Mannheim, University of Heidelberg, Germany, <sup>2</sup>Department of Radiation Oncology and Nuclear Medicine (NEMROCK) Faculty of Medicine, Cairo University, Cairo, Egypt, <sup>3</sup>Department of Gynaecology and Obstetrics, University Medical Centre Mannheim, University of Heidelberg, Germany

## Background/Purpose

The TARGIT-E trial (Trial registration NCT01299987) as a prospective single-arm observational study (phase II) was designed to assess the efficacy and toxicity of IORT (intraoperative radiotherapy) alone in elderly patients ( $\geq 70$  years) with low risk invasive ductal breast cancer (cT1 cN0). Here, we report the results of the first-defined safety analysis.

## Methods

80 patients were treated according to the TARGIT-E protocol and therefore they received breast-conserving surgery and – whenever possible – IORT with 20 Gy to the applicator surface. WBRT (whole breast radiotherapy) was only added to IORT if risk factors were evident in the final pathology report or used as an alternative when IORT was not applicable. Primary endpoint was the rate of local recurrence. Secondary endpoints were ipsi- or contralateral breast cancer, cancer specific and overall survival, cosmetic outcome and quality of life. All patients were treated with breast-conserving surgery. In 51% patients IORT only was given, in 36% patients IORT was followed by WBRT and in 13% patients no IORT was applicable.

## Results

With a median follow up of 20.5 months all patients were alive and no local relapse was reported. 7 SAE (serious adverse event) within 7 patients were documented, where 2 SAE had potential associations to IORT alone and 3 SAE had potential associations to IORT and WBRT. 4 of these 5 radiation related toxicities resolved after conservative treatment. In 1 case surgical revision of a cutaneous fistula was performed. No long-lasting complications occurred in patients treated with IORT only. The other 2 SAE were not radiation associated. No SUSAR (serious unexpected adverse reaction) and no grade IV or V toxicities were recorded.

## Conclusion

The concept of targeted intraoperative radiotherapy alone with 20 Gy applied with the Intrabeamsystem in elderly patients is safe and feasible. To confirm these results longer follow-up is needed.

# Breast related quality of life outcomes from the TARGIT-A Study in Western Australia

T.Corica<sup>1,2</sup>, D.Joseph<sup>1,3</sup>, C.Saunders<sup>3</sup>, M.Bulsara<sup>4</sup>, A.Nowak<sup>2</sup>, M.Taylor<sup>1</sup>

<sup>1</sup>Department of Radiation Oncology, Sir Charles Gairdner Hospital, Perth, Australia , <sup>2</sup>School of Medicine and Pharmacology, University of Western Australia, Perth, Australia , <sup>3</sup>School of Surgery, University of Western Australia, Perth, Australia , <sup>4</sup>Institute of Health and Rehabilitation Research, University of Notre Dame, Perth, Australia

## Background

The international randomized TARGIT-A trial compared experimental once-off intra-operative radiotherapy (IORT) to 6-7 weeks of daily conventional external beam radiotherapy (EBRT) in women with early breast cancer. TARGIT-A found IORT to be non-inferior compared to EBRT in terms of reducing the risk of local cancer recurrence and survival, however its effect on breast-related quality of life outcome has not yet been reported.

## Methods

Quality of life data were collected from 126 TARGIT-A patients randomized between 2003 and 2007 in Western Australia. Patients completed the combined EORTC core questionnaire (QLQ-C30) and Breast Specific Module (BR23) in addition to the Body Image after Breast Cancer Questionnaire (BIABC) at baseline and then annually thereafter. EORTC questionnaires were also completed at months 3, 6 and 9 post baseline. Relevant quality of life domains were chosen for analysis by an expert panel and analysed according to treatment group and cosmetic outcome.

## Results

IORT patients tended to fare better than EBRT patients in breast-specific quality of life domains. Statistically significant differences were found for Breast Symptoms at Months 6 and 9 and Years 1-5; and Arm Concerns at Years 1 and 3 (which includes a question about breast pain). Clinically significant differences were seen at Month 6 and Year 1, with EBRT patients having moderately more severe breast symptoms which improved beyond those time points.

Cosmetic outcome had little influence on most quality of life domains, but potentially affected the Body Image (worse for the EG group) and Sexual Function (better for the EG group) domains.

## Conclusion

Patients treated with IORT on the TARGIT trial in Western Australia have significantly better short term breast-related quality of life compared to patients treated with EBRT. IORT patients continue to have better scores than EBRT patients over time however the differences do not reach clinical significance beyond Year 1.

Cosmetic outcome does not appear to have an influence on most domains of breast-specific quality of life, however further exploration into the Body Image and Sexual Function domains may be warranted.

This evidence is important to facilitate the decision-making process for patients and clinicians when discussing radiotherapy options for early breast cancer treatable with breast conserving surgery.

# Quality of Life and Toxicity Outcomes for Patients with Early Stage Breast Cancer Treated with Intraoperative Radiation Therapy: A Prospective Analysis

Corinne Costellic, DO<sup>1</sup>, Aiste Gulla, MD<sup>2</sup>, Elizabeth Hechenbleikner, MD<sup>2</sup>, James Clarke, MS IV<sup>3</sup>, Brian Collins, MD<sup>2</sup>, Sonali Rudra, MD<sup>2</sup>, Krysta Chaldeckas, BS, CCRP<sup>4</sup>, Sulakshana Seevaratnam, BS<sup>4</sup>, Russell Langan, MD<sup>2</sup>, Monique Gary, DO<sup>1</sup>, Shawna Willey, MD<sup>2</sup>, Eleni Tousimis, MD<sup>2</sup>.

<sup>1</sup>MedStar Georgetown University/Washington Hospital Center, <sup>2</sup>MedStar Georgetown University Hospital, <sup>3</sup>Georgetown University Medical School, <sup>4</sup>Georgetown University.

## Purpose

Intraoperative radiation therapy (IORT) is an appealing treatment strategy for early stage breast cancer because it conveniently delivers a single dose of radiation at the time of breast conserving surgery (BCS) and decreases excess radiation exposure to normal tissues. This prospective single institution pilot study summarizes patient-reported quality of life (QoL) outcomes and clinician-reported toxicity following IORT.

## Materials/Methods

The Intrabeam system (Carl Zeiss, Oberkochen, Germany) was used to perform IORT. All patients received 50kV of low energy photons in a single 20Gy fraction to the lumpectomy cavity over 17.3-45.3 minutes (mean 22.3 minutes) at the time of BCS. Forty patients who met criteria for IORT were enrolled since January 2013 and followed prospectively for 2-years. Self-administered, validated QoL questionnaires were provided to patients at 1-week, 1-month, 6-month, 1-year, 1.5-year, and 2-year postoperative appointments. At the same interval appointments, clinician-reported radiation-related toxicity evaluations were performed.

## Results

Ninety percent of patients completed QoL surveys and 57% of toxicity evaluations have been done to date. Grade 1 toxicities were noted in 60%: breast pain (56%), breast swelling (47%), nodularity (43%), dermatitis (34%), fibrosis (34%), arm pain (26%), indentation (17%), seroma (13%), and hematoma (8%). Grade 2 toxicities were noted in 17%: breast and arm pain (4%), wound infection (4%), breast indentation (4%), and breast indentation plus nodularity (4%). No grade 3-5 toxicities or evidence of recurrent disease have been identified.

The median reported 'Best Imaginable Health State' was 80 on a scale 0-100. Patients reported favorable outcomes for physical, social/family, and emotional well-being. Half of patients surveyed experienced some negative effects with functional well-being: difficulty with sleeping well (27%), ability to work (25%), and finding work fulfilling (38%). Forty-one percent of patients had additional concerns such as feeling less sexually attractive (27%) and worrying about the effect of stress on their illness (25%). A minority of patients (41%) experienced significant symptoms of decreased energy (22%), feeling tired (22%), feeling fatigued (19%), and frustration over being too tired to do things they want (19%). Results on upper extremity and breast symptoms were generally positive; the most commonly reported negative symptoms were oversensitivity of the affected breast (30%) and breast pain (19%).

## Conclusion

Our results demonstrate the majority of our patients have favorable toxicity and QoL outcomes with no grade 3-5 toxicities, good overall health score, and no evidence of local recurrence at 1.5-years. IORT is a convenient way to

deliver safe, effective radiation to patients undergoing BCS for early stage breast cancer given its low toxicity profiles and positive QoL outcomes.

# Late toxicity and cosmetic outcome following Intraoperative Radiotherapy as a boost or as accelerated partial breast irradiation: a monocenter experience

S. Key<sup>1</sup>, S.Vourch<sup>1</sup>, P. Miglierini<sup>1</sup>, O. Miranda<sup>1</sup>, S.Guilbert<sup>2</sup>, PF. Dupré<sup>2</sup>, O. Pradier<sup>1</sup>, U.Schick<sup>1</sup>

<sup>1</sup>Radiotherapy Unit, CHU Morvan Brest; <sup>2</sup>Gynecological Cancer Unit, CHU Morvan Brest.

