Review on Radiation Therapy Information Systems

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Abstract

Aim: Clinical and pre-clinical radiotherapy data represent one of the most valuable assets for radiation therapy and oncology institutions. The present study aimed to review various clinical information systems used in the field of radiotherapy and the critical success factors influencing the system implementation.

Method: This review study was completed in 2022. In this study, papers related to clinical information systems in the field of oncology were retrieved by using keywords. The databases and the search engine were Scopus, PubMed, Science Direct, Web of Knowledge, Ovid, Medline, and Google Scholar and the time frame was between 2010 and 2022. Initially, a total of 427 papers were retrieved, and finally, 18 related papers were selected.

Results: The main clinical information systems used in radiotherapy included developing a patient's electronic chart checks (two studies), establishing a web-based Integrated Radiation Oncology Information Platform, implementing a web-based Electronic Data Capture system, developing a data archiving system, developing a prototype software for the anonymization of radiation therapy treatment plans, creating a national radiation oncology registry, identifying deficiencies in treatment plans and radiotherapy simulation, creating a web-based radiotherapy system and other related studies (nine studies).

Conclusion: The use of clinical information systems in the field of radiotherapy is inevitable, mainly due to the wide range of benefits that these systems have. However, to implement these systems successfully, proper choice of technology, user training, application of standards, use of big data, periodic evaluations, as well as workflow identification are required for effective use of these systems.

Keywords: Neoplasms; Hospital Information Systems; Radiotherapy; Hospitals

Cancer is a leading cause of death and disability in the world today. According to a report (GLOBOCAN) in 2020, 1 in 5 people are diagnosed with cancer during their lifetime and 1 in 8 men and 1 in 11 women die due to the disease (1). Radiation Oncology is the field of medicine that utilizes ionizing radiation safely and effectively in the treatment, palliation, and cure of malignant diseases (2).

Radiotherapy (RT) is an interdisciplinary field, based on physics, radiation biology, mathematics, computer science, and electrical and mechanical engineering. Increasing sophistication in computer-assisted diagnostic imaging, image processing, treatment planning, and delivery has improved the accuracy and distribution of radiation dose in patients leading to a significant increase in tumor control and the consequent probability of cure (3).

Currently, in RT departments, there is an increase in the complexity of storage and availability of RT data. Thus, there are different manufacturers and stand-alone Information Systems (IS) for single-purpose applications (4).

The use of clinical information systems in RT is one of the most valuable areas for research since using these systems facilitates clinical activities (5). Moreover, clinical information systems can help to reduce adverse drug reactions and to increase dosing accuracy by providing information on how to make good use of medicines in cancer care (6).

According to the literature review, using information systems for data management in RT cause increasing access to information, improves the quality of clinical care, decreases medical errors, and incident reporting, reduces clinical documentation time, and reporting outcomes, maintains confidentiality, improves resource allocation, increasing user satisfaction, and providing rich data for clinical trials and scientific investigations (2, 3, 6, 7). However, these benefits can be hindered due to the lack of interoperability between the IS, lack of physicians' support, user resistance, lack of necessary training, and lack of user-centered design approach during the development of these systems (3, 4, 6, 8, 9).

Although the design and implementation of clinical information systems in RT have been investigated in different studies, the number of studies related to the application and the critical success factors influencing system implementation is limited. The present study aimed to review different studies regarding the application of various clinical information systems in radiotherapy and the critical success factors influencing system implementation.

Method

This was a review study that was completed in 2022. The main databases and search engines used to search data were Scopus, PubMed, Science Direct, Web of Knowledge, Ovid Medline, and Google Scholar. The key terms included neoplasms, health information technology, electronic medical records, radiation, RT information system, information management, and hospital that were combined using Boolean operators (AND, OR, …) to find related articles.

To review the latest studies the time frame for seeking papers was between 2010 and 2022, and all relevant full-text papers which were in English were selected. The non-English articles, letters to the editor, and books were excluded from the study. Initially, 427 papers were obtained, and 15 duplicates were removed. Lack of access to the abstract and the full text was another reason for removing 39 papers. The remaining papers (n=373) were evaluated. After reviewing the abstracts, 355 papers were removed due to their poor consistency with the aim of this research. The remaining papers (n=18) were used for further investigation (Figure 1) and were evaluated in terms of objectives, methods, and results.

