3D IMAGE-BASED GYNECOLOGIC BRACHYTHERAPY PHYSICS

Hideo KUBO

Abstract: This paper is based on my invited talk at the JASTRO Brachytherapy Subcommittee meeting in June of 2003 in Tokyo. The talk materials are derived from the presentation of low dose-rate (LDR) gynecologic cancer therapy given at the University of California, Davis Cancer Center by Dr. Fritz Lerma of Mallinckrodt Institute of Radiology (MIR), Washington University, St. Louis. For more than 5 years, a brachytherapy program has been pushed forward at MIR and the University of California at San Francisco. In particular, Dr. Jeff Williamson of MIR, now at the Medical College of Virginia, emphasized the importance of CT image-guided brachytherapy treatment, 3D simulation of anatomy and applicators, and dose calculations based on Monte Carlo applicator simulations. The use of CT images has differentiated the treatment modalities from the past in that it allows more quantitative data analysis and provides more accurate dose distribution information. Dr. Williamson has single-handedly developed the frontier of gynecologic brachytherapy in the U.S. Dr. Lerma was his disciple and worked with him for two years during the program development period. Therefore, I believe Dr. Lerma's materials reproduced here with his permission belong in the forefront of the brachytherapy treatment approach to gynecologic cancers in North America.

This paper begins with an Introduction followed by the LDR Gynecologic brachytherapy program, and Motivations to push CT image-guided treatment planning forward at Mallinckrodt. As a practical example of 3 dimensional image-guided radiotherapy, this paper will elaborate on the accurate matching of applicator contours delineated in a CT space and Monte Carlo simulation methods. The use of CT and Monte Carlo simulations of applicator in a CT space allows treatment plan dose calculations solely on the basis of the Monte Carlo method if the full Monte Carlo calculations and dose measurements by 3 dimensional (3D) water phantom scan are in agreement. The conventional 2D single source superposition method does not take into account the presence of applicators. Therefore, the scattering and absorption of photons produced by the nearby sources are not accounted for. As a result it shows some dose deviations, in particular, near the source.

At the end, this paper introduces positron emission tomography (PET) image-guided brachytherapy treatment planning. This modality is compared with the conventional 2D image-guided treatment plans. The PET images are known to reflect more physiologic information than CT images, even though the CT images provide better geometrical resolution than PET. The PET-based 3D treatment planning certainly belongs to the frontier of 3D image-guided brachytherapy treatment planning and delivery. As proved from the prostate study by magnetic resonance spectroscopy (MRS), the tumor cell concentration within the tumor is not necessarily uniform. In this respect, though not proven yet, the PET images may shed some light on the tumor cell distribution for the gynecologic (GYN) cancer.

Key words: Cervix cancer, Intracavitary brachytherapy, 3D image-based brachytherapy, PET guided implant
小線源治療の線量率と分割の生物モデルの再考に向けて

