



Design of Radiotherapy Information System

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Abstract. This paper aims to address the challenges faced by the Department of Radiation Therapy at Peking University Shenzhen Hospital in terms of quality control, documentation, third-party coordination, and radiation therapy workflow. Based on the principles of workflow management and personalized requirements of our department, this study summarizes the responsibilities of clinical staff and designs standardized workflow guidelines for three radiation therapy projects: external beam radiotherapy planning treatment, external beam radiotherapy simple treatment, and brachytherapy treatment. The study also establishes our radiotherapy information system (RIS) by connecting servers, devices, third-party systems, and RIS workstations through a network, creating a comprehensive operating environment for our department. The developed system comprises seven major functional modules and aims to optimize and streamline the radiation therapy process while supporting paperless office operations and seamless integration with internal hospital systems. The implementation of our system is expected to standardize and coordinate the behavior of clinical healthcare professionals, thereby improving the efficiency of medical services, clinical execution, and patient satisfaction.

Keywords: Radiation therapy; Information management; Radiotherapy Information System; Radiotherapy quality control; Process management

1 Introduction

Radiation therapy is one of the essential modalities for treating malignant tumor [1]. Computer technology enables the standardization, refinement, and sharing of information in radiation therapy workflows [2]. The overall process of radiation therapy is complex, involving multiple roles and diverse data, with long treatment cycles for patients [3]. A comprehensive radiation therapy procedure requires collaborative coordination among various professionals within the department [4], as well as the allocation and support of numerous medical devices. Simultaneously, inter-device communication and handling of multiple complex data types are necessary. Therefore, the primary

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task in developing radiotherapy information system (RIS) is to standardize the business processes.

Since the establishment of the Radiation Therapy Department at Peking University Shenzhen Hospital (hereinafter referred to as "our hospital"), the following issues have been identified and urgently need to be addressed:

(1) The majority of node confirmations among clinical healthcare professionals are currently reliant on paper-based forms, which are susceptible to loss and pose difficulties in monitoring and tracking.

(2) Quality control management for various aspects of medical staff operations, including workflow compliance, is lacking, resulting in an inability to monitor and provide reminders for non-standard practices.

(3) Patient information registration has not been seamlessly integrated with Hospital Information System (HIS), necessitating manual transcription of patient data. This manual process not only hampers the efficiency of physician-patient interactions but also leads to suboptimal user experiences.

(4) Within our Radiation Therapy Department, three distinct treatment modalities are employed, namely external beam radiotherapy planning treatment, external beam radiotherapy simple treatment, and brachytherapy treatment. However, issues persist in terms of unclear processes and cumbersome operational procedures associated with these treatment projects.

In order to address the challenges in the radiation therapy department, our hospital has adopted an information system to analyze and enhance the radiation treatment process. This initiative aims to harmonize the clinical workflow among healthcare professionals and facilitate the digitization, standardization, and systematization of radiation therapy procedures. The primary objective is to provide radiation therapy patients with more convenient and efficient services. This research topic aligns with the healthcare context and the overarching theme of the paper.

2 Related Works

Numerous hospitals, institutions, and companies have been exploring the applications of information technology to address the complexities of radiation therapy business processes. Zhao^[5] is one of the earliest hospitals in China to develop and implement a computer-based RIS, which integrates treatment, medical records, and billing mechanisms. Tian^[6] has simplified the treatment process and achieved a paperless office environment. Given the intricate nature of radiation therapy procedures, Li^[7], Wu^[8], Zhao^[9] have conducted process optimization and refinement, although they focused only on a single type of radiation therapy without further segmentation. Tang^[10] and Zou^[11] have emphasized the role of various personnel and incorporated role-based functions into their radiation therapy process management. Yang^[12] has developed their system by adding standardized personnel division and follow-up tasks to the existing framework.

Previous studies have shown that the use of information technology can address existing issues in radiation therapy departments, leading to improved healthcare service

quality [13]. However, previous studies only focused on general radiation therapy processes without detailed segmentation. Building upon the previous research and considering our hospital's specific circumstances, this paper aims to organize the responsibilities of clinical staff members and streamline the processes of the three types of radiation therapy projects in our department. Additionally, the paper introduces follow-up tasks to develop a comprehensive RIS. The ultimate goal is to reduce costs, enhance efficiency, and provide convenient services to both clinical professionals and patients.