Results

The findings indicated that most papers were published in 2012 and 2014 (Figure 2). These studies were conducted in the following countries: USA (nine), Germany (two), Australia (two), India (one), Taiwan (one), Ireland (one), Japan (one), and Portugal (one). (Table 1)

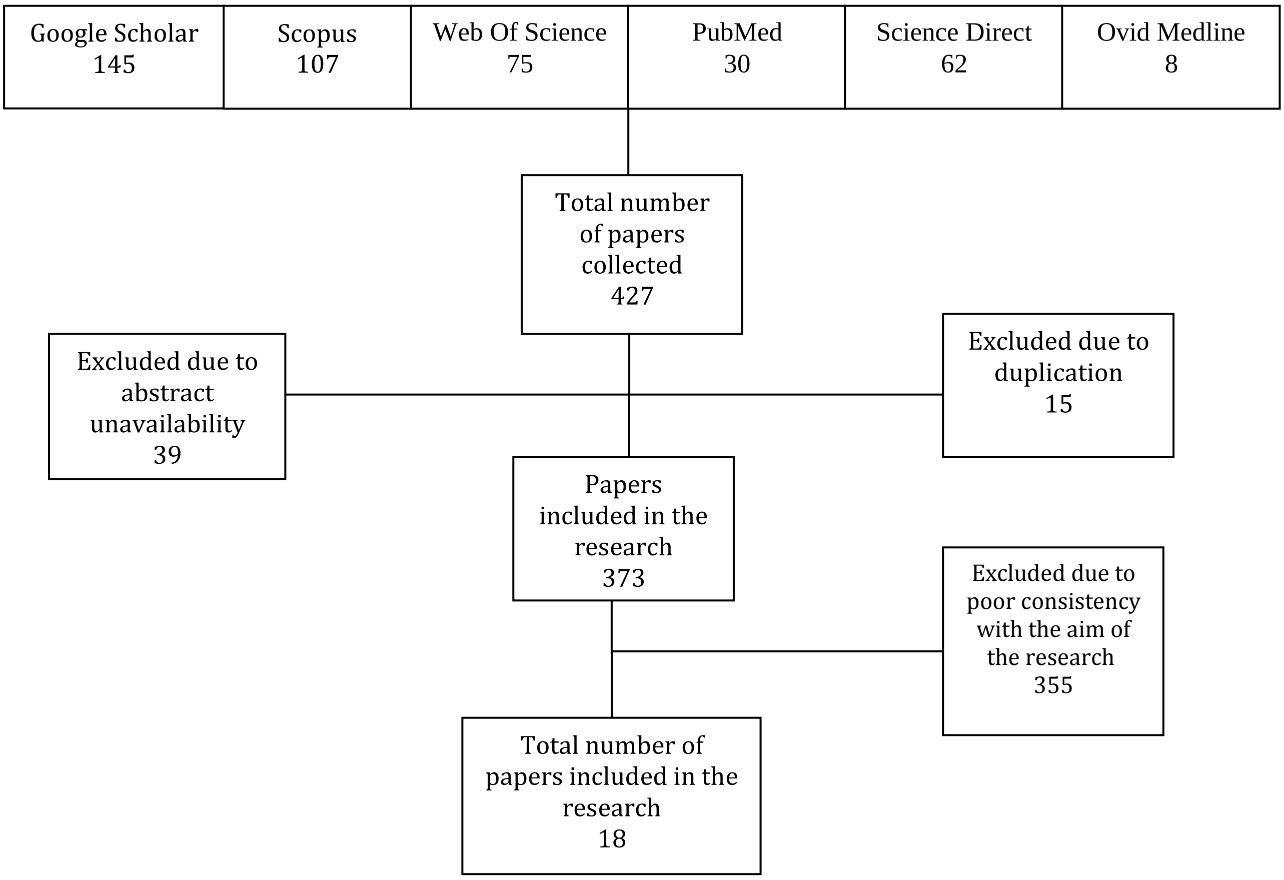

Figure 1: The Process of selecting papers for research

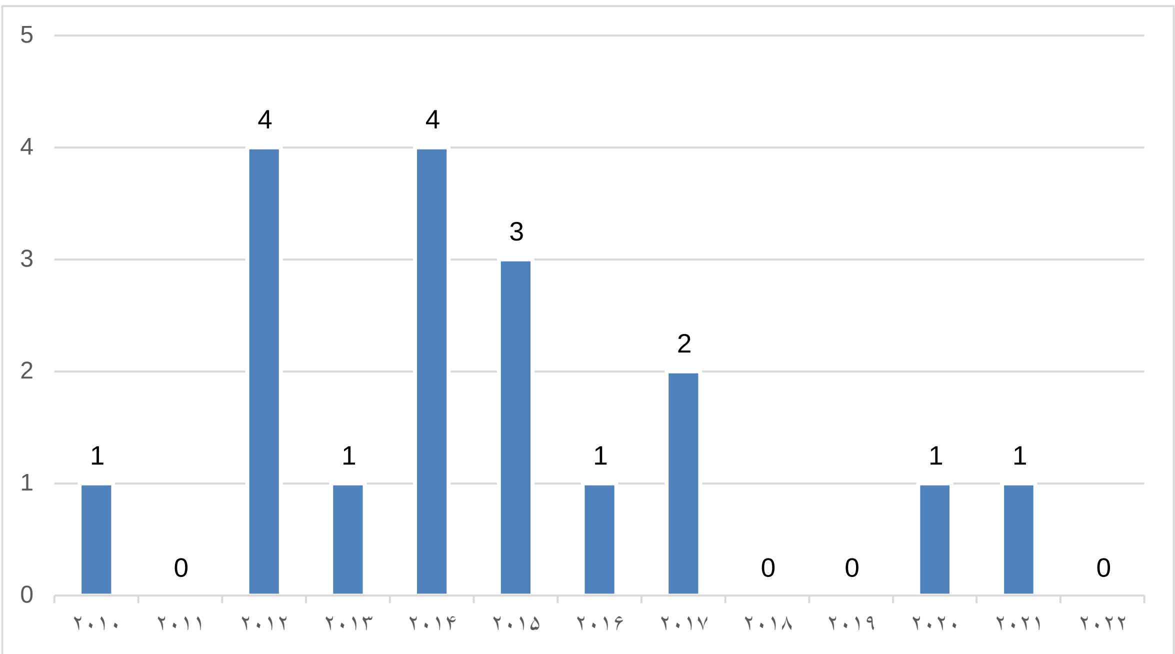

Figure 2: Number of papers published by the year

Table 1: Studies related to the application of various clinical information systems in the field of RT

No	Author, Year	Country	Objective	Methods	Results
1	Mukundan et al, 2021 (2)	India	To RT of error during treatment delivery on a tele cobalt machine.	Checklist development	The checklist helped to rectify 41 documentary lapses and 28 errors in RT treatment parameters while also identifying 12 instances where treatment plan modifications were due and 30 where the patient was due for review by the radiation oncologist. The average time to go through the checklist was between 2.5 and 3 min.
2	Vogelius et al, 2020 (8)	USA	To discuss data interoperability issues within and across organizational boundaries that hamper the introduction of big data and data science techniques in radiation oncology.	Qualitative	Data science should be multidisciplinary and it should involve statistical capabilities, and computational and domain knowledge from clinical radiation oncology. At the semantic level, creating common underlying models and codification of the data, including the use of data elements with standardized definitions, and an ontology remains a work in progress. Methodological issues in data science and the use of large population-based health data registries were identified.
3	T.Pawlicki et al, 2017 (10)	USA	To discuss the background for incident reporting and learning systems	Review study	Incident learning systems can be local, national, or international, each having the same basic goals but facilitating different audiences and environments. A key component of any reporting and learning system is timely and effective analysis of near-misses and incidents as well as feedback to the users of the system. It is important for staff to know that reports are acknowledged, analyzed, and acted upon. There is a need to comply with current European legislation and other national systems, which can be addressed together with the steps required for comprehensive management of an incident.
4	L.C.Chen et al, 2017 (3)	Taiwan	To establish a web-based Integrated Radiation Oncology Information Platform (IROIP) to grasp data from several independent information systems, such as Health Information System (HIS) and RT Information System (RIS).	Software development	This integration demonstrated a real-time manner, resulting in a more effective way to enhance treatment efficacy and increase patient safety. Staff safety was also guarded during RT by preventing intra-mural infections. After implementing the e-control of IROIP, the overall processing time of the pre-RT workflow was shortened from 12.2 days to 8.9 days ($P < 0.001$). After online use of automatic alert of IROIP for patients' abnormal data before each RT treatment, the rate of developed severe leukopenia was decreased from 94% to 58% ($P < 0.001$). More notably, the intra-mural