井上 俊彦，吉岡 靖生，田中 英一

RECONSIDERATION OF A BIOLOGICAL MODEL FOR DOSE-RATE AND FRACTIONATION IN BRACHYTHERAPY

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Abstract: Clinical results of HDR brachytherapy show better than those of the LDR one. Most radiation biologists could not predict these results. At the beginning, they presumed that LDR brachytherapy was one of the best treatment modalities for cancers of the uterine cervix, mobile tongue and others. They criticized that HDR brachytherapy was a harmful modality from a biological standpoint. They proposed equations such as Nominal Standard Dose (NSD), Time Dose and Fractionation factor (TDF), Cumulative Radiation Effect (CRE) to be mandatory for the biological dose-rate conversion from LDR to HDR brachytherapy. However, these equations had not included the parameter of treatment volume that was one of the most valuable factors. Moreover, these equations consisted of parameters that were obtained from clinical results, not from the biological experiments. Instead of these biological equations, the new concept of the linear-quadratic (LQ) model was proposed. Effects of dose-rate for LDR brachytherapy and fractionation for HDR could be considered, however that of treatment volume could not be considered. In the classical Manchester system for brachytherapy, dose-rate was mainly affected by the treatment volume, because of the standard application of the Radium employed. The original prescribed dose in LDR brachytherapy of interstitial and intracavitary technique for cancers of the mobile tongue and uterine cervix using Paris and Manchester systems was 60 Gy over 144 to 168 hours. Although the prescribed dose was apparently changed by dose-rate, however, the variety of dose rate originally resulted from the size of the treatment volume in clinical practice. In addition, the 60Co from a high intensity source and the new 192Ir micro-source of relatively short half-life changed these rules. However, these sources enable us to use HDR brachytherapy with more accuracy. Now we need a new biological model with original treatment parameters obtained from the modern HDR brachytherapy itself.

Key words: Brachytherapy, Dose rate, Fractionation, Biological model
医療における具体的なリスクマネジメント：安全と安楽

押田 茂実，勝又 純俊

MEDICAL ACCIDENTS AND RISK MANAGEMENT

Shigemi OSHIDA, Sumitoshi KATSUMATA

Abstract: When a medical accident happens there are instances where patients, their relatives or the bereaved sue for compensation and this is referred to as "medical conflict." If a medical conflict, the patient's side goes to court and this is "medical litigation". In a medical accident happened, there is an inquiry as to whether or not a civil act, and/or criminal act, and/or the administrative responsibility has been committed. The purpose of medical risk management is investigation into the cause, building a prevention system, and decreasing accidents.

Key words: Medical accident, Malpractice, Risk management, Incident report
CONCOMITANT CHEMORADIATION THERAPY WITH UFT AND LOW DOSE CDDP FOR T2 GLOTTIC CARCINOMAS

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(Received 3 September 2003, accepted 1 December 2003)

Abstract: Purpose: To improve the local control of T2-stage glottic carcinomas, we performed concomitant chemoradiation therapy with UFT (uracil and tegafur) and low dose CDDP. The predictive value of MR findings was also evaluated.

Methods and Materials: Thirty six patients with T2N0-stage glottic carcinomas were included in this study. Tumors adjacent to the thyroid cartilage on MRI were classified as "adjacent", and undetectable tumors or tumors separate from the cartilage were classified as "intact". Radiation therapy with 64 Gy/32 fractions was delivered by 4 MV linear accelerator. Intravenous infusion of CDDP (4 mg/m²) and oral administration of UFT (450 mg/body) were continued concomitantly from day one of irradiation for four weeks. Kaplan-Meier methods were used to estimate the time to local recurrence distribution. Differences were determined using log-rank tests for univariate analysis.

Results: No severe acute and late adverse effects (grade 3 or more) were observed. Two-year local control rate with chemoradiation therapy was 82%. According to MR findings, local control rates were 95% for intact lesions (n=20) and 68% for adjacent lesions (n=16) (p=0.0249).

Conclusion: Concomitant chemoradiation therapy with UFT and low dose CDDP was considered to be effective for T2-stage glottic carcinomas. However, the results were not enough for tumors adjacent to the thyroid cartilage on MRI.

Key words: Glottic carcinoma, Radiation therapy, Chemoradiation therapy, MRI
DOSE EQUIVALENT RATE MEASUREMENT IN USING THE 103PD BRACHYTHERAPY SOURCE AND EXAMINATION ON SAFETY

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Abstract: In the U.S. and Europe, brachytherapy by permanent implantation of radioactive seeds, 125I or 103Pd is often performed for treatment of prostate cancer. In Japan, in March 2003, the Ministry of Health, Labor and Welfare permitted the use of 125I seeds under the observance of the related laws and discharge criteria. With a view to popularize 103Pd seeds like 125I, we implanted 103Pd seeds into the prostate site of a humanoid body phantom, measured dose equivalent rate around it, and obtained basic data on which discharge criteria are based upon. We also calculated the exposure dose of carers, based on obtained data.

