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学　位　論　文　名	A MONTE CARLO DOSE CALCULATION SYSTEM FOR ADVANCED RADIOTHERAPY TREATMENT PLANNING （高精度放射線治療計画のための Monte Carlo 線量計算システムの開発）
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論　文　内　容　の　要　旨

Radiotherapy has become increasingly conformal since the advent of three-dimensional (3D) conformal radiotherapy (CRT), intensity-modulated radiotherapy (IMRT) and stereotactic radiotherapy (SRT). Although such advanced radiotherapy techniques would achieve better dose distributions conformed to the targets while sparing the surrounding normal tissues, they are less forgiving in terms of treatment uncertainties. The accuracy required for dose computation is generally between 1% and 2% ; however, large errors in the doses computed by conventional dose calculation algorithms exceeding that criteria have been reported.

The rationale of this thesis was to develop and commission an integrated Monte Carlo (MC) dose calculation system, MCRTV (Monte Carlo for Radiotherapy Treatment plan Verification). MCRTV has been developed for clinical treatment plan verification and can be used for both conventional photon beam calculation and advanced radiotherapy treatment planning including 3D-CRT, IMRT and SRT. It is now well accepted that MC is the most accurate dose calculation method. Theoretically, once an MC dose calculation system is properly commissioned, it can provide the dose calculation benchmark results. The MCRTV system consists of the originally written EGS4/PRESTA MC codes and the associated software. MCRTV has an interface with a commercial treatment planning system (TPS) (Eclipse, Varian Medical Systems, Palo Alto, CA, USA) and reads the information needed for MC computation transferred in DICOM-RT format. The phase-space data of our 15 MV photon beam from Varian Clinac 2300C/D has been developed and several benchmarks have been performed under homogeneous and several inhomogeneous conditions. The MC results agreed with the ionization chamber measurements to within 1% and 2% for homogeneous and inhomogeneous conditions, respectively. The MC calculation for a clinical prostate IMRT treatment plan validated the implementation of the beams and the patient/phantom configuration in MCRTV.

A specific MC code for a CyberKnife stereotactic radiosurgery system has also been developed. Stereotactic beams make it difficult to measure the accurate dose due to lateral electronic disequilibrium. We have calculated the in-water depth dose curves for field sizes of 5, 15, 30 and 60 mmϕ and compared with those measured with a diamond detector. It was observed that the calculated and measured depth dose curves for the 60 mmϕ field were in relatively good agreement (less than 2%), whereas there were considerable discrepancies for other smaller fields.

SRT for extracranial tumors has been performed to treat primary and secondary lung cancer and has subsequently been named stereotactic body radiotherapy (SBRT). The promising results of several clinical studies on SBRT have been reported mainly from Japan. Dose calculation accuracy is diminished due to heterogeneous anatomies such as lung and bones especially in the thoracic region for conventional dose algorithms, which have been used for most studies. MC is expected to provide the accurate doses delivered to patients and the clinical outcomes would then be evaluated properly.

論文審査の結果の要旨

本論文では、放射線治療において最も高精度な線量計算アルゴリズムとして認知されている、Monte Carlo（MC）法を用いた線量計算システムを独自に開発し、その精度検証を行っている。汎用 MC コードの EGS4/PRESTA をベースに、直線加速器の詳細なモデリングから X 線の発生過程、患者体内の線量計算までを行うプログラムを独自に作成し、最も予想される代表的な３種類の条件で計算モデルの検証を行った結果、必要な精度（＜＝２％）を達成した。また、商用治療計画システムとのインターフェースを開発し、臨床応用の基盤を構築した。

当システムは、複雑な治療技術でも高精度な線量データを提供することが可能であり、治療計画の品質保証（quality assurance : QA）における臨床的有用性は極めて大きい。特に、当計算コードは将来的に希望施設に配布予定であり、放射線治療の質向上への貢献が期待できる。

したがって、本論文は大阪大学博士（保健学）の学位授与に値する。