



ORIGINAL RESEARCH PAPER

Oncology

A LITERATURE REVIEW OF RECTAL DOSIMETRY IN INTRACAVITARY BRACHY THERAPY

KEY WORDS:

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Rectal dosimetry has fascinated the radiation oncologist ever since the inception of brachytherapy in cervix. This is perhaps due to the accessibility of rectum as a region for dosimetry compared to other organ at risks and due to the fact that rectum by all means is a site which delimits the target volume dose

From available literature the first of the study in this regard was by SIEVERT, R. M. et al in the paper **Radium- und Ultrastrahlung neubeinigen Untersuchungen tiber die Anwendbarkeit derselben in der Physik und der Medizin;** But English translation of this study is not available but through metanalysis it is incurred that it was the first of the attempt in this regard carried out at RADIUM-HEMMET . It was pioneering study which came at the following important conclusions on why the measured dose cannot be considered because of the technical difficulties encountered in obtaining them. Sievert points out mainly the following points for this discrepancy (a) the position of the patient at the time of measurement (i.e., lithotomy position, knee-chest position, or supine) ; (b) the position and angle of the probe; (c) pressure applied to the tip of the instrument against the mucosa; (d) the variations of the individual doctor in carrying out the technic; (e) instrument variations (e.g., finite diameter of ionization chamber, method of calibration); and (f) interference caused by the hardware of the radium carriers, requiring that they be moved slightly in order to insert the probe into the bladder. The study though the first of its kind was a landmark study as it paved way for further studies which aimed at overcoming each of these nuances

While addressing these issues Kottmeier and Gray in their study **"Rectal and Bladder Injuries in Relation to Radiation Dosage in Carcinoma of the Cervix. A 5 Year Follow-up"** made a very important observation that the correlation of measured doses with complications is not a linear one. In the series it was observed that there was practically no correlation whatsoever between Grade I bladder and rectal complications and the bladder-rectal doses; correlation was better in the more severe complications, but again, a well defined linear increase in complications with increasing dose was not apparent. The above study became more robust as the study by Fletcher et al **Clinical Significance of Rectal and Bladder Dose Measurements in Radium Therapy of Cancer of the Uterine Cervix,** in which a review of about 500 cases in came up with the same conclusion that there was not always a direct correlation between increasing dose and the complication rate; factors other than dose (e.g., procidentia, cystocele, rectocele, race, age) were also implicated. These findings diverted the direction of further studies to address the relevance of rectal dosimetry.

In the post 1950's with the advent of supervoltage, external radiation now contributes a greater part to the treatment program with proportional decrease in dose from radium. This significantly deviated the direction of studies with respect to rectal dosimetry because the external radiation delivered to the bladder and rectum

is easily calculated, one was less likely to find severe extremes of dosage in these organs because the percentage contribution of radium has decreased and the opportunity for over dosage is consequently diminished. With the change to increasing total-pelvis irradiation, the increased volume of tissue exposed to high doses has partly replaced the high local radium doses as a cause of complications. This hypothesis was further addressed in the study by CHAU et al in their study **Complications in High Dose Whole Pelvis Irradiation in Female Pelvic Cancer.**

Though there was a reduced interest in the research area due to the above mentioned reasons ,there was a renewed interest in this field during the late 1960s as seen in the literature due to newer advances in the dosimetric techniques and advent of refined radiotherapy techniques.

With respect to dosimetric techniques first of the improvisation was perhaps by Scott as reported in literature through his study **Direct vesical and rectal dose measurement at the time of intra-uterine radium application by SCOTT RM et al.** unfortunately the original article is only indexed but data is not available , through metanalysis of the article it was a pioneering attempt to evaluate the rectal dose using CdS diodes. This study paralleled that of K. W. KOSCHEL **RECTAL DOSE MEASUREMENT WITH CdS DOSIMETERS** in which he described a simple dosimeter for the measurement of a rectal dose with radon or radium insertions his unit incorporates a CdS dosimeter and a transistorized D.C. amplifier, enabling dose-rates of 0-100r/hr., 0-200r/hr., and 0-500 r/hr. to be measured on three meter ranges. It was inferred in the study that this dosimeter could measure to an accuracy of 2%.

Another improvement in dosimetry over the traditionally used rigid scintillation probes came up with the study of J. J. SHELDON et al **A NEW RECTAL DOSIMETRY CATHETER FOR USE IN RADIATION THERAPY OF CARCINOMA OF THE UTERINE CERVIX,** using lithium fluoride in small capsules which were inserted in a flexible catheter in tandem was developed. This "dosimetry catheter," inserted in the rectum for variable periods of time, gave measurements which were compared with those of a rigid scintillation probe that is in general clinical use. It has been demonstrated that the dose rates obtained with the scintillation probe and those obtained by the flexible dosimetry catheter are approximately the same to the level of the vaginal radium. He concluded that Further careful studies of the actual dose range of tolerance to the rectal mucosa, as recorded by the rectal dosimetry catheter, may lead in the future to the better understanding of the dose range tolerance of the rectal mucosa to radium and radium-equivalent material.

A landmark study during this period which covered all aspect of rectal dosimetry was the one by RODNEY R. MILLION et al **Modification of Technic for Bladder and Rectal Measure-**

**ments in Carcinoma of the Cervix.** The study observed the various aspects 1. Measurements with the patient supine, as compared to those obtained in the lithotomy position, usually show an increase in bladder readings and a decrease in the rectal dose. 2. Bladder and rectal readings should be used as relative and not absolute values in the measured organs. Each institution should develop its own normal range, and only marked deviations from it should be considered abnormal. 3. Bladder and rectal readings play a minor role in the control of radium dosage and will become more of historic interest with the increased employment of total pelvis irradiation and the rigid after-loading tandem.