As a result, the 1 cm dose equivalent rate, considering absorption at the prostate or other organs, was calculated 0.00006 $\mu$Sv•m$^{-2}$•MBq$^{-1}$•h$^{-1}$, and the exposure dose of carers was sufficiently below the dose limitation of IAEA or NRC.

Therefore, for the use of 103Pd seeds, there is almost no need to be concerned about the risk of radiation exposure to people around the patient, and its safety seems superior to 125I seeds. We consider outpatient treatment is possible under the existing law, which is a standard treatment pattern in the U.S. and Europe.

Key words: 103Pd seeds, Brachytherapy, Prostate, 1 cm dose equivalent rate

要旨: 欧米では前立腺癌に対する治療法として, 永久挿入用線源である 125I, 103Pdを使用した組織内照射法が盛んに施行されている。本邦においては, 平成15年3月の厚生労働省通知により退出基準と関係法令の遵守を担保に, 103Pdシード線源の使用が可能となった。

103Pd線源と同様, 125I線源の本邦での普及を目的に, 人体ファントム前立腺部に103Pd線源を挿入し周辺線量当量率測定を行い,退出基準の根拠となる基礎データを取得した。また, この値を基に介護者等の被曝線量の試算を行った。

その結果, 前立腺部での患者の組織・臓器による吸収を考慮した見掛けの103Pd線量当量率定数は, 0.00006 $\mu$Sv•m$^{-2}$•MBq$^{-1}$•h$^{-1}$という値となり, 介護者等の被曝線量は, 0.00006, 0.00004の線量拘束値を十分下回る結果を得た。

前立腺部への103Pd線源の使用は, 患者周囲の者が受ける放射線被曝のリスクを懸念する必要はほとんどなく, その安全性は125I線源よりもさらに優れていると考えられる。また, 欧米で行われている外来での日帰り治療が本邦の現行法規制下においても十分可能であると考える。
THE EVALUATION OF THE DEGREE OF IMPAIRMENT OF PULMONARY PERFUSION IN LUNG CANCER PATIENTS TREATED BY RADIOThERAPY BY THE QUANTIFICATION OF NONUNIFORM DISTRIBUTION OF LUNG PERFUSION SCINTIGRAPHY SPECT

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Abstract: Purpose: By means of quantifying the nonuniform distribution of pulmonary perfusion in Lung Perfusion Scintigraphy SPECT (Single Photon Emission Tomography), which is called "SPECT" for short, we evaluated the degree of functional impairment of pulmonary perfusion in non-operated lung cancer patients treated by the radiotherapy.

Materials and Methods: Sixty-eight patients with non-operated lung cancer treated with radiotherapy, and who either received or did not receive chemotherapy, from February, 1996 to August, 2002, were examined using SPECT within 6 weeks prior to, or within 2 weeks following radiotherapy. This group was called "irradiated lung cancer patients". Twenty-six patients, who were called "follow-up irradiated lung cancer patients", were reexamed within four weeks after radiotherapy. On the other hand, 323 patients without lung cancer, who were subdivided into four groups; pulmonary, cardiac, cardio-pulmonary, and non-cardio-pulmonary. The SPECT was examined in the supine position after infusing Tc-99m-MAA, 185 MBq in a bolus, mainly into an antecubital vein with the patient's arm elevated. From reconstructed SPECT images, the volume of lung as a whole calculated at 10 % of thresholds was assumed to be the "Baseline Lung Perfusion Volume" (BPV), and the functional volume rates were calculated in 10% threshold widths from 10 % to 100 % of the threshold. Assuming the total absolute differences in functional volume rate between each subject and the control to be the distribution index of the lung as a whole (D index), we quantified the degree of nonuniform distribution of the lung as a whole in each subject. In the same way, the distribution index of the left or right lung respectively was calculated as Dl or Dr index assuming the volume of left or right lung were calculated at 10 % of the threshold as left or right BPV and calculating the functional volume rates of each lung in 10% threshold widths from 10 % to 100 % of the threshold.