## Objectif

Partial breast irradiation with intraoperative radiotherapy (IORT) demonstrated his non inferiority compared to whole breast irradiation (WBRT) in the Targit A trial in term of local control. Few reports, however, focused on late toxicity and cosmetic outcome. The present study evaluates late breast and skin toxicities observed following this technique at our institution.

## Methods

Between 04/11 and 02/14, 71 patients with early invasive breast carcinoma (BC) were treated with breast conservative surgery followed by IORT using 50-kV x-rays delivered by the Intrabeam device. Criteria to identify eligible patients were as follow: age > 55 years, invasive BC, cT1, cN0, Grade 1-2, significant expression of hormone receptors and no ErbB-2 expression on the biopsy. Twenty Gy were prescribed at the applicator's surface after tumor resection. In case of unfavorable histological prognostic factors on the resection specimen, including N+, grade 3, ErbB-2 overexpression or presence of an in situ component, external WBRT to an equivalent dose of 46 Gy in 23 fractions was administered 4 weeks after IORT. During follow-up (FU), toxicity was prospectively graded using the LENT SOMA scale for BC radiotherapy and cosmetic outcome were assessed by two different radiation oncologists and the patient herself, using a cosmetic scale of 0 to 100%.

## Results

IORT was given as exclusive radiation therapy in 51 (71.8%) patients, whereas 20 (28.2%) patients received additional WBRT. After a median follow up of 30 months (14-45 mo, range), no loco-regional or distant recurrence was observed. Grade  $\geq 2$  subcutaneous fibrosis, retraction and hyperpigmentation were detected in 3 (15%), 7 (35%) and 3 (15%) of patients treated with IORT+WBRT, compared to 1 (2%), 1 (2%) and 0 patients in the IORT group, respectively. Overall, IORT followed by WBRT was associated with a significantly higher risk of developing grade  $\geq 2$  late toxicity compared to IORT alone (3.9 vs 35%,  $p=0.001$ ). The only serious adverse events were 2 infections. At last FU, objective and subjective cosmetic outcome in the IORT alone group were both very good with a mean score of 83 and 86% (range 30-100) and better than in the IORT+ WBRT group (73 and 72%).

## Conclusion

IORT with 50 kv-X ray using INTRABEAM® is well tolerated with little late skin toxicity and very good cosmetic outcome. Although our inclusion criteria were substantially stricter than those of the TARGIT-A trial, around 30% of the patients had to receive external WBRT after IORT. This, however, leads to a significantly higher risk for developing late high grade skin and breast toxicity compared to patients treated with IORT alone. As such, patient's selection optimization is needed in order to further reduce the risk of late severe toxicity.

## Cosmetic outcomes from the TARGIT-A Study in Western Australia

T.Corica<sup>1,2</sup>, D.Joseph<sup>1,3</sup>, C.Saunders<sup>3</sup>, A.Nowak<sup>2</sup>, M.Bulsara<sup>4</sup>, M.Keshtgar<sup>5</sup>, N.Williams<sup>5</sup>, M.Taylor<sup>1</sup>

<sup>1</sup>Department of Radiation Oncology, Sir Charles Gairdner Hospital, Perth, Australia, <sup>2</sup>School of Medicine and Pharmacology, University of Western Australia, Perth, Australia, <sup>3</sup>School of Surgery, University of Western Australia, Perth, Australia, <sup>4</sup>Institute of Health and Rehabilitation Research, University of Notre Dame, Perth, Australia, <sup>5</sup>University College London, United Kingdom

### Background

The international randomized TARGIT-A trial compared experimental once-off intra-operative radiotherapy (IORT) to 6-7 weeks of daily conventional external beam radiotherapy (EBRT) in women with early breast cancer. TARGIT-A found IORT to be non-inferior compared to EBRT in terms of reducing the risk of local cancer recurrence and survival, however its effect on subjective cosmetic outcome has not yet been reported.

### Methods

Cosmetic outcome data were collected from 126 TARGIT-A patients randomized between 2003 and 2007 in Western Australia. Patients, their radiation oncologist and research nurse were asked to complete a subjective cosmetic assessment questionnaire at baseline (before radiotherapy) and annually thereafter for at least five years. Subjective data were also compared to objective data that had been scored using the BCCT.core rating system.

### Results

There is no difference in cosmetic outcome between patients receiving IORT and EBRT, as scored by patients, doctors, nurses and the objective BCCT.core system, measured at annual intervals from before radiotherapy to 5 years post. Overall, an Excellent-Good (EG) cosmetic result was scored more often than a Fair-Poor (FP) result for both treatment groups across all time points. The worst patient-reported score for the IORT group was at Year 1 with 74% of patients scoring an EG result, however scores improved to above baseline levels by Year 2 and beyond. EBRT patients did not improve to baseline scores, with the worst score of 68% recorded at Year 5. There was fair to poor reliability between the four scoring systems across all time points, with the BCCT.core system scoring the worst scores, followed by patients, nurses and then doctors.

### Conclusion

We now have evidence that patients treated with IORT on the TARGIT trial in Western Australia have similar cosmetic outcomes, if not a bit better, than patients treated with EBRT. Furthermore, clinicians are more optimistic in their subjective assessment of cosmesis compared to patients. This evidence is important to facilitate the decision-making process for patients and clinicians when discussing radiotherapy options for early breast cancer treatable with breast conserving surgery.

# Lessons From Initiating And Implementing Intraoperative Radioation Therapy For Breast Cancer At A Public Hospital In Israel: Multidisciplinary Care In The Operating Theatre

Dr. Tanir Allweis<sup>1</sup>, Dr. Eliezer Mavor<sup>1</sup>, Dr. Viktor Korakin<sup>1</sup>, Dr. Sergey Levin<sup>1</sup>, Dr. Sachi Hatzubi<sup>1</sup>, Dr. Victor Bouyevitch<sup>1</sup>, Dr. Tami Magen<sup>1</sup>, Dr. Noa Ben Baruch<sup>2</sup>

<sup>1</sup> Dept. of General Surgery ,<sup>2</sup> Dept of Oncology, Kaplan Medical Center, Rehovot

## Aims

To describe the first steps in initiating and implementing intra operative radiation therapy (IORT) in conjunction with lumpectomy for early breast cancer, and highlight some of the challenges and solutions which we encountered.

## Materials and Methods

IORT was initiated at our institution in March 2014, about 4 years after the idea was proposed to the hospital management. The initiative was approved by the organization's central authorities and extended to 4 more of the organizations hospitals. Setting up the program required training of staff, and building a system to facilitate the work flow between all those involved: surgeons, oncologists, radiation technologists, nurses and administrative staff. A designated informed consent form was composed and approved by the Israel Medical Association.

## Results

Thirty three patients were treated at our institution during the first year. The average age was 66.5 years and the average tumor size was 12.5 mm. Post-operative erythema prompting prescription of oral antibiotics was noted in 7 patients (21%), and 2 patients (6%) developed a frank wound infection necessitating drainage. Comprehensive intra-operative margin assessment with specimen X-ray and/or ultrasound as well as routine use of Margin Probe was performed in each case, and one (3%) was found to have positive margins on final pathology and underwent re-lumpectomy. Two patients (6%) were found to have a positive sentinel lymph node and went on to receive whole breast radiation. Special issues we encountered included questions of radiation safety by staff, a patient with a cardiac pacemaker and system malfunction.

## Conclusions

performing IORT after lumpectomy is simple and straight forward, but requires several logistic and administrative adjustments. Monitoring and follow up of these patients is crucial, and we are planning to establish a national, or at least institutional registry for these cases in Israel.

## **Introducing Intrabeam into New Zealand. Our experience and things we learnt along the way...**

Whineray Kelly EL\*, Pearse M.<sup>1</sup>, Craddock L.<sup>2</sup>

<sup>1</sup>Focus Radiotherapy, Auckland, New Zealand, <sup>2</sup>Southern Cross Hospital North Harbour, Auckland, New Zealand.

The first patients received Intrabeam IORT for breast cancer on August 30<sup>th</sup> 2013 after a 2 year project to introduce this to New Zealand in the private sector. Since then over 50 patients have been treated with 12% of patients requiring adjuvant EBRT to follow. There have been no cases of surgical complications, and as expected, due to short follow up, no local recurrences.

A large part of the success has been collaboration and education of our multidisciplinary team including working with radiology to establish size of lesions, ensuring the pathologists confirm ductal type on staining, and also discussing each core biopsy to see the potential for an upgrade. Post operatively, we have been working with the radiologists so they are familiar with the radiological appearance of the surgical site after IORT on their follow up imaging.

Along with introducing it, we have been working with the National Health Committee to have this introduced to the public system which it is considering for all cancer streams. The (ongoing) process of introducing Intrabeam into both the private and public systems has been disappointing at many stages, with conflicts exposed at multiple levels which have been ignored, leaving us wondering whether the patient and their treatment actually features in this?! We are hopeful, however that the National Health Committee will recommend Intrabeam for introduction when it makes its decision in July 2015.

# The challenges and advantages of starting a service for delivery of TARGeted Intraoperative radioTherapy (TARGIT - IORT), for early stage breast cancer, in a UK District General Hospital, with no Radiation Centre

Dr Julian Singer<sup>1</sup>, Mr Howard Bradpiece<sup>1</sup>, Mr Ashraf Patel<sup>1</sup>, Miss Stephanie Jenkins<sup>1</sup>, Mr David Dommett<sup>2</sup>, Prof Jayant Vaidya<sup>3</sup>.