No	Author, Year	Country	Objective	Methods	Results
					infection rate also decreased from 26.1% to 6.7% (P <0.05). Remarkably, by using IROIP, the processing time required for pre-RT "time out" to check laboratory data was significantly reduced from 40 min to <1 min (per 100 patients per day)
5	Pan et al, 2016 (11)	USA	To implement a web-based Electronic Data Capture (EDC) system for routine clinical care, and to describe the experience piloting this system for breast cancer patients receiving RT.	Software development	The EDC system has been used by 25 providers for 1,296 patients. In the most recent month, 978 clinical notes were generated. The average clinician documentation time over a typical course of radiation was reduced from 22.4 minutes per patient with dictation to 7.1 minutes with EDC.
6	García et al, 2015 (12)	Australia	To review RT planning tools that are specifically adapted to Intraoperative radiation therapy (*IORT*).	Review study	RADIANCE was a prominent IORT planning system, CE and Food and Drug Administration (FDA) certified, developed by a consortium of companies, hospitals, and universities to overcome such technological backwardness. RADIANCE provided all basic RT planning tools which are specifically adapted to IORT. This included image visualization, contouring, dose calculation algorithms—Pencil Beam (PB) and Monte Carlo (MC), Dose-Volume Histogram (DVH) calculation, and reporting. Other new tools, such as surgical simulation tools have been developed to deal with specific conditions of the technique.
7	Kerstin et al, 2015 (13)	Germany	To characterize current developments in combining patient data from all involved systems in RT departments and practices.	Quantitative	University hospitals, community hospitals, and private practices are equally equipped concerning IT infrastructure for clinical use. However, private practices have a low interest in research work. All respondents stated the biggest obstacles to introducing a documentation system into their unit lie in funding and support of the central IT departments
8	Mukai et al, 2015 (14)	Japan	To develop a data archiving system for RT	Software development	The main subjects in the medical informatics field that they focused on were patient demographics and visit information, RT order and delivery information, communication of treatment follow-up information, and laboratory test.
9	Wayne Newhouse,	USA	To develop a prototype software	Software development	They extended an open-source code to process all relevant PHI and to allow for