Once the role of rectal dosimetry and the confounding factors were established later studies focused on the alternate methods for dosimetry. One of the alternatives of the newer lot was thermoluminescence, R Das et al in their paper **Thermoluminescence dosimetry for in-vivo verification of high dose rate brachytherapy for prostate cancer** used LiF:Mg,Ti Thermoluminescence Dosimetry (TLD) rods of 1 mm diameter, with up to 11 detectors positioned every 16 mm separated by radio-opaque markers. and measured doses were compared with predictions from the treatment planning system. they observed that in general there was good agreement between measured and predicted doses with the average difference between measured and planned maximum dose being 0.1 Gy. But significant association between dose and any clinical endpoints was observed in the patients available for clinical evaluation. They made this interesting observation that the rectal measurements proved to be more difficult to interpret as there is more variability of TLD position between planning and treatment. But the study concluded that the TLD in-vivo measurements are easily performed in urethra and rectum during HDR brachytherapy of prostate patients. They verify the delivery and provide information about the dose delivered to critical structures. The latter may be of particular interest if higher doses are to be given per fraction such as in HDR monotherapy.

Once there was an influx of many modalities for in vivo dosimetry, focus was shifted to comparative study between different methods, a comprehensive evaluation in this regard was done by Kapp K.s et al in **Dosimetry of intracavitary placements for uterine and cervical carcinoma: results of orthogonal film, TLD, and CT-assisted techniques.** The study raised more uncertainties and ambiguities rather than coming at a consensus, the main observations were that when doses to the specified reference points of bladder neck and rectum from orthogonal film dosimetry were compared with the corresponding points on CT scans, similar values were obtained for both methods with a maximum deviation of +/- 10%. Despite the determination of multiple reference points the study revealed that this information was inadequate to predict doses to the entire rectum and bladder. If conventional methods are used for dosimetry it is recommended that doses to the bladder base should be routinely calculated, since single point measurements at the bladder neck seriously underestimate the dose to the bladder. An important result of this study was lack of accuracy of point dosimetry with regard to rectal dose measurement as they concluded that the rectal dose should be determined at several points over the length of the implant due to the wide range of anatomic variations possible.

Most of the ICBT studies were Ir 92 based, one of the reviews available with regard to Co 60 ICBT based in vivo dosimetry is study of Zaman ZK et al, **Comparison of planned and measured rectal dose in-vivo during high dose rate Cobalt-60 brachytherapy of cervical cancer.** In this study Real-time measured rectal doses were compared to calculated doses by the treatment planning system (TPS). They observed that the differences between calculated and measured dose ranged from 8.5% to 41.2%. corresponding to absolute dose differences ranging from 0.3 Gy to 1.5 Gy. A linear relationship was observed between calculated and measured doses with linear regression R(2) value of 0.88, indicating close association between the measured and calculated doses. In general, absorbed doses for the rectum as calculated by TPS were observed to be higher than the doses measured using the diode probe. They concluded that In-vivo dosimetry is an important quality assurance method for HDR brachytherapy of cervical cancer.

One of the caveats of dosimetry is the algorithm which is used, this issue was addressed in a landmark study which compared the Monte-Carlo based algorithm to in vivo MDCT dosimetry by Bostani M et al titled **Accuracy of Monte Carlo simulations compared to in-vivo MDCT dosimetry.** The findings in this study was that the calculated mean per cent difference between TLD measurements and Monte Carlo simulations was -4.9% with standard deviation of 8.7% and a range of -22.7% to 5.7% which demonstrated a very good agreement between simulated and measured doses in-vivo. Taken together with previous validation efforts, this work demonstrates that the Monte Carlo simulation methods can provide accurate estimates of radiation dose in patients undergoing CT examinations.

The growing relevance of in vivo dosimetry is with the advent of SRS/SRBT as the need for real time monitoring has come up as a larger dose per fraction is being delivered leaving only a small margin for error, hence most of the studies in the latter part of this decade were in this regard, a notable paper was by Legge K et al **Real-time in vivo rectal wall dosimetry using MOSkin detectors during linac based stereotactic radiotherapy with rectal displacement.** They observed that the average difference between the final measured and final planned doses for all arcs measured was 3.4% of the final planned dose, with a standard deviation of 10.3% and concluded that the MOSkin detectors were an effective tool for measuring dose delivered to the anterior rectal wall in real time during prostate SBRT boost treatments for the purpose of both ensuring the rectal doses remain within acceptable limits during the treatment and for the verification of final rectal doses.

But the study which helped to prevent most of the likely errors that could have crept into this study was the one by Waldahauss et al where they studied the various physical and clinical considerations that could influence rectal dosimetry (**In-vivo dosimetry for gynaecological brachytherapy: physical and clinical considerations**). They initially investigated the diode calibration and factors influencing diode response and phantom studies compared doses measured and computed by the treatment planning system and estimated a uncertainty for diode measurements. other important finding in this study were the differences between calculated and measured doses ranging from -31 to +90% (mean 11%) for the rectum and from -27 to +26% for the bladder. They noticed that the Shifts in probe position of 2.5mm for the rectal probe and 3.5mm for the bladder probe caused dose differences exceeding 10%. Study ultimately conclude that diode accuracy and reproducibility is sufficient for clinical applications, but also cautioned that accurate in-vivo dosimetry geometric conditions are of utmost importance and recommended that in-vivo dosimetry should be performed in addition to computation.