<sup>1</sup>Princess Alexandra Hospital, Harlow, UK; <sup>2</sup>Southend General Hospital, Southend, UK; <sup>3</sup>University College Hospital, London, UK

## Purpose

In 2010 we proposed a business case to purchase Zeiss Intrabeam and start up IORT to treat early stage breast cancers in the TARGIT A and TARGIT B trials, at the Princess Alexandra Hospital, Harlow, UK. We present data for the first 17 IORT treated patients.

## Methods

Breast cancer patients from our hospital, need to travel a range of 10 to 30 miles to the nearest radiotherapy centre in London. We demonstrated that by purchasing the Intrabeam equipment and employing a physicist and radiographer and participation in TARGIT A and B trials, we would make financial savings for the local hospital. In spite of successful purchase of Intrabeam equipment, we had to overcome political resistance by some London radiation centres by persuading the London breast tumour board and radiotherapy tumour board and satisfy radiation safety guidelines that our hospital could safely deliver IORT, before we were able to commence. By collaboration with Professor Jayant Vaidya from University College Hospital London and Mr David Dommett, Southend Hospital physics department, we were able to overcome these obstacles and start the TARGIT B study.

## Results

Between July 2014 and March 2015, 17 breast cancer patients have been treated with IORT. Each of our 3 breast surgeons were trained by Prof Vaidya for 5 pilot patients each. Age range 43 – 78. To date no patient has local or distant recurrence. One patient experienced pain at the site of IORT 6 months later. The majority of our patients received external beam radiotherapy afterwards. There were financial savings in both TARGIT A and B type treatments, since a single treatment of IORT cost around £2000 and external beam electron boost 16 Gy in 8 fractions cost a similar amount, but there are savings in travel costs. In addition there is considerable social impact on the woman who frequently requires her family or partner to help drive her to the radiotherapy centre and the whole round trip can take many hours and impact on the patient and her partner's occupation.

## Conclusion

Intrabeam IORT for early stage breast cancer can be safely set up in a district general hospital with no previous linear accelerator facilities, when there is sufficient support by expert surgeon, physicist and radiographer from radiation centres. IORT is still not accepted as standard of care for early stage breast cancer in the UK and was only permitted as part of a phase III randomised trial (TARGIT B trial). Whether IORT is delivered as the booster dose (TARGIT B trial) or as the sole treatment (TARGIT A trial), there are financial, social, environmental and psychological advantages for the patient.

# Investigation of Field Shaping in low-kV Intra-Operative Radiotherapy (IORT)

Anil Sethi PhD<sup>1</sup>, Sukhdeep Gill MS<sup>1</sup>, Bonnie Chinsky MS<sup>1</sup>, Bahman Emami MD<sup>1</sup>, William Small MD<sup>1</sup>

<sup>1</sup>Loyola University Medical Center, Maywood, IL 60153, USA

## Purpose

Recently introduced flat and surface applicators in intra-operative radiotherapy (IORT) produce circular regions of uniform dose in a plane. IORT treatment sites, however, are often irregularly shaped. We propose a technique for field shaping with lead cutouts and investigate resulting isodose distributions.

## Methods and Materials

A 50-kV INTRABEAM X-ray device with superficial (flat and surface) applicators was commissioned at our institution. The effect of field shaping on dose distributions was examined by attaching 1mm thick lead foils (cut-outs) of various apertures to the end of applicators. Percent depth dose (PDD), surface dose (Ds), dose profiles (DP), penumbra (80/20 width) and output factors (OF) were measured using Gafchromic (EBT3) films. For a typical flat applicator, treatment times were calculated to deliver 1Gy dose at 5mm depth. Film results were verified by repeat measurements with a thin-window parallel plate ion-chamber (PTW 34013A) in a water tank.

## Results

To evaluate the impact of field shaping, dose inter-comparisons were performed in pairs: flat 4cm open applicator (4-open) vs. flat 6cm with a 4cm cutout (6x4); 2-open vs. 4x2, etc. Compared to 4-open, the 6x4 applicator had a lower dose rate (0.35 vs. 0.22 Gy/min), smaller surface dose (3.42 vs. 1.85 Gy), greater dose homogeneity (x1.9), and larger penumbra (3.6 vs. 1.8 mm). Similar results, although more pronounced, were obtained when 2-open was compared to 4x2 applicator. The latter had a lower dose rate (x0.36), smaller surface dose (x0.46), greater dose homogeneity (x2.2) and larger penumbra (x2.4). In general, an applicator with a field shaping aperture is dosimetrically similar to the parent applicator provided cut-out size is not drastically smaller (< x0.5 diameter).

## Conclusions

Field shaping may be necessary for IORT of irregularly shaped targets. 1mm thick lead foil attached to the end of an applicator is ideal for dose shaping. In general, compared to smaller open applicators, large applicators equipped with field defining apertures produce more homogenous target dose with a lower surface dose, but at the expense of longer treatment times.

# Patient Preferences for Adjuvant Radiotherapy - outcomes from the TARGIT-A Study in Western Australia.

T.Corica<sup>1,2</sup>, A.Nowak<sup>2</sup>, C.Saunders<sup>3</sup>, M.Bulsara<sup>4</sup>, D.Joseph<sup>1,3</sup>, M.Taylor<sup>1</sup>

<sup>1</sup>Department of Radiation Oncology, Sir Charles Gairdner Hospital, Perth, Australia, <sup>2</sup>School of Medicine and Pharmacology, University of Western Australia, Perth, Australia, <sup>3</sup>School of Surgery, University of Western Australia, Perth, Australia, <sup>4</sup>Institute of Health and Rehabilitation Research, University of Notre Dame, Perth, Australia

## Background

The international randomized TARGIT-A trial compared experimental once-off intra-operative radiotherapy (IORT) to 6-7 weeks of daily conventional external beam radiotherapy (EBRT) in women with early breast cancer. TARGIT-A found IORT to be non-inferior compared to EBRT in terms of reducing the risk of local cancer recurrence and survival, with the preferred treatment approach being IORT during WLE. IORT during WLE may not however be logistically feasible in some instances. Being able to offer IORT as a separate procedure still has the advantage of offering a more convenient treatment option compared to 6 weeks of treatment, but it may come at a higher risk of local recurrence. The investigation of patient preferences for treatment can help identify what risk of recurrence patients would be willing to accept in order to choose IORT over EBRT and in what setting.

## Methods

A cross-sectional study of patient preferences and their determinants in 209 women who had radiotherapy on the TARGIT trial was performed in 2011. Preferences were determined by a self-rated questionnaire using validated trade-off methodology. A further 126 off-trial patients recently diagnosed with breast cancer who were yet to receive any radiotherapy also completed the preference questionnaire between 2013 and 2015.

## Results

TARGIT-A patients completing the patient preference questionnaire showed the only significant factor driving their hypothetical preference for treatment was the treatment they had received as part of the trial, such that 60% of IORT patients would accept IORT at an increased risk of 4%-6% in contrast to 12% of patients in the EBRT group. Only 2% of IORT patients indicated they would not have IORT at all, in contrast to 43% of EBRT patients.

Off-trial patients' preferences showed that 83% found IORT as an acceptable treatment option, with 22% selecting the highest risk presented (an increase of 4-6% compared to EBRT) as an acceptable risk of recurrence in the trade off for convenience and less side effects. Hypothetically, if all treatment modalities offered equivalent outcomes, 13% of patients chose EBRT, 26% chose IORT as separate procedure and 61% chose IORT during WLE as their preferred option.

## Conclusion

Patients receiving EBRT on the TARGIT-A trial were risk-averse, whilst patients who had IORT valued the convenience of IORT highly. TARGIT-A participants justified the treatment they were randomly allocated to, which questioned the validity of post-treatment patient preference studies. Off-trial patients yet to receive radiotherapy were very accepting

of IORT as a hypothetical treatment option, both as a separate procedure and during WLE, even if it came at the cost of a higher risk of recurrence.

This evidence is important to facilitate the decision-making process for patients and clinicians when discussing radiotherapy options for early breast cancer treatable with breast conserving surgery.

# The Challenge of Implementing a New Intraoperative Program: Initial Experience At Our Hospital

Pla M Jesus <sup>1</sup>, Eraso M Aranzazu <sup>2</sup>, Sancho Ismael <sup>3</sup>, Martínez Eva <sup>4</sup>, Picon Cristina <sup>3</sup> Ponce Jordi <sup>1</sup>, Guedea Ferran<sup>2</sup>

<sup>1</sup>Department of Gynaecology, Bellvitge University Hospital (HUB). <sup>2</sup>Department of Radiation Oncology, Institut Català d'Oncologia (ICO). <sup>3</sup>Medical physics Department ICO, <sup>4</sup>Surgical nurse HUB.L' Hospitalet de Llobregat. Barcelona. Spain

## Purpose

To summarize the consecutive steps needed to successfully implement a new Intraoperative device in a large tertiary care hospital. We describe the steps we needed to take before we could start Intraoperative treatments. We also report our initial results.