No	Author, Year	Country	Objective	Methods	Results
	2014 (15)		code to meet the requirements for the anonymization of RT treatment plans and to develop a way to validate that code and demonstrate that it properly anonymized treatment plans and preserved data integrity.		the automatic anonymization of multiple Electronic Medical Records. The prototype code successfully anonymized multiple treatment plans in less than 1 min/patient. They also tested commercial optical character recognition (OCR) algorithms for the detection of burned-in text on the images, but they were unable to reliably recognize text. In addition, they developed and tested an image filtering algorithm that allowed them to isolate and redact alpha-numeric text from a test radiograph. Validation tests verified that PHI was anonymized and data integrity, such as the relationship between DICOM unique identifiers (UID) was preserved.
10	Skripcak et al, 2014 (16)	Germany	To discuss a framework for conceptual packages of ideas focused on strategic development for international research data exchange in the field of RT and oncology.	Qualitative	Creating a robust and usable RT-specific data exchange strategy was challenging but feasible. It required investments and the full commitment of participating institutions. However, such a strategy was a fundamental prerequisite enable in the gable multi-centric pooling of cancer research data into common well readable, and reusable datasets. This process allowed seamless collaboration on large-scale international studies and computer-aided analysis of the high-quality clinical research data and will be the basis for rapid knowledge generation in the field of RT.
11	Moore et al, 2014 (17)	USA	to consider what computational advances are likely to be implemented in clinical radiation oncology in the coming years and how the adoption of these changes might alter the practice of RT.	Quantitative	Four main areas of likely advancement were explored: cloud computing, aggregate data analyses, parallel computation, and automation. As these developments promised both new opportunities and new risks to clinicians and patients alike, the potential benefits were weighted against the hazards associated with each advance, with special considerations regarding patient safety under new computational platforms and methodologies.
12	Shakeshaft, 2014 (18)	Australia	To guide safe work practices and a suitable level of quality control without detailed work instructions.	Qualitative	Both the OIS and OPACS have become mission-critical systems in any modern radiation oncology department. It is important as part of the commissioning process to ensure that business continuity planning has been performed. Two critical steps in the design of a disaster recovery plan are identifying and evaluating risks and defining the recovery strategy in RT.

No	Author, Year	Country	Objective	Methods	Results
13	Efstathiou et al, 2013 (19)	USA	To design the national radiation oncology registry for collecting standardized information on cancer care delivery among patients treated with RT.	Software development	An electronic infrastructure was developed to provide connectivity across radiation oncology and hospital information systems. The initial set of radiation practice metrics include physician board certification and maintenance, ordering of staging scans, active surveillance discussion, dose prescriptions for low-risk/high-risk disease, radiation fields for low-risk/high-risk disease, image-guided radiation therapy use, androgen deprivation therapy use, post-brachytherapy implant computed tomography dosimetry, collection of toxicity assessments, and longitudinal patient follow-up.
14	Oliveira et al 2012 (4)	Portugal	To assess the experopinionsnion of DICOM-RT and information system interoperability in the RT context.	Quantitative	Results showed that the RT departments have some equipment and information systems from different vendors contributing to the heterogeneity of RT workflows. The experts had low knowledge about the information system integrations and DICOM-RT.
15	Santhanam et al, 2012 (20)	USA	Identify deficiencies with simulation and treatment planning orders and develop corrective measures to improve safety and quality.	Software development	An interdisciplinary group evaluated and decided to replace the Microsoft word-based form with a web-based order system. This ordering system has mandatory fields and context-sensitive logic, an ability to create templates, and enables an automated process for communication of orders through an enterprise management system. The average time to complete the Simulation and treatment Planning Electronic (SIMPLE) form was 3 minutes, as compared with 7 minutes for the word-based form.
16	Santos et al, 2012 (21)	USA	To map the level of clinical practice compatibility with a radiation oncology information system (ROIS) through a workflow and clinical process-based method.	Mixed method (Qualitative and Quantitative)	Practice-specific processes and infrastructure maps were generated. The developed survey was applied and the results indicated a range of ROIS compatibility with clinical workflow and infrastructure. The survey results combined with experiential feedback provided specific guidance to improve both ROIS performance and clinic-specific processes and infrastructure.
17	Yang et al, 2012 (22)	USA	To improve the quality and efficiency of patient chart checking in radiation oncology departments	checklist development	The software was successfully implemented in the clinical environment and has demonstrated the feasibility of automation of this common task with modern clinical tools. The software integrates multiple disconnected systems and successfully supports the analysis of data in diverse formats.

No	Author, Year	Country	Objective	Methods	Results
18	Joanne Cunningham 2010 (7)	Ireland Sweden Austria	To investigate The Radiation Oncology Safety Information System (ROSIS)	Software development	A total of 1074 ROSIS reports were analyzed; 97.7% related to external beam radiation treatment and 50% resulted in incorrect irradiation. Many incidents arose during pre-treatment but were not detected until later in the treatment process. Where an incident was not detected before treatment, an average of 22% of the prescribed treatment fractions were delivered incorrectly. The most commonly reported detection methods were "found at the time of patient treatment" and during "chart-check".