Results: The D index of irradiated lung cancer patients was 26.4 ± 1.4, which was almost equal to that of the pulmonary group including the chronic obstructive pulmonary diseases, and significantly higher than that of cardiac or non-cardiopulmonary group. The irradiated lung cancer patients with complications of pulmonary or cardiopulmonary diseases showed a significantly increased D index, compared with patients without complications. Distribution index of tumor-bearing lung (Dn index) was significantly higher than that of non-tumor-bearing lung. The Dn index of tumor-bearing lung of small cell carcinoma patients significantly increased, compared with that of adenocarcinoma patients, and significantly increased according to whether or not the primary tumor occupied the hilar region and degree of extension of tumor invasion especially in the hilum as well as the mediastinum. In the follow-up irradiated lung cancer patients, the D index and Dn index of non-tumor-bearing lung post-radiotherapy significantly increased, compared with pre-radiotherapy.

Conclusions: It is considered that the distribution index quantifying nonuniform distribution in the SPECT enables evaluation of the degree of impairment of lung as a whole, tumor-bearing lung, and non-tumor-bearing lung in lung cancer patients, and results in presenting a useful indicator for radiotherapeutic planning and following up respiratory function after radiotherapy.

Key words: Lung perfusion scintigraphy, SPECT, Lung cancer, Radiotherapy
要旨：【目的】肺血流シンチグラフィ（口内に放射性物質を投与し、その分布をX線で観察する方法）を用いて放射線治療の対象となった肺癌症例の肺血流の不均等性を定量化した不均等分布値を用いて放射線治療の対象となった肺巣症例の全肺および原発巣を有する片側肺（担癌肺）の機能的損傷の程度を把握、評価した。

【方法と対象】1991年1月から1996年1月まで、肺切開例を除く、放射線治療が単独または化学療法に併用された症例のうちで、初回放射線治療の開始前1週間から開始後1週間以内に発症した症例（放射線療法が施行された症例）を対象とした。また、放射線治療で、放射線治療を完了した症例を対象とした。統計的検定は、非計量的データを用いたt検定を用いて検討した。結果は、放射線治療前後の不均等分布値を検討する対象とした。同時に、放射線治療療法の効果を大きく肺疾患、心疾患、肺不張、心肺不全に分けた。放射線治療は、対象型ガンマカメラを用い、被験者は、安静時、仰臥位で呼吸を停止させ、主として，右上肢の上腕皮静脈から注入し，急速静注し，0秒、60秒，180秒を経過させ、0秒，60秒，180秒を計測した。結末後、直ちに画像データを収集し、後の再構成を行った。計算画像から体のX線写真で算出された全肺血流像を全肺の基準肺血流像，0秒，60秒，180秒を測定し，0秒，60秒，180秒を算出した。さらに，全肺の血流における0秒，60秒，180秒までの血流像と全肺の基準肺血流像の相関を求めるために、各症例に対する血流の合計を求めた。コントロール例の平均値の相関を求めた。左右肺の不均等分布値（0秒，60秒，180秒）を算出した。また、左右の片側肺毎に、基準血流像（0秒，60秒，180秒）および機能的分布値を求める方法で左右肺の不均等分布値（0秒，60秒，180秒）を算出した。

【結果】放射線治療例の0秒，60秒，180秒の平均値は0秒，60秒，180秒で、非癌性例の慢性閉塞性肺疾患などの肺疾患と同様で、心疾患や非心疾患より有意に高かった。また、基礎疾患を合併した症例は非合併例に比し有意に高かった。放射線治療例の不均等分布値（0秒，60秒，180秒）は対側の非癌性例に比して有意に高かった。また、小細胞癌例は腺癌例に比して有意に高く、担癌症例の原発巣を推定するため，担癌症例の発展の程度に応じて、特に肺癌リッパ節転移がある場合に有意に増加した。放射線治療例では、全肺および非癌性の不均等分布値が治療開始時に比して有意に増加した。