3 Process Design

3.1 Analysis of Departmental Staff Responsibilities

The personnel in the radiation therapy department play a pivotal role within RIS who can be classified into five distinct role groups: department director, registration team, physician team, physicist team, and technician team. Together, these roles handle more than 50 operational procedures, and their specific responsibilities are outlined in **Table 1**. This study focuses on constructing our RIS by leveraging the responsibilities of clinical healthcare professionals. Through the optimization of workflows and the implementation of information management practices, the aim is to standardize role behaviors and ensure the accurate and precise execution of each step. This will ultimately facilitate the delivery of precise and efficient radiation therapy to patients.

Table 1. Responsibilities of Personnel in Radiation Therapy Department

Role Group	Role	Responsibilities
	Department Director	View and manage patient information and treatment records within the department, access statistics on department operations, manage personnel information, functional permissions, etc.
Registration Group	Registration Nurse	Responsible for patient information registration, query, deletion; manual patient check-in, queue management, risk assessment, boost injection; charge viewing and confirming, etc.
physician Group	Superior Physician	View and manage basic information, application information, treatment information, charge information, etc., for all patients within the assigned ward; review patient treatment plans, etc.
	Responsible Physician	View and manage basic information, application information, treatment information, charge information, etc., for assigned patients; request CT simulation, apply and confirm treatment plans; conduct patient case follow-up, etc.
Physicist Group	Superior Physicist	Responsible for quality control management of equipment within the department, including setting up, executing, and documenting equipment quality control plans, reviewing treatment plans, etc.
	Physicist	Responsible for treatment plan design, validation, query; execution and documentation of quality control plans, etc.
Technician Group	CT Technician	Responsible for CT simulation appointment schedule, immobilization producing, CT simulation scanning, images importing, target area contouring and verification, etc.
	Treatment Technician	Responsible for scheduling treatment appointments, implementing treatment according to the plan, documenting treatment processes, etc.

External Beam Radiotherapy Planning Treatment.

Detailed Steps of external beam planning treatment:

(1) Patient registration in outpatient or inpatient settings: Patient information is registered and integrated with HIS, which can be achieved by scanning the patient's medical card to retrieve their information or manually entering it. A front desk staff member takes a patient's photo for identification during the radiation therapy process. A treatment consent form is signed either electronically or manually and uploaded for archiving (outpatients sign at the outpatient department, while inpatients sign before department registration). Patient risk assessment forms such as fall risk assessment and nutritional risk assessment are maintained in this step.

(2) Responsible physician submits requests for immobilization and Computed Tomography (CT) simulation: After receiving the patient's registration, the responsible physician reviews the patient's medical record and submits requests for immobilization and CT simulation. If boost injection is required, an injection certificate (including medication and dosage information) is also signed. Once the requests are completed, a CT simulation appointment is scheduled, and a detailed CT simulation charge statement is issued.

(3) Registration nurse confirms charge and patient payment: The registration nurse confirms the CT simulation charge statement and synchronizes the charge information (including maintaining the item codes in the billing system) before printing the invoice. The patient then makes payment based on the invoice.

(4) CT simulation: The patient self-checks in by facial recognition, QR code scanning, or other methods based on the scheduled appointment time. For elderly patients and others who require assistance, registration desk confirmation is obtained before manually setting the patient's check-in status. The CT technician calls the patient (or the nurse at the desk calls the patient based on the queue) for CT simulation. Immobilization is completed after the patient arrives in the treatment room (if it is a boost project, the nurse administers the injection and signs for confirmation, followed by verification and confirmation by the CT technician). CT simulation scanning is then performed.

(5) Treatment application submission: After completing the CT simulation, the responsible physician can submit the treatment planning application. The CT technician imports the examination images into the contouring system and performs target area contouring, which is then reviewed by the superior technician.

(6) Treatment plan design: The physicist designs the treatment plan, which is then reviewed by the superior physicist. After the review is completed, the responsible physician confirms the plan, and superior physician approves it. After approval, the physicist issues a detailed treatment charge statement, which is then confirmed by the registration nurse, and the patient makes the payment. The physicist also needs to verify the treatment plan and parameters.

(7) Treatment implementation: After confirmation of the treatment parameters, the treatment technician follows the plan and schedules the treatment time with the patient (typically scheduling the entire course of treatment at once, with the flexibility to modify the appointment time during this period). When the scheduled treatment time approaches, the patient self-checks in at the department (or manually checks in). The

treatment technician calls the patient for treatment, records process data, and proceeds to the next treatment according to the treatment cycle. At the end of the process, the treatment technician confirms the completion of treatment and signs, followed by confirmation and signature by the responsible physician.