## Material and methods

Implementation of a new intraoperative radiotherapy system with Intraoperative (IORT-IB) at our hospital was undertaken in two phases. The first phase involved careful consideration and discussion of the suitability of offering IORT-IB. Phase two included all of the practical steps needed to implement Intraoperative treatments.

Phase one: Multidisciplinary meetings to discuss the suitability of offering IORT-IB were organized. Eventually, agreement was reached to implement this new system. Next, we determined the clinical criteria for Intraoperative treatment based on available published data (i.e., the ASTRO criteria for partial breast irradiation). Eligibility criteria for exclusive IORT-IB were: age > 60 years; invasive ductal or other favourable tumour subtypes; unifocal and unicentric lesions < 2 cm; distance between the tumour and the skin (measured by ultrasound without pressure) > 1 cm; G1 or 2; RH positive; pN0 without vascular invasion. Based on this work, we wrote a treatment protocol for the entire process and presented the plan to hospital management.

Phase two: The first step in this phase was to select and renovate the operating room considered most suitable for the procedure. After renovation and adaptation was completed, we requested official permission from the Spanish Nuclear Safety Council to perform this treatment. While awaiting regulatory approval, we trained the nurses in all relevant aspects of IORT-IB and also provided support staff and anaesthesiologists with details about the procedure.

## Results

The first IORT-IB treatment was performed on December 17, 2014, shortly after receiving official approval. To date, we have performed 17 procedures. The most common spherical applicator size was 3 cm. After pathological evaluation of the resected specimens, and in accordance with a risk-adapted approach, 10 patients (41%) were treated with IORT-IB as the exclusive radiotherapy treatment.

## Conclusion

Implementation of this new IORT-IB system required a systematic, step-by-step approach. Moreover, we had to overcome some initial resistance.

Although we are aware that the number of patients who could benefit from IORT-IB will increase in the near future, we have preferred to be cautious by limiting the indications for this treatment during our initial experience with the device.

## TREATMENT OF SKIN CANCER WITH INTRABEAM

Natalia Jankarashvili<sup>1</sup>, Maia Topeshashvili<sup>1</sup>

<sup>1</sup>Tbilisi Cancer Center Ltd, Tbilise, Georgia

### **Purpose**

The standard mean dose of external beam radiotherapy (RT) for skin cancer (BCC and SCC) is 60-66Gy (30-33 fraction) to the tumor or tumor bed. Superficial beams with Intrabeam in some cases may be alternative to EBRT with less side effects, better cosmetic results and quite small number of treatment fractions.

### **Methods and Materials**

Between May 2013 till April 2015 we treated 20 patients with skin cancer (SCC – 5; BCC – 15; 1 patient with 2 keloids), which totally consisted 29 tumor lesions (in some cases several lesions in 1 patient). Minimal dose per fraction was 6 Gy on tissue surface and maximum 21. Minimum number of fractions 3.

Early and late toxicity, cosmetic results and local control were assessed in all cases.

### **Results**

After 6 weeks all patients were evaluated. A very good quality of life and cosmesis was good to excellent in all patients. In 3 patients, in which tumor was very superficial and flat, we have observed complete response after 3 fractions of treatment. In 6 patients we have done total 4 fractions and in 10 patients total 6 fractions. Finally in 13 cases was achieved complete response, in 2 case no result and 5 patients are at this moment under observation.

### **Conclusion**

Our results revealed that Radiotherapy with Superficial beam is excellent treatment option for not deeply invasive tumors located on the flat surface of the skin and also in some exophytic tumors.

## IORT Spherical Applicator Gauges

Simon C. P. Lam, Biophysics Research and Development<sup>1</sup>, Yang Xu, Medical Physics<sup>1</sup>, Matthew West<sup>1</sup>, Medical Physics<sup>1</sup>, Gregory Ingram, Medical Physics, Dosimetry<sup>1</sup>

<sup>1</sup>Cancer Treatment Centers of America at Western Regional Medical Center, Goodyear, USA

There are repeated reminders in the INTRABEAM® Spherical Applicators: Instruction for Use. manual: “Make sure that the applicators have not been cleaned and sterilized more than 100 times and that they are no longer used after that.”

The Technical data sheet also specifies: “Lifetime: Max. 100 cleaning and sterilization cycles.”

In clinical procedures measurement of the cavity and determining the appropriate applicator that has the best fitting to the cavity, is a trial and error process. It is quite frequent, that two or three applicators are used to check for the right fit. And only the best fitted applicator is used for treatment. The other applicators are subjected to cleaning and sterilization that use up the 100 cycles.

It motivates us to search for suitable material as gauges with identical dimension to the applicators in dimension and has no limit to cleaning and sterilization cycles.

Investigation on the appropriate material for the gauges and the concern on the regulatory issues on using the gauges in clinical setting were done with due diligence,

A set of five 316L stainless steel one-piece gauges were fabricated with high precision machining. They serve as simple sizing device with infinite repeated cleaning and re-sterilization. The INTRABEAM® applicators are only used after a proper sizing is done; there is no need for extra cleaning and sterilization on applicators not used for IORT treatment.

# Feasibility of the treatment of eyelid skin basal-cell carcinomas with superficial X-rays with flat applicators of an INTRABEAM device

B. Pinar<sup>1,2</sup>, N. Rodríguez-Ibarria<sup>1</sup>, M.A. Cabezón-Pons<sup>1</sup>, M. Lloret<sup>1,2</sup>, P.C. Lara<sup>1,2</sup>, D. Macías, I. San Miguel

<sup>1</sup>Hospital Universitario de Gran Canaria Dr. Negrín, Radiation Oncology, Las Palmas de Gran Canaria, Spain.

<sup>2</sup>Universidad de Las Palmas de Gran Canaria, Las Palmas de Gran Canaria, Spain.

## Background:

Superficial radiotherapy is the treatment of choice for non-melanoma cutaneous carcinoma, exclusively and adjuvant after surgery with involved margins, close margins or perineural invasion. INTRABEAM device 50 KV x-rays could be useful as a superficial way of delivering radiation therapy. Thickness of tissue treated with flat and surface applicators is only a few millimetres, depending on the applicator's size, making these applicators ideal for superficial lesions, compared to high energy electrons and iridium brachytherapy.

## Methods:

In our Centre, we start including two patients in an Intrabeam superficial radiotherapy using flat applicators. The first patient is a 59 years old male with a basal-cell carcinoma in ocular cantus resected with close margins and perineural invasion. The second patient is a 85 years old female with a basal-cell carcinoma of the eyelid in its third local recurrence after surgery and superficial radiotherapy with 50 KV x-rays twice in other Radiation Department, without any other therapeutic option.

We have decided to use the 10 mm flat applicator, because lesions diameters are less than 0.4 cm, but also 0.3 cm thickness, with the fractionation scheme from Our Lady of Mercy, New York, delivering one weekly fraction of 10 Gy, in three weeks. Flat applicators are going to be employed due to their dosimetric profile, with a deeper delivery of the dose, we decided to specify the dose at 5 mm deep, covering all the volumes.

## Results:

We have performed a previous CT scan and a dosimetric approach using a Radiance Intraoperative Planning System, analyzing the ideal position of applicators depending on clinical target volume localization. Both patients will need ocular protección that is going to be individually designed, and local anesthesia for the procedure. We are going to evaluate the feasibility and tolerability of the whole process, and the acute effects overall conjuntival acute toxicity.

## Conclusion:

Superficial radiotherapy with flat applicators of an INTRABAEAM device seems to be a feasible approach also for treating skin cancer in complicated localizations.

## **INTRABEAM therapy for breast cancer: Comparative Cost Analysis**

B. Pinar<sup>1,2</sup>, N. Rodríguez-Ibarria<sup>1</sup>, M.A. Cabezón-Pons<sup>1</sup>, D. Rey-Baltar<sup>1</sup>, J. Blanco Suarez<sup>1</sup>, L. García-Cabrera<sup>1</sup>, L.A. Henríquez-Hernández<sup>1,2</sup>, M. Lloret<sup>1,2</sup>, P.C. Lara<sup>1,2</sup>.

<sup>1</sup>Hospital Universitario de Gran Canaria Dr. Negrín, Radiation Oncology, Las Palmas de Gran Canaria, Spain.

<sup>2</sup>Universidad de Las Palmas de Gran Canaria, Las Palmas de Gran Canaria, Spain.

### **Purpose**

Using an INTRABEAM device as IORT has well known advantages in the treatment of selected early stage breast cancer. Trying to elucidate if INTRABEAM treatment's cost supposes an added advantage, we have calculated the real cost of IORT in breast cancer, comparing with conventional EBRT.

### **Materials and Methods**

Between Jan-2013 and April-2015, 90 patients of our centre have been treated with IORT during conserving surgery, delivering 20 Gy to the applicator surface. Costs were estimated by: time of operating room (OR), radiation oncologist, physicist and technician; disposable material; applicators and total equipment cost (considering 50 patients per year in 10 years). For EBRT costs' calculations, institutional fares and prices for distance travelled by patients daily were included.

