Personalised tracking of radiation doses is becoming a reality

Professor Jun Deng of Yale University School of Medicine has focused his extensive experience in therapeutic radiology and dose risk analysis to create a new system of tracking patient exposure in great detail. Establishing a personal organ dose archive (PODA) to track and accumulate each patient’s organ doses in four dimensions, opens the possibility of using big data techniques to better inform clinicians and the patients themselves.

Radiation has a long history of therapeutic use, from the first use of X-rays to image bones at the end of the nineteenth century through to the advanced image-guidance technologies in cancer radiotherapy used today for the treatment of tumours. The effects of excessive doses of radiation have also been well documented over this time; improving the precision of radiotherapy has been driven by the need to reduce the unpleasant side effects of this treatment.

Despite these developments, patients are being exposed to doses from imaging and treatment which have the potential to damage normal tissues and promote the formation of secondary tumours, without a clear way to track an individual’s accumulated exposure. Furthermore, as radiotherapy becomes ever more precise, such dose tracking also needs to have improved precision, so that a clear picture of the patient’s exposure in four dimensions can be generated.

A CONTINUING PROBLEM

Currently, although tumour control has been improved significantly with the advent of advanced beam delivery and image-guidance technologies in cancer radiotherapy, normal tissue toxicity continues to be of growing concern in the clinic. Leakage and scatter doses associated with advanced beam delivery are not accurately considered by commercial treatment planning system (TPS) dose calculation methods, so an improved method of recording received dose is required.

At the same time, TPS dose calculations are normally only performed for specifically identified and delineated at-risk organs within the therapeutic volume of interest, while providing no dose information for other organs. Added to this, organ doses on treatment day can be quite different from planned doses due to changes in organ volume, shape and location.

In addition, imaging doses are also not considered in total dose accumulation because current commercial TPS cannot simulate kilo-voltage X-ray dose deposition. For these reasons and without warning some patients may accumulate dangerously high doses in radiosensitive organs over time and be susceptible to radiation-related side effects.

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A NEW APPROACH
PODA achieves this aim, generating an organ specific and time-realised map of doses received from therapeutic as well as diagnostic radiation exposure. Compiling and consolidating the data which may be scattered through various institutions and medical record databases, PODA generates a single patient archive, informing clinicians across institutions and preventing the loss of these vital records over the course of the patient’s lifetime. The system’s strength lies in its ability to accurately accumulate personal organ dose data throughout an extended period. This can be achieved by using the well-established Monte Carlo dose calculation, accelerated by graphics processing unit (GPU) and parallel computing. Monte Carlo is an improved method compared to commercial TPS and is designed to follow energetic particles from generation through to patient absorption to accurately calculate the dose received. This necessitates a comprehensive gathering of data from all ionising radiation exposures and all relevant organs, quantitatively applying these to three-dimensional dose distributions.

A POWERFUL TOOL
When data pooling and sharing is needed in the clinical situation, the power of PODA will be the ability to draw meaningful conclusions based on statistical certainties. This pooling of data is becoming increasingly convenient and efficient in the era of big data, as patient records are electronically stored and accessable to clinicians to make informed decisions. Although particularly beneficial to cancer patients receiving radiotherapy, PODA is also applicable to other fields using ionising radiation. Computed Tomography (CT), Positron-Emission Tomography (PET) and fluorescence in diagnostic imaging contain a small but inherent risk of tissue damage and carcinogenesis. Prof. Deng and his colleagues have shown that this is particularly true for children, who are at increased risk of developing leukaemia and other cancers from imaging scans such as CT. Holding a PODA which details these exposures and removes associated with them for their lifetime, would clearly be valuable in ensuring that the risk of any such future procedure continues to be outweighed by the therapeutic value.

A BRAVE NEW WORLD
In a world of increasing access to personal data and cloud computing, Prof. Deng envisions that this data will not only be available to any clinician working with the patient, but to the patient themselves. “I am often approached by physicians, physicists or patients asking for an estimate of the dose from a CT or CBCT procedure. I am often approached by physicians, physicists or patients asking for an estimate of the dose from a CT procedure,” he says, “usually I tell them ‘give me some time and I’ll give you some information’, because I have Monte Carlo treatment planning available in-house that allows me to do that dose calculation.”

It is this experience that has led him to develop an application for Apple’s iPhone which allows the patient and clinicians to calculate the dose themselves from easily obtained information. CT Gently is the start of improved patient access to vital data on their radiation exposure. Portability is at the heart of the PODA concept, so integrating these data into smartphone applications and fitness trackers is the logical next step. "We hope to provide the patient with all the information that they want, maybe even before they see the doctor," Deng explained. “This may give the clinician second thoughts on how to provide the most appropriate, lower dose imaging procedure to a specific patient.”

The app can help identify clinically justified and customised imaging procedures tailored to individual patients for improved diagnosis and screening. Normal tissue toxicity resulting from cumulative doses of radiation is not uncommon in patients receiving radiotherapy, a form of therapy that millions of patients receive every year. Prof. Deng’s development of PODA has the potential to provide an important safety mechanism, helping to prevent irreversible radiation damage to normal tissues and provide a comprehensive organ dose database to help clinicians make informed decisions for individual patients.