Intelligent ePR system for evidence-based research in radiotherapy: proton therapy for prostate cancer

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Abstract

Purpose Proton therapy (PT) utilizes high energy particle proton beam to kill cancer cells at the target region for target cancer therapy. Due to the physical properties of the proton beam, PT delivers dose with higher precision and no exit dose compared to conventional radiotherapy. In PT, patient data are distributed among multiple systems, a hindrance to research on efficacy and effectiveness. A data mining method and a treatment plan navigator utilizing the infrastructure and data repository of a PT electronic patient record (ePR) was developed to minimize radiation toxicity and improve outcomes in prostate cancer treatment.

Materials/method(s) The workflow of a proton therapy treatment in a radiation oncology department was reviewed, and a clinical data model and data flow were designed. A prototype PT ePR system with DICOM compliance was developed to manage prostate cancer patient images, treatment plans, and related clinical data. The ePR system consists of four main components: (1) Data Gateway; (2) ePR Server; (3) Decision Support Tools; and (4) Visualization and Display Tools. Decision support and visualization tools are currently developed based on DICOM images, DICOM-RT and DICOM-RT-ION objects data from prostate cancer patients treated with hypofractionation protocol proton therapy were used for evaluating ePR system effectiveness. Each patient data set includes a set of computed tomography (CT) DICOM images and four DICOM-RT and RT-ION objects. In addition, clinical outcomes data collected from PT cases were included to establish a knowledge base for outcomes analysis.

Results A data mining search engine and an intelligent treatment plan navigator (ITPN) were developed and integrated with the ePR system. Evaluation was based on a data set of 39 PT patients and a hypothetical patient.

Conclusions The ePR system was able to facilitate the proton therapy workflow. The PT ePR system was feasible for prostate cancer patient treated with hypofractionation protocol in proton therapy. This ePR system improves efficiency in data collection and integration to facilitate outcomes analysis.

Keywords Electronic patient record · Proton therapy · Knowledge discovery · Data mining · Prostate cancer · Hypofractionation · Evidence-based

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Abbreviations

AJCC American Joint Committee on Cancer
CSS Cascade Stylesheet
CT Computed Tomography
CTCAE Common Terminology Criteria for Adverse Events v3.0
Introduction

Prostate cancer and proton therapy

Proton therapy may be used to treat prostate cancer. Protons are energized to specific velocities that determines the energy deposition within the target, thereby killing cancer cells, allowing for maximum dose to the target region while minimizing dose to surrounding tissues. The proton depth dose (Bragg Peak) is inversely proportional to the square of the particle velocity. This translates to fewer doses to normal healthy tissue in the body while depositing most of the energy within the target tumor located at a certain depth within the body. In addition, proton beams have no exit dose which also minimizes damage to healthy tissue beyond the target tumor. However, the Bragg Peak from a proton accelerator may only cover a few millimeters of tissue; therefore, a modulator is used to spread out the peak to the width of the target tumor. Figure 1 shows doses achieved by proton beam in comparison with gamma ray photon beam in conventional radiation therapy [1]. The depth dose curve of the thin pencil of beam of protons is shown in red. The weighted superposition of proton beams of different energies (Bragg peaks with different proton ranges) makes it possible to deposit a homogenous dose in the target region. The resulting range modulated proton beam distribution is called spread out Bragg peak (SPBP), shown in blue. This SPBP allows the dose to be confined around the tumor and the drop off right after the target, sparing the healthy tissue beyond it. The depth dose curve of a photon beam (the modality used today in most hospitals for radiation therapy) that shows the characteristic exponential decrease in the dose with depth is shown in green.

Challenges of proton therapy

Uncertainty of dose and treatment schedule

Conventional radiation therapy, given in sufficient doses, can control many cancers. However, because of the difficulty for physicians to adequately conform the irradiation pattern to the cancer, healthy tissues may receive a similar dose and can be damaged. Consequently, a less than desired dose is frequently used to reduce damage to healthy tissues and to avoid unwanted side effects. On the other hand, in proton therapy, the treatment usually has greater tumor control than photon beam in conventional radiation therapy. The power of protons is that higher doses of radiation can be used to control and manage cancer while significantly reducing damage to surrounding healthy tissue and vital organs. Unfortunately, the tumor is not just a separate target that can be irradiated without side effects to other healthy tissues of nearby critical