### **Results**

For the 90 IORT patients, treatment time was registered by the device's software, with an average of 24.32 min (15.97-49.07 min), meaning an added OR cost of 338.03 € (212.04-651.6 €). Equipment total cost pro-rated considering 50 patients/year in 10 years was 1600 €/patient. Adding staff time and disposables, procedure's average total cost has been 2,409.03 € (2,283.03-2,722.6 €).

The average 90 EBRT calculated cost was 3,980.43 €/patient. Considering daily patient's trips twice 25 days, total cost increased in 134 € (9.5-2679 €), supposing a final cost of 4,107.33 €. For both procedures there has been included the cost of first appointment and simulation CT scan.

For patients treated with INTRABEAM, an average of 1,754.30 €/patient have been saved, comparing with equivalent EBRT delivered in our department.

### **Conclusion**

INTRABEAM treatment presents an economical advantage comparing with conventional 5 weeks EBRT, with an average saving of 1,754.30 € per patient.

## Experience of 47 cases using INTRABEAM for intracranial malignant tumors

Dr.Mingxing Wu MD<sup>1</sup>

<sup>1</sup>Department of neurosurgery, International Hospital, Tiantan Puhua, Beijing

### Purpose

The purpose of this study was to assess the safety and efficacy of the intraoperative radiotherapy (IORT) using INTRABEAM in patients with intracranial malignant tumors.

### Material and methods

The study involved 47 patients: 28 cases of glioblastoma, 5 cases of anaplastic astrocytoma, 3 cases anaplastic oligodendroglioma, 3 cases of anaplastic ependymoma, 2 cases of astrocytoma, 2 cases of ependymoma, 4 cases of other type intracranial malignant tumor . The dose of IORT ranged from 8-12Gy. Prescription depth was 2mm. Overall survival (OS) of 26 cases of glioblastoma (GBM) which were divided into primary group and recurrent group were assessed. The statistical analysis entailed Kaplan-Meier curves. The threshold of statistical significance was set at  $p = 0.05$ .

### Result

There weren't severe radioactive damage in all of the patients after IORT. Mean OS of primary GBM group and recurrent GBM group were  $19.2 \pm 2.2$  months and  $10.4 \pm 3.3$  months, respectively. Mean OS of primary GBM were significantly better than recurrent ones ( $p = 0.027$ ).

### Conclusions

INTRABEAM is a safe IORT facility. It can significantly improve the prognosis of GBM. It has a good application prospect in Neurosurgery

## **IORT OF PRIMARY BRAIN TUMORS AND BRAIN METASTASES**

Natalia Jankarashvili<sup>1</sup>, Maia Topeshashvili<sup>1</sup>, Giorgi Magalashvili<sup>1</sup>; Edisher Magalashvili<sup>1</sup>

<sup>1</sup>Tbilisi Cancer Center Ltd, Tbilise, Georgia

### **Purpose**

The standard radiotherapy (RT) course of primary brain tumor is maximum safe resection, chemo-RT and adjuvant chemotherapy. After this kind of multidisciplinary treatment median disease free survival is about 12-14 months. During recurrence, secondary course of EBRT is not allowed and the only remaining choice is chemotherapy and operational intervention. The standard time from excision of tumor from brain, till the beginning of RT course is 3-4 weeks. In some cases at this time tumor is enlarging and reaching almost the same preoperative volume.

Intraoperative radiotherapy (IORT) may decrease tumor progression time after the operation, before beginning of RT. Also this treatment modality may perform local control of the tumor bed, once tumor excision of primary brain tumors are performed and also of brain metastasis in not irradiated as well as in previously irradiated patients.

### **Methods and Materials**

Between November 2014 till April 2015 we have evaluated 6 patients with brain tumor operated and IORT applicator was placed in the tumor bed. Prescribed dose was 10Gy on 2mm depth in case of brain metastasis and 20Gy on tissue surface in case of primary brain tumor. The meningeal sheet in all cases was protected from radiation. Acute and late toxicity and local control were assessed. Local control was evaluated on contrast enhanced brain MRI.

### **Results**

After a median follow-up during 5 months no local recurrences were observed within the primary tumor bed. All patients are alive without disease. No Adverse Events (AE) (late subcutaneous fibrosis within the boost area) were detected. A very good quality of life was in all patients.

### **Conclusion**

Our results revealed, that IORT given in primary and metastatic brain tumors is safe, no clinical or investigated side effect were detected. All patients are alive and no recurrence on brain MRI yet.

# High dose-low energy intraoperative radiotherapy in treatment of malignant parotid tumors

Bahman Emami, MD<sup>1</sup>, Anil Sethi, PhD<sup>1</sup>, Mehee Choi, MD<sup>1</sup>, Eric Thorpe, MD<sup>2</sup>, Richard Borrowdale, MD<sup>2</sup>, Bonnie Chinsky, MS<sup>1</sup>, Karan, MD, MBA<sup>1</sup>, William Small, MD<sup>1</sup>

<sup>1</sup>Department of Radiation Oncology, Loyola University Medical Center, Maywood, IL 60153, USA,

<sup>2</sup>Department of Otolaryngology, Loyola University Medical Center, Maywood, IL 60153, USA

## Objective

The aim of this study was to investigate the feasibility of high dose-low energy intraoperative radiation (IORT) therapy using INTRABEAM<sup>®</sup> (Carl Zeiss Surgical, Oberkochen, Germany) in treatment of malignant parotid tumors.

## Methods and Materials

Between March 2014 and March 2015, 7 patients with primary malignant parotid tumors received intraoperative radiation therapy after surgical resection at Loyola University Medical Center (Maywood, IL). The median dose prescription was 6Gy (range, 5-8Gy) prescribed to 5mm depth in a single fraction delivered with use of cylindrical shaped flat applicator attached to 50kV x-ray energy source (INTRABEAM). The flat applicator (size 3-6cm) was placed at the high-risk area within the surgical cavity (parotid bed), which was delineated by the surgeon as the area with high likelihood for close or positive margins. The average IORT delivery time was 20 minutes. The single fraction was one the sole treatment for one patient, while the remaining six patients received additional external beam radiotherapy (median dose 50Gy) four weeks after surgery.

## Results

All seven patients underwent successful completion of intraoperative radiotherapy. With follow up time of one to 12 months, there have been no acute side effects or complications related to IORT. We are now in the process of initiating a prospective trial evaluating the use of IORT for malignant parotid tumors at our institution.

## Our limited experience in abdominal INTRABEAM IORT: a report on 4 cases

Günther Gademann<sup>1</sup>, Peter Hass<sup>1</sup>, Serban Costa<sup>2</sup>

<sup>1</sup>Clinic for radiotherapy, <sup>2</sup>Womens' hospital, University of Magdeburg

### Purpose

Is there an application area for Intrabeam-IORT in abdominal tumors? What is the range of good indications? What applicators and radioprotection materials are useful?

### Materials and Methods

We treated intraoperatively 4 very selected patients. Three patients had recurrent disease of gynaecological primaries, two of them had previous radiotherapy or radiochemotherapy, one patient had endometrial cancer and a low grade NHL. She refused any locoregional radiotherapy and chemotherapy and only admitted to the IORT during resection of a infiltrating aortal lymphnode metastasis (adeno-ca).

We treated all patients with a single surface doses between 12 and 14 Gy using applicators with 3 and 5 cm diameter, radioprotecting sheets were attached in every case. One patient received in addition a radiochemotherapy of the pelvis with 50,4/1,8 Gy and cisplatin

### Results

The indications were set when the local recurrence was removed and suspicious however it was a suspicious for R1-resection. The applicator diameter was manually and visually selected and had to fit into the resection area. In all patients the ball shaped applicators had satisfactory contact to the resection hole. In one patient with a deep paravaginal recurrence the length of the applicator was borderline.

There were no acute or late side complications in all patients.

One patient (with additional RCT) has stable disease since 11 months, two recurred out-field in the pelvis after 3 and 12 months, one shows local stability, however developed distal metastases.

### Conclusions

IORT in the pelvis and par aortal region for gynaecological recurrent tumors was feasible. The normal ball shaped applicators fitted very well to the surgical hole, radioprotection for the bladder, the bowel or the nerves was necessary. All patients showed local control, however two recurred regionally, one distally. Only one is tumor free since 11 months.

The indications were very carefully selected and the decision for IORT was finally made intrasurgically. We can currently see no definite indication for Intrabeam IORT, on the other hand it is a safe treatment with a potency for very local cure.

# First experience of intraoperative radiotherapy in pancreatic cancer and liver colorectal metastasis combine treatment

Shabunin A.V.<sup>1</sup>, Bedin V.V.<sup>1</sup>, Tavobilov M.M.<sup>1</sup>, Karpov A.A.<sup>1</sup>

<sup>1</sup>Russian medical academy of postgraduate study, Botkin Moscow city hospital, Moscow

## Background

Overall survival rate improving in patients with ductal adenocarcinoma of the head of pancreas and patients with colorectal liver metastasis requires aggressive additional treatment options.