The findings showed that the use of clinical information systems in the RT department was examined in different studies. Software development was the research methodology in seven studies (3, 7, 11, 14, 15, 19, 23). Other studies used checklist development (2, 22), quantitative methods (4, 13, 17), qualitative methods (8, 16, 18), mixed methods (qualitative and quantitative) (21), and review study (10, 12). The aims of these studies were designing a checklist for RT technicians (RTTs) to reduce chances of error (2), developing a patient's electronic chart (22), establishing a web-based Integrated Radiation Oncology Information Platform (IROIP)(3), implementing a web-based Electronic Data Capture system for routine clinical care (11), developing a data archiving system for RT (14), developing a prototype software code to meet the requirements for the anonymization of radiation therapy treatment plans (15), creating a national radiation oncology registry (19), identifying deficiencies in treatment plans and RT simulation (23), creating a web-based RT system (7), characterizing current developments in combining patient data in RT departments (13), considering computational advances in clinical radiation oncology (17), assessing expert's opinion about DICOM-RT and information system interoperability (4), discussing data interoperability issues within and across organizational boundaries (8), discussing a framework for research data exchange in the field of RT (16), providing guidance for safe work practices(18), determining the level of compliance of clinical activities with a RT information system (21), reviewing RT planning tools which are specifically adapted to IORT (12) and discussing the background for incident reporting and learning systems (10).

In 2021, Mukundan et al (2) developed a physical checklist for RT technicians (RTTs) in India. The development and use of the checklist have helped in reducing errors and also improving workflow. It is recommended to utilize such physical checklists in all RT centers with tele cobalt machines. Also, the success of the checklist depended upon leadership, teamwork, and acceptance of a need to inculcate a "safety culture," with voluntary error-reporting and a willingness to learn from such errors. Also In the United States, A patient's Electronic Chart Check (ECCK) was created by Yang et al (22) to collect electronic data and analyze patient's treatment information. The system was able to provide more time for more important tasks by eliminating simple and repetitive activities.

In 2017, Chen et al (3) established a web-based Integrated Radiation Oncology Information Platform (IROIP) to enhance working efficiency and increase patient safety.

The findings showed that an Integrated Information Platform is useful in not only effectively integrating data from different information systems, but also alerting abnormal medical data to allow immediate intervention. These abilities enhanced the working efficiency and increased patient safety. In another study, Cunningham et al (7) developed a voluntary web-based cross-organizational and international reporting and learning system. While the majority of the incidents reported to this international cross-organizational reporting system were of minor diametric consequence, they affected on average more than 20% of the patient's treatment fractions.

In 2013, Efstathiou et al (19) showed that The overall goal of the national radiation oncology registry was improving the quality of cancer treatment by assessing outcomes and providing real-time care. In Santhanam et al study (23), an intelligent simulation and treatment Planning Electronic (SIMPLE) order system were designed. The system provided an opportunity to create and save templates of treatment plans and simulations. After executing the SIMPLE Plan the incidence of events in the RT department decreased from 13% to 6%. In addition, the average time required to complete the electronic forms compared to the word-template forms decreased from seven minutes to three minutes. In 2016 (11), a web-based data collection system was developed to improve clinical documentation in RT. The results indicated that in addition to facilitating the reporting of outcomes, the system reduced the average time of documentation by physicians from 22 to 7 minutes per patient, and 92% of respondents were satisfied with the system. In research conducted by Mukai et al (14), A filing system for the RT department was created. In this system, electronic medical records were used as input for collecting RT data, and another system was used for reporting and summarizing RT. Also, this system was created by using standard technologies. In 2014, Newhauser et al (15) developed a prototype software code to meet the requirements for the anonymization of RT treatment plans. The prototype code successfully anonymized multiple treatment plans in less than 1 min/patient. Also, validation tests verified that protected health information (PHI) was anonymized and data integrity, such as the relationship between DICOM unique identifiers (UID) was preserved.

About the application of DICOM-RT (a standard method for data transfer in RT workflows that describes six