(8) Follow-up: After the patient completes the entire treatment course, the responsible physician creates a follow-up plan and conducts follow-up visits accordingly, recording detailed follow-up information. Once the follow-up is completed, the entire treatment management process concludes.

External Beam Radiotherapy Simple Treatment.

The process of external beam radiotherapy simple treatment is similar to the planning process, with slight variations in the steps involving the medical physicist and treatment technologist. After CT simulation, the CT technologist does not perform target area contouring but proceeds directly to the application for simplified treatment. Once approved by the responsible physician, the medical physicist fabricates the lead molds. After confirmation by the superior physician, the medical physicist performs a verification of treatment parameters, and the treatment technologist initiates the treatment.

Brachytherapy Treatment

The process of internal brachytherapy (after-loading) is generally similar to external beam radiation therapy, with some variations in the steps involving the responsible physician, CT technologist, and treatment technologist. After patient registration for after-loading treatment, the responsible physician is required to submit requests for immobilization and brachytherapy, as well as schedule the appointment for the after-loading device. During CT simulation, the technologist performs the placement of the source applicator under the guidance of the responsible physician. The responsible physician also evaluates the need for needle insertion, which is carried out if necessary, or alternatively, a catheter is placed to accommodate the source applicator insertion. Following the implementation of treatment by the treatment technologist, the responsible physician is responsible for catheter removal and scheduling the next treatment session.

4 System Implementation

4.1 Analysis of Functions in Radiotherapy Information System

Our RIS is divided into seven functional modules: Registration Management, Medical Records Management, Treatment (Planning) Management, CT simulation Management, Treatment Implementation Management, Data Management, and System Management. The functions of each module are described as follows in **Table 2**.

Table 2. Introduction to Modules of RIS

Module	Submodule	Function Description	
Registration Management	Patient Information Registration	View/edit basic patient information, upload profile pictures.	
	Informed Consent Signing	Online signing/offline signing, scanning and uploading of consent forms.	
	Equipment Reservation Queue Management	View equipment room reservation status. Set patient check-in, call patients for CT simulation/treatment.	
	Billing Confirmation	View detailed billing information, one-click confirmation, print receipts.	
	Risk Assessment	Fill out fall risk assessment forms, nutrition risk assessment forms, view assessment forms.	
	Injection Execution Immobilization Application	View injection information form, sign injection execution. Set application information and submit.	
	CT Simulation Application	Set application information and submit.	
	Boost Injection Submission	Confirm injection drugs and dosage, sign.	
	CT Simulation Appointment	Submit appointment time, modify appointment time.	
	Medical Records Management	Charge Details	Set charge details and submit.
Treatment Application		Apply for simple treatment/planned treatment, submit application information.	
Treatment Confirmation		Treatment plan confirmation, simple treatment confirmation, confirmation by the superior physician.	
Treatment Follow-up		Develop follow-up plan, record follow-up, view follow-up details.	
Treatment Plan		View imported treatment plans, associate treatment plans, submit treatment information.	
Treatment (Planning) Review		View treatment (planning) information, submit treatment (planning) review status.	
Treatment Plan Verification		View treatment verification information, submit treatment plan verification status.	
Lead Mold Production		Submit lead mold production status.	
Treatment Parameters Confirmation		Submit check parameters confirmation status.	
Treatment (Planning) Management		Charge Details	Set charge details and submit.
	CT Simulation	View CT simulation request form, submit CT simulation status.	
	Immobilization	View CT simulation request form, submit immobilization status.	
	Injection Information Verification	View injection information, submit injection information verification status.	
	Image Import	Submit image import status.	
	Target Area Contouring	Submit target area contouring status.	
	Target Area Review	Submit target area review status.	
	Treatment Appointment	View treatment implementation plan, submit treatment appointment, modify appointment time.	
	Treatment Implementation Management	Calling	View call number list, initiate call number.
		Treatment Implementation Course Management	Record treatment details data. Interrupt course, cancel course, end course, transfer to history.
Quality Control Management		View quality control plans, implement quality control, record quality control processes, view quality control data.	
Data Management	Data Analysis	View department operation monitoring, view business data statistics.	
	System Management	User Management	View user information, create users, set user permissions, manage user status.
System Settings		Manage system parameters, data dictionaries, report	

Module	Submodule	Function Description
	Consumable Management	templates, etc. Maintain consumable information, view consumable information and inventory details, manage consumable in/out.
	Equipment Maintenance	Maintain equipment information, view equipment list and details, add/edit/delete equipment maintenance records.