## Methods

Records for 11 patients with colorectal liver metastasis (CRM) and 13 patients with pancreatic head cancer treated by intraoperative radiotherapy (IORT) in Pirogov Moscow Municipal Hospital and in Botkin Moscow Municipal Hospital since august 2013 were reviewed. IORT was performed using Carl Zeiss Intrabeam PRS 500 system. After resection stage and confirming negative frozen section margin results and no local bleeding a single dose of 10-15 Gy IORT boost was delivered using 50-kV x-rays to a depth of 1 mm from the applicator surface. Depending on the tumor size we used applicators from 1,5 to 5 cm. Then was made histological study and electron microscopy of irradiated resection margin.

## Results

All of 11 patients with CRM underwent atypical resection (R0) with IORT and 13 patients underwent pancreatic head resection with IORT. The median dose of IORT was 12 Gy. Histologically it was no evidence of radiation injury, but after electron microscopy examination it was observed fat cells and endothelium destruction. The median follow-up period was 18 months. At the time of the analysis, 4 (36%) patients from CRM IORT group had disease recurrence (new liver metastasis in the same and others liver segments). The 1-year local control (LC) and overall survival (OS) rates were 63% and 87%. As for pancreatic cancer group, 5 (38,5%) had disease recurrence (liver metastasis). The 1-year local control (LC) and overall survival (OS) rates were 100% and 82%.

## Conclusion

The use of IORT in CRM and pancreatic surgery was associated with good local control and OS. Effective influence by Carl Zeiss Intrabeam PRS 500 system on liver tissue and pancreatic head bed was confirmed.

# Intraoperative radiotherapy in locally-advanced and recurrent rectal cancer: retrospective review of 68 cases

Sergey Potemin<sup>1</sup>, Ivan Uvarov<sup>1</sup>, Igor Vasilenko<sup>1</sup>

<sup>1</sup>Department of Colorectal Surgery of the Regional Oncological Center of Krasnodar, Krasnodar, 350040, Russia.

Correspondence to: Sergey Potemin, MD, PhD. Department of Colorectal Surgery of the Regional Oncological Center of Krasnodar, Dimitrov Street 146, Krasnodar, 350040, Russia. Email: spotemin@hotmail.com.

## Background

The addition of intraoperative radiation therapy (IORT) to the multimodal treatment of locally advanced or recurrent rectal cancer may improve local control. Although electron beam IORT is the most common modality, technological advances now permit the use of photon beam IORT. However, few studies have investigated these devices in rectal cancer.

## Methods

Retrospective review of patients (pts) treated with surgery and IORT for stage T3-T4 rectal cancer or pelvic recurrence between December 2012 and December 2014. Patients with distant metastasis were excluded. IORT was delivered with the Intrabeam Photon Radiosurgery System (PRS). The study sample included 68 pts (41 males, 27 females) ranging in age from 33 to 82 (median, 67) years. Most patients (47) had stage II primary rectal cancer (PRC), while 21 pts had stage III disease. Nine of this pts presented recurrent rectal cancer (RRC). Wanebo staging for the nine PRC cases was: Tr3 (6 pts), Tr4 (2 pts), and Tr5 (1 pt). A dose of 5.07 Gy was prescribed to a depth of 1 cm (surface dose range was 9.4-17.0 Gy; median, 14.8 Gy). Median duration of IORT was 31.9 (range, 15-36) minutes. The spherical applicator was 5 cm in diameter in 61 cases and 4.5 in seven cases. A subgroup analysis (23 pts) was performed to assess those patients with the longest follow-up (range, 17-28 minutes; median, 20.7 minutes). Of these, 18/23 (78%) received adjuvant chemotherapy. Overall survival (OS) and disease-free survival were calculated with the Kaplan-Meier method.

## Results

In 18 of the 68 pts (26.4%), the tumour was attached to the sidewall. Margins were positive in 7 pts (10.3%). In the 23 pts subgroup with long-term follow-up, OS was 87.0%. Local recurrence occurred in 3 of 23 pts (13%). Four cases (17.4%) of distant metastasis (lung: 3 cases; liver: 1 case) were recorded. No intraoperative complications attributable to IORT were registered. Median postsurgical discharge time was 17.7 (range, 9-25) days. No cases of hydronephrosis or ureter fibrosis after IORT were documented.

## Conclusions

Intrabeam PRS appears to be a safe technique for delivering IORT in rectal cancer patients. Although operating time increased slightly, outcomes in terms of toxicity, local recurrence, and survival were all quite good in comparison with other IORT delivery methods.

Keywords: Colorectal cancer; intraoperative radiation therapy (IORT); local disease recurrence

# **Preliminary outcome of intraoperative radiotherapy for High-risk patients with differentiated thyroid cancer T4 primary tumors or recurrent lesions: A single-institute experience**

Weidong Wang<sup>1</sup>, Zhaobin Li<sup>1</sup>, Weiwei Yu<sup>1</sup>, Youben Fan<sup>1</sup>, Xiulong Zhang<sup>1</sup>, Lihua Peng<sup>1</sup>, Lihua Zhang<sup>1</sup>

<sup>1</sup>Department of Radiation Oncology, Shanghai Jiaotong University affiliated Sixth People's Hospital, No. 600 at Yishan Rd. Shanghai 200233.

## **Purpose**

Few data exist on using IORT for high risk patients with well-differentiated thyroid cancer patients T4 primary tumors and recurrent lesions. The purpose of the present study was to review our experience with the use of IORT for T4 primary or recurrent cancer of the thyroid gland.

## **Methods and Materials**

Between 2014.04 and 2015.04, 10 patients were treated with gross total resection and IORT for T4 primary or recurrent cancer of the thyroid gland, including 5males and 5females. The median age was 51.3years (range 30–62). IORT was administered as a single fraction of 4 Gy with 50 KV X ray using Intrabeam system, flatten applicator was utilized in diameter of 2-5 cm. The median follow-up period was 6.5mons.

## **Results**

No patient experienced local recurrence, the 1-year overall survival rate after surgery and IORT was 100%. No perioperative fatalities occurred. No complications developed in all patients.

## **Conclusions**

IORT results in effective local disease control at acceptable levels of toxicity and might be considered for patients with T4 primary or recurrent cancer of the thyroid gland. Further study is needed to prove the conclusion.

# Monte Carlo Modeling of IORT Dose Distributions in a Commercial Treatment Planning System

Anil Sethi PhD<sup>1,2,3</sup>, Bonnie Chinsky MS<sup>1,2,3</sup>, Marie Vidal PhD<sup>1,2,3</sup>, Paula Ibáñez MS<sup>1,2,3</sup>, Jose Udias PhD<sup>1,2,3</sup>, Carlos Illana Alejandro PhD<sup>1,2,3</sup>

<sup>1</sup>Loyola University Medical Center, Maywood, USA; <sup>2</sup>Universidad Complutense de Madrid, Spain; <sup>3</sup>Radiance GMV, Madrid, Spain.

## Purpose

IORT dose distributions for flat and surface applicators were measured at our institution. For real-time 3D rendering of patient dose, a Monte Carlo (MC) based dose calculation algorithm has been recently developed and implemented in a commercial treatment planning system (TPS). We compare measured and MC based IORT doses in realistic phantoms consisting of tissue, air, and bone materials.

## Methods and Materials

Using a 50-kV INTRABEAM X-ray device equipped with flat and surface applicators, percent depth-dose (PDD), dose-profiles (DP) and output factors (OF) were obtained. The effect of tissue inhomogeneities on dose distributions was examined by placing air-cavities and bone and tissue equivalent materials of different density ( $\rho$ ), atomic number (Z), and thickness ( $t = 0-4\text{mm}$ ) between applicator and detector (film or ion chamber). For dose calculations, a hybrid MC model that accounts for photoelectric and Compton interactions ( $\leq 50\text{kV}$  X-rays) was used. The MC model uses applicator geometry information, measured dose in water and a genetic algorithm to fit the X-ray energy spectra. Implementation in a commercial TPS (Radiance, GMV Spain) further allows fast real-time CT dose calculation. The latter can be used for IORT pre-planning (realistic dose calculations, dose prescription, and applicator selection) and quality assurance (treatment time verification).

## Results

The hybrid MC model has been shown to be robust in water medium providing good agreement (1%/1mm) with measured doses. Based on our inhomogeneity measurements, dose enhancement due to 1mm, 2mm, 3mm and 4mm air cavities was 10%, 16%, 24%, and 35% respectively. X-ray attenuation by 2mm thick cortical bone resulted in a significantly large (58%) dose decrease. These results are currently being validated using hybrid MC model. Our subsequent goal is to calculate accurate doses in patient treatment geometries.

## Conclusions

Fast and accurate real-time calculation of IORT dose distributions is now feasible within a hybrid MC model. Coupled with a commercial TPS, this can radically improve IORT planning, delivery and documentation.

# An in-air and in-water investigation of the INTRABEAM system dosimetry using a Monte Carlo source model

<sup>1</sup>P. Watson, <sup>1</sup>M. Popovic, <sup>1</sup>J. Seuntjens.

<sup>1</sup>Medical Physics Unit, McGill University, Montreal, Canada.

## Purpose

Air kerma standards for low energy x-ray devices used in electronic brachytherapy or intraoperative radiotherapy critically depend on accurate knowledge of the primary spectrum of the source. Using the EGSnrc Monte Carlo (MC) code, a source model of the INTRABEAM system has been developed and validated in-air, using detailed attenuation measurements. This model was then used to study dosimetric properties in water for the bare source and spherical applicators.