【結論】0秒，60秒，180秒の血流分布の不均等性を定量化した不均等分布値は、担癌肺、非癌性肺、そして全肺の機能的損傷を定量的に把握することを可能とし、放射線治療計画や治療後の経過観察において有用な指標の一つとなりえるのではないかと考えられた。
**PALLIATION OF RECURRENT ESOPHAGEAL CANCER AFTER DEFINITIVE RADIOTHERAPY WITH INTRALUMINAL BRACHYTHERAPY**

A PRELIMINARY REPORT


(Received 16 October 2003, accepted 14 January 2004)

Abstract: Purpose: The objective was to assess the feasibility, toxicity, and efficacy of palliative intraluminal brachytherapy (ILBT) for recurrent esophageal cancer after definitive radiotherapy. Method: From January 2000 to December 2002, 10 consecutive patients with recurrent esophageal cancer after definitive radiotherapy completed allocated ILBT, were enrolled into the analysis. All patients presented with a WHO dysphagia score III or more (III: 7; IV: 3). The ILBT was delivered with a special assembled applicator composed of three layers of plastic tubes, inserted transorally. The active treatment length of ILBT was defined as the site of recurrent esophageal tumor plus 1 cm each from the proximal and distal margins. The ILBT was performed by high-dose-rate iridium-192 remote after-loading technique. The ILBT consisted of 2 to 4 fractions of 3 Gy at 1-week intervals. The prescribed dose was specified at a 1 cm depth from the mid-dwell position and the dosimetry was calculated using computer-based software. Patients were followed up monthly and assessed for relief of dysphagia and development of complications. Result: All patients completed the allocated ILBT schedule. Eight patients died (2 from distant metastasis; 3 from respiratory failure by tumor invasion; 2 from aspiration pneumonia; 1 from chemotherapy-induced sepsis). The median survival of the 10 patients was 5 months (range 2 to 32), and the estimated 1-year actuarial survival was 24%. Time to recurrence of more than 3 months was the only prognostic factor for longer survival (p=0.01). When the response of ILBT was assessed one month after treatment, eight patients achieved improvement of dysphagia, while two patients got worse. The median dysphagia progression-free interval (DPFI) of the 8 responders was 3 months (range 2 to 7). The predictive parameter for good ILBT response was an initial dysphagia score (p=0.01). Only one patient developed tracheo-esophageal fistula 3 months after ILBT. Conclusion: Fractionated ILBT is a feasible method of palliation for recurrent esophageal cancer after definitive radiotherapy. Prescribed dose with 9-12 Gy in three to four fractions weekly is well tolerated

Key words: Esophageal cancer, Brachytherapy, Recurrence, Palliation

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INVESTIGATION OF THE OPTIMAL DOSE ON POSTOPERATIVE RADIOTHERAPY FOR KELOID
LOW DOSE RADIOTHERAPY FOR EARLOBE KELOID

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Abstract: Radiotherapy following excision for keloids has shown to decrease the recurrence rate. But until now, no literature has reported the optimal dose of postoperative radiotherapy for keloids. We investigated the optimal dose of postoperative radiotherapy for keloids following excision.

Between July 2000 and March 2003, 21 patients with 29 keloid sites were treated with excision, sutured, and postoperative irradiation with a 4 MeV electron beam. The total dose were 12 Gy per 3 fractions. The results were evaluated at 6-38 months (Ave. 18 months) after treatment.

The effectiveness rate of total sites was 79%. The effectiveness rate was 43% in sites with highly stretched tension such as the chest wall, shoulder, abdominal wall and fingers and 91% in sites without highly stretched tension such as earlobes. As the results of analyzing therapeutic outcomes, the effectiveness rate in sites without highly stretched tension were significantly higher than those with highly stretched tension (p=0.0062).