4.2 Design of Radiotherapy Information System

The architecture of our RIS is depicted in **Fig 2**. Our hospital utilizes network connections to link servers, devices, third-party systems, and RIS workstations to create the overall operating environment of the departmental system. The main equipment includes CT simulation machines, accelerators (2 units), and brachytherapy machines. The auxiliary systems consist of radiation contouring software (manual and automatic contouring), radiation planning systems (built-in to the equipment), laser positioning systems, optical surface systems, and various equipment quality control systems, which are integrated and connected to the basic information systems (HIS, Electronic Medical Record (EMR), Picture Archiving and Communication System (PACS), etc.). Two core servers are currently applied, one for structured data storage (database server) and the other for storing patient imaging data (image server). Supporting servers are also deployed to facilitate the operation of other third-party systems, forming our comprehensive management platform for radiation therapy.

RIS includes the following workstations:

- (1) Physician Workstation: Supports the Medical Records functional module.
- (2) Technologist Workstation: Supports the CT Simulation module.
- (3) Physicist Workstation: Supports the Treatment (Planning) module and sub-functions such as appointment scheduling, treatment implementation, and course management in the Treatment Implementation module.
- (4) Call Number Workstation: Supports the call number sub-function in the Treatment Implementation Management, allowing patient calling in different rooms (CT room, treatment room) and enabling the setting of call number rules and content.
- (5) Data Management Workstation: Supports the Data Management functional module.
- (6) System Management Workstation: Supports the System Management module.
- (7) Integration and Interface: Interfaces and integrates with HIS, billing system, integration platform, and other third-party systems.

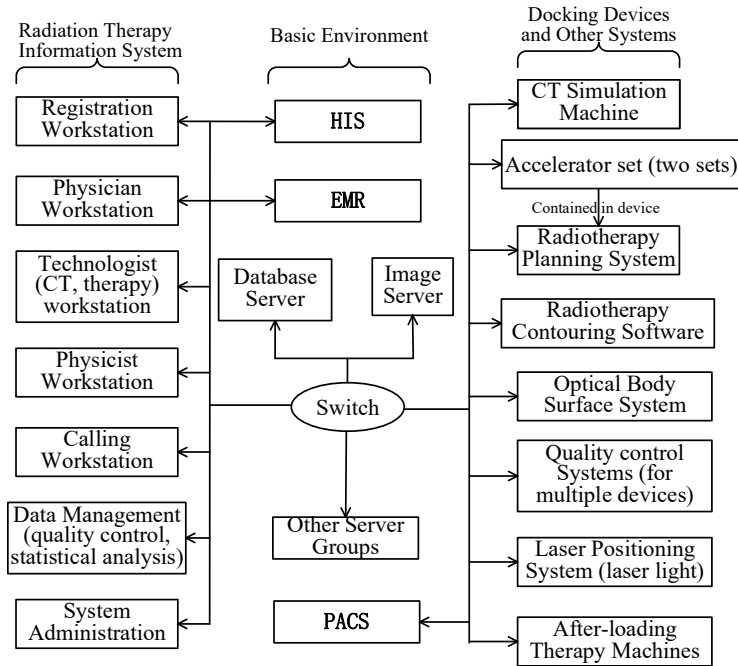


Fig. 2. System Architecture

5 Conclusions

Through the analysis of existing business processes, our hospital has prioritized the goal of ensuring safe and efficient implementation of radiation therapy. We have successfully optimized and improved the radiation therapy workflow through the utilization of information technology, addressing the challenges in our Radiation Therapy Department:

(1) Our RIS supports electronic signature pads to sign informed consent, follow-up, quality control and other paperless office;

(2) Confirmation steps have been incorporated into the workflow, allowing progress to the next operational node only after confirmation by relevant personnel. This has standardized personnel behavior and facilitated quality control management;

(3) Integration with internal hospital systems such as HIS, billing system, and integration platform has been established. This integration enables automatic retrieval of patient information, significantly reducing workload and facilitating clinical access to radiation therapy data.

(4) Our system sorts out three treatment processes: external beam radiotherapy planning treatment, external beam radiotherapy simple treatment, and brachytherapy treatment. RIS strictly adheres to these workflows for operational node management.

RIS has successfully facilitated collaborative operational nodes and standardized processes within the clinical department. It has achieved precise management of

business workflows, improved the efficiency of medical services, enhanced clinical execution, and increased patient satisfaction, enabling better service for a wide range of patients.

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