## Materials and Methods

The INTRABEAM source was modeled using the EGSnrc user code, cavity. Photon fluence spectra emitted by the source were scored for the bare probe and spherical applicators of 3.5 cm, 4.0 cm, and 4.5 cm diameter. HVL was determined analytically from the simulated spectra by calculating the attenuation of air-kerma for a given thickness of aluminum and source-to-detector air gap. Beam collimation was provided by a lead cylinder surrounding the INTRABEAM source. Foils of high purity aluminum were placed at the exit of the collimator, and attenuation measurements were performed using a PTW 23342 parallel-plate chamber. The measured HVL was determined by curve fitting of the experimentally determined attenuation data.

For simulations in water, the egs\_chamber user code was used to calculate the dose from the INTRABEAM source to a small water cavity with the same dimensions as the active volume of a PTW 34013 soft x-ray chamber. The complete PTW 34013 chamber was also explicitly modelled to study chamber perturbation factors. Simulated percent depth dose curves (PDDs) for the bare probe and spherical applicators were derived and compared with measured reference data. The effect of volume averaging in steep dose gradients due to chamber dimension tolerance was investigated.

## Results and Conclusions

The INTRABEAM spectra generated with EGSnrc agree well with published results generated using GEANT4[1]. Our results indicate that the presence of the lead collimator, due to the emission of fluorescent x-rays, had a non-negligible effect on HVL measurement for the spherical applicators. Upon comprehensive analysis of sources of experimental errors, we conclude that the simulated HVLs were in good agreement with measurement for the bare probe and spherical applicators.

The simulated PDDs for the spherical applicators were in good agreement with the measured reference data (RMS = 1.9%, 1.5%, and 0.8% for the 3.5 cm, 4.0 cm, and 4.5 cm applicators, respectively). For the bare probe PDD, the percent difference between simulation and measurement in the steep dose gradient close to the source (< 5 mm) was as large as 10%. The differences in this region may be explained by chamber volume averaging and a shifted point-of-measurement.

[1] Nwankwo, O., et al. "A virtual source model of a kilo-voltage radiotherapy device", *Physics in Medicine and Biology*, 58.7 (2013): 2363.

# Liquid Scintillation Dosimetry of an Intraoperative X-ray Source

Peter Sandwall<sup>1,2,3</sup>, Cameron Ditty<sup>1,2</sup>, Jessica Guarnaschelli<sup>2</sup>, and Ching Ho<sup>2</sup>

<sup>1</sup>Vantage Oncology, Manhattan Beach, CA

<sup>2</sup>TriHealth Cancer Institute, Montgomery, OH

<sup>3</sup>Corresponding author: peter.sandwall@vantageoncology.com

## Purpose

A method for obtaining dose distributions from an intraoperative x-ray source is demonstrated. Luminescent images were digitally acquired and analyzed, with relative dose plotted as a function of distance from the bare probe tip.

## Materials and Methods

A leaded glass phantom was filled with commercial liquid scintillation counting (LSC) fluid, Ultima Gold (PerkinElmer, Waltham, MA). 8.0 megapixel CMOS detector was used to collect images and videos. Red, green, and blue color channels were separated. The blue channel was selected with smoothing applied and isodose lines overlaid. The elemental composition of LSC fluid was compared to water and soft tissue.

## Results

Acquired videos allowed for visualization of the swept nature of the beam. The LSC fluid was determined to have a lower effective Z (5.9) than water (7.2) and tissue (7.1). Depth dose data compared to Monte Carlo values for water observed an under-response (max, 9.49% at 5mm).

## Conclusion

The dose distribution of an intraoperative x-ray source was visualized with fluorescent imaging. Additional mathematical refinement is required to obtain meaningful results comparable to the clinical depth dose data. Optimization of LSC fluid composition, photographic parameters for image collection, and derivation of correction factors are attractive areas of future study.

# Optimized Monte-Carlo based dose computation for low energy X-rays IORT implemented in Radiance TPS.

M. Vidal<sup>1</sup>, P. Ibáñez<sup>1</sup>, P. Guerra<sup>2</sup> and J.M. Udías<sup>1</sup>

<sup>1</sup>Grupo de Física Nuclear, Dpto. Física Atómica, Molecular Nuclear, Moncloa Campus of International Excellence, Universidad Complutense de Madrid, Madrid, Spain, <sup>2</sup>Department of Electronic Engineering, ETS de Ingenieros de Telecomunicación, Moncloa Campus of International Excellence, Universidad Politécnica de Madrid, Madrid, Spain

## Introduction

Intra-Operative Radiation Therapy with low energy X-rays (XIORT) is largely used for breast cancer treatment [1] and more and more centers are now involved in other clinical applications such as kyphoplasty [2] and superficial intraoperative radiotherapy [3]. These treatment areas are heterogeneous and dose gradients are very high. Users need a precise and fast method to compute dose distributions in patient data. This work proposes a fast and precise method to calculate dose distributions delivered by INTRABEAM® (Carl Zeiss editec) from pre-processed Monte-Carlo phase space data, optimized to user provided simple experimental data.

## Methods

We developed a strategy to determine realistic Phase Space (PHSP) files. On one hand, monoenergetic PHSP files were generated with a full Monte-Carlo simulation using the penEasy [4] code, a simulation for each energy up to 50 keV, in 1 keV bins. It takes several hours of CPU time to build up a database, but this only needs to be done once. These monochromatic PHSP files were binned and parameterized in terms of the relevant variables to make them easy to manipulate. On the other hand, percentage depth dose (PDD) curves were computed from each of the monoenergetic PHSP. A combination of those PDD is fitted to the experimental PDD of each applicator by means of a genetic algorithm [5] which optimized the energy spectrum. Finally, the binned precomputed monoenergetic PHSP files and the energy spectrum obtained by the genetic algorithm were combined to build the PHSP file optimized to describe the dose distribution of the considered applicator. From the final optimized PHSP file, the dose is computed by an in-house hybrid Monte Carlo algorithm [6] which takes into account condensed history simulations of both photoelectric and Compton interactions for X-rays up to 50 keV. The whole dose optimization and computation process was validated against Monte-Carlo simulations performed with penEasy as well as with gafchromic films dose measurements both in water and heterogeneous phantoms (bone, lung, air) for the spherical, needle, surface and flat applicators.

## Results

Once the monoenergetic PHSP files and PDD database has been computed and stored, building the PHSP file optimized to a particular depth-dose curve in water only takes a few minutes in a single core (i7@2.5 GHz), for all the applicators considered in this work. From that PHSP file, the hybrid Monte Carlo code is able to compute dose distributions within 5 minutes. For all the applicators, dose distributions computed with the proposed strategy are in good agreement with the Monte Carlo simulations performed with penEasy. Gamma index calculation shows that more than 95% and 90% of the voxels fulfill the dose distance criteria of 2%/1mm in water and in the heterogeneous phantoms respectively.

## Conclusion

The Monte Carlo PHSP files fitted to the experimental PDD for each applicator as described here, combined with the hybrid MC dose calculation tool compute fast and precise dose. This method is implemented into Radiance® (GMV SA, Spain), an IORT Treatment Planning System, for spherical, needle, surface and flat INTRABEAM® applicators.

## References

- [1] Vaidya, J. S. *et al.* 2010. TARGIT-A trial. *Lancet*, 376, 91-102.
- [2] Schneider, F. *et al.* 2011. *Int J Radiat Oncol Biol Phys.* 81(4):1114-9.
- [3] Schneider, F. *et al.* 2014. *J Appl Clin Med Phys*, 15, 4502.
- [4] J. Sempau *et al.* 2011. *Med. Phys.* 38(11), 5887.
- [5] C. Fernández-Ramírez *et al.* 2008. *Phys. Rev. C* 77(6), p. 065212.
- [6] M. Vidal *et al.* 2014. *Radiother. & Oncol.* 111(S1).

## Practical aspects to calibration, commissioning and using a breast IORT system

D. Dommett, Principal Clinical Scientist<sup>1</sup>, S. Khan, RPA and physicist<sup>2</sup>

<sup>1</sup>Southend General Hospital, Southend, UK; <sup>2</sup> Swindon Great Western Hospital, Twick, UK

### Purpose

Intrabeam IORT is not only suitable, but perhaps the method of choice for providing breast radiotherapy in non-radiotherapy centres. A few sites in the UK provide this service with a couple more starting up. However it is still not a widespread technique in the UK, possibly due to the cost and difficulties involved. However recent examples such as the Princess Alexandra in Harlow and the Great Western Hospital in Swindon have shown it can be achieved successfully. This presentation discusses some of the practical aspects involved based on experiences at both of these hospitals.

It covers the radiation protection requirements, such as room surveys, equipment and monitoring. It highlights the importance of staff training and some of the issues that arise, especially regarding the change in working practices.

An explanation of the calibration and commissioning required is given, along with examples and results obtained. This will include the tests for HVL, Output, Isotropy and PDD.

The cost and time implications associated with the procedure are covered, along with a system walk through, critical information and numerous little hints for those considering introducing this service at their centre.