Our study suggested that the optimal dose of postoperative radiotherapy was 12 Gy or less for keloids in sites without highly stretched tension, much as the earlobe.

Key words: Keloid, Postoperative radiotherapy, Electron beam irradiation, Optimal dose

要注：古くからケロイドに対する放射線治療は行われてきているが、これまでケロイドの術後照射に対する至適線量に関する報告が無かった。今回、我々は耳介を中心としたケロイドに対する術後電子線照射療法の至適線量を検討した。対象は平成12年10月から平成13年3月までに術後電子線照射を施行した21例で、発生部位を高張力部位（前胸壁、下腹壁、肩、手指）と低張力部位（耳介）の二つに分け、それぞれ14例、7例で部位とされている。全例で12 Gy（2 Gy）の照射を施行しており、観察期間は術後1ヶ月～3ヶ月（平均1ヶ月）である。ケロイド全体の有効率は43%であったが、高張力部位のケロイドの有効率86%（再発率7%）に対し、低張力部位のケロイドの有効率が91%（再発率11%）と有効率に有意な差を認めた（p=0.0062）。12 Gyという低線量でも耳介の様々な低張力部位のケロイドに対して非常に良好な有効率が得られ、同部に対する術後電子線照射療法の至適線量は12 Gy以下であることが示唆された。

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A CASE REPORT OF ANGIOBLASTOMA (NAKAGAWA) EFFECTIVELY TREATED WITH RADIATION THERAPY

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(Received 5 November 2003, accepted 14 January 2004)

Abstract: Angioblastoma, that was first reported by Nakagawa in 1949, is a rare vascular tumor that usually appears in early childhood. It is seen as an erythematous patch to a reddish-brown area, that is frequently an indurated plaque with tenderness and usually occurs on the trunk or thigh. We report a case: a 5-month-old girl with angioblastoma on the temple, which showed a good response after 6- Gy irradiation. Low dose electron beam irradiation with 6-10 Gy may be an effective method for management, if other treatments have a high morbidity rate or result in a poor outcome.

Key words: Angioblastoma, Tufted angioma, Radiation therapy
EFFECTS OF INCORRECT PLACEMENT OF PORTAL FILMS ON TREATMENT FIELD VERIFICATION

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Abstract: Purpose: To evaluate, at our facility, the effects of incorrect placement of portal films on treatment field verification and the slant angles of portal film acquisition.

Methods and Materials: Geometric differences (pseudo-setup errors) between the correctly placed portal films (in which the film plane is perpendicular to the x-ray beam axis) and the incorrectly placed portal films (the film plane is not perpendicular to the x-ray beam axis) were mathematically calculated. Thirty-four portal films (25 patients) were analyzed in this study. These portal films were grouped into 2 categories according to the gantry angle: (1) the orthogonal group (i.e. treatment beam angles are of 0°, 90°, 180° and 270°), and (2) the oblique group (other beam angles). The slant angles of each group were evaluated.

Results: Mathematical calculations showed that pseudo-setup errors increased with an increase of the slant angle of the portal film and increased distance between the field-edge and an anatomical reference point. The mean slant angles of portal film acquisition for the orthogonal group and the oblique group were 3.4° (max=12.3°) and 6.0° (max=24.5°), respectively.

Conclusion: To minimize pseudo-setup errors associated with incorrect placement of portal films, an anatomical marker nearest to the field edge should be selected as the reference point for treatment field verification. However, the best way to completely eliminate the pseudo-setup errors is for film plane to be perpendicular to the x-ray beam axis.

Key words: Pseudo-setup errors, Incorrect placement of portal films, Treatment field verification
A STUDY ON STANDARDIZATION AND PRECISION IMPROVEMENT OF DELIVERED DOSE ESTIMATION

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