### Results

The results of room surveys at two Trusts will be presented and how the issues that arose were addressed, along with the different methods used for initial commissioning and audit. A comparison of the different results and what centres should expect will be explained.

### Conclusion

We believe that when the National Institute for Clinical Excellence (NICE) in the UK authorises this treatment many new smaller centres will be implementing Intrabeam IORT to address the needs of local patients and provide an alternative to the time, difficulties and expense associated with conventional radiotherapy. The presenters have experience in setting up this service at different centres and so provide slightly differing perspectives based on their expertise. This presentation should help answer questions and provide relevant information for anyone considering implementing this service at their centre.

# Micro-Commissioning of an INTRABEAM Intraoperative Radiotherapy (IORT) X-ray Source (XRS) using EBT3 Gafchromic film in conjunction with multichannel film dosimetry and Matlab analysis

T. Burrows<sup>1</sup>

<sup>1</sup>Royal Free Hospital, Radiotherapy Dept., London

## Purpose

The Zeiss INTRABEAM® source, as in other departments, is returned for calibration on an annual basis after which it must be re-commissioned for clinical use. As a Zeiss water tank is unavailable in this department, re-commissioning currently involves an output measurement in solid water using an ion chamber, an assessment of isotropy using thermoluminescent dosimeters and measurement of depth doses using EBT radiochromic film [1]. This is a very time consuming process and due to the characteristics of the radiation and equipment the results may be subject to positional errors. By using laser micro machined EBT3 Gafchromic film, multichannel film dosimetry and Matlab analysis it is possible to streamline the re-commissioning process into a single check.

## Material

- Laser micro machined EBT3 Gafchromic film.
- Epson 11000 XL Scanner
- Matlab

The film is machined to fit a 4.5 cm applicator. Central axis markings aid in film positioning and source location. Film is scanned using an Epson 11000XL scanner and dose maps are created using Matlab and an in-house triple channel film dosimetry [2,3].

## Methods

The film is taped around a 4.5cm applicator ensuring good contact with the surface. The whole arrangement is submerged in water and irradiated with a prescription of 1.2 Gy at 1.0 cm from the probe surface. Measurements of output, isotropy and depth doses are performed for a single exposure. Symmetry is assessed at 1.0 cm from the surface of the probe and is normalised to the Z-axis. Assuming a zero degree position on the Z-axis, symmetry is assessed from -150° to +150°. Depth dose is assessed on the Z-axis and absolute dose is measured at the prescription point. Two film exposures are performed to characterise both the X and Y axes.

## Results

Symmetry results vary from -7 to +4% which is in good agreement with the anisotropic distribution previously recorded measured using thermoluminescent dosimeters. Typical absolute dose measurements are reproducible to within 3% but overestimate dose at the prescription point by 21% on average. Measured depth doses agree to within  $2\% \pm 3\%$ . For current methods a tolerance of 5% and action level of 10% is in use.

## Conclusion

Results indicate that EBT3 is a viable option to assess percentage depth dose and probe symmetry and provides consistent absolute dose measurements. The technique is still experimental and will need further investigation, particularly in the assessment of absolute dose but, shows the potential to streamline the re-commissioning process if a Zeiss water tank is unavailable or act as a quick additional independent check on the INTRABEAM system. Comparing the technique with current practice at the Royal Free London micro-commissioning using film can fully characterise the system in a significantly shorter time requiring fewer exposures.

## References

1. Eaton DJ, Earner B, Faulkner P, Dancer N. *A national dosimetry audit of intraoperative radiotherapy* Br J Radiol. (2013) Dec;86(1032):20130447.
2. Micke A, Lewis DF, and Yu X. *Multichannel film dosimetry with nonuniformity correction*. Med. Phys. 38(5), 2523 (2011).
3. Micke A, Lewis DF, and Yu X. *An efficient protocol for radiochromic film dosimetry combining calibration and measurement in a single scan*. Med. Phys. 39(10), 6339 (2012).

# Proposal for a quality assurance programme and measurement of skin dose in breast treatments with radiochromic film

Sancho I<sup>1</sup>, Onses A<sup>1</sup>, Eraso A<sup>2</sup>, Pla M.J<sup>3</sup>, Ponce J<sup>3</sup>, Guedea F<sup>2</sup>, Picon C<sup>1</sup>

<sup>1</sup>Medical Physics department, Catalan Institute of Oncology (ICO), <sup>2</sup>Department of Radiation Oncology, Catalan Institute of Oncology (ICO), <sup>3</sup>Department of Gynecology, Bellvitge University Hospital (HUB), L' Hospitalet de Llobregat, Barcelona, Spain

## Purpose

In October 2014, an IntraBeam was installed in our hospital. From measurements and verifications done during acceptance and commissioning, we propose a periodic quality assurance programme of the device. Moreover, we have implemented a systematic method for measuring skin dose with radiochromic film in breast treatments.

## Material and Methods

1- Proposal for a quality assurance programme: During commissioning we verified different dosimetric and geometric parameters of both X-ray source (XRS) and applicators. A subgroup of these tests was selected for a periodic quality assurance. Frequency and tolerances were defined based on results obtained both in acceptance and commissioning.

2- Measurement of skin dose in breast treatments with radiochromic film: Before irradiation the Surgeon places four 2 cm x 2 cm pieces of sterilized EBT2 Gafchromic film on the patient skin around the surgery scar always at the same positions: cranial, caudal, right and left with respect to patient orientation. After treatment, these pieces are scanned and values are converted into dose by using a calibration curve for sterilized films at specific beam quality. 90<sup>th</sup> percentile of dose values within film piece is selected for dose reporting. Doses measured are compared to values estimated from the applicator surface to skin distance measured by the Radiation Oncologist during surgery.

## Results

1- In the following table, tests and tolerances are presented for the proposed biannual quality assurance programme:

Test	Commissioning		Biannual quality assurance programme			
	XRS	Applicator	XRS	Tolerance	Applicator	Tolerance
PDD	√	√	√	±8% at 20 mm		
Beam quality	√	√	√	3%		
Isotropy	√	√	√	3%		
Dose linearity	√					
Integrity and geometry		√			√	Functional

2- In the following table, we present skin dose measured for the first 8 patients and comparison to dose estimation. Results show that in general, theoretical dose calculated from estimation during surgery can be taken as an upper limit for the skin dose, but in one case, maximum dose measured was 75% more than dose expected. In this case, applicator size was 2.5 cm that could have led to a less accurate positioning of the applicator inside the cavity.

	App. diameter (cm)	Distance app-skin (mm)	Estimated dose	Left	Caudal	Right	Cranial	Difference max.-estim. (%)
Patient 1	3.0	15	3.5	1.8	1.0	1.8	2.2	-37
Patient 2	3.5	22	1.6	1.6	1.6	0.8	0.6	0
Patient 3	3.5	15	2.9	1.5	2.5	2.3	1.7	-14
Patient 4	3.5	12	3.9	2.2	2.6	1.9	2.8	-28
Patient 5	3.5	10	4.8	2.6	1.5	1.7	2.4	-46
Patient 6	3.5	15	2.9	1.5	1.2	1.5	2.0	-31
Patient 7	3.5	15	2.9	1.2	1.0	1.8	1.5	-38
Patient 8	2.5	13	3.6	2.8	2.2	5.1	6.3	+75

### Conclusions

It is important to define both tests and tolerances of a periodic quality assurance programme of IntraBeam before starting treatments.

It is feasible to measure skin dose for breast treatments with radiochromic films. It is important to measure skin dose to detect any inconsistency with expected values. Higher dose measured could be helpful to follow-up any possible skin toxicity.

# Dosimetric characterization of INTRABEAM® flat and surface applicators for dermatologic applications

M. Goubert<sup>1</sup>, L. Parent<sup>1</sup>

<sup>1</sup>Département d'Ingénierie et de Physique Médicale, Institut Universitaire du Cancer de Toulouse, France, Université Paul Sabatier Toulouse III, France

## **Purpose/Objectives**

The Intrabeam system is a miniature accelerator emitting a 50 kV isotropic radiation. Its flat and surface applicators convert a spherical dose distribution into a flat one. This study aims at characterizing the dosimetric behaviour of these applicators for dermatologic applications.

## **Material/methods**

Dosimetric characterization was carried out in two steps. Firstly characterization was made in standard conditions for dermatologic applications, which is with the applicator directly on contact with the skin. Secondly, characterization was made in more clinical conditions, with obliquities and heterogeneities.

## **Results**

Behaviours of flat and surface applicators are different and have already been studied before. In standard conditions, dose rates and dose distribution results differ from previously published studies due to differences in the x-ray source design. The study showed that when contact between the applicator and the skin of the patient is not perfect there is a dose distribution spread on the edge of the irradiation field where the contact is not made. Dose loss due to lack of backscatter radiations is significant. By contrast, influence of a denser material behind the measurement point has no significant influence on the dose at this point. Thickness of tissue treated with flat and surface applicators is only a few millimetres, depending on the applicator's size.

## **Conclusion**

The INTRABEAM® system with surface and flat applicators is a reliable way of treating superficial cutaneous malignancies as long as there is a good contact between the applicator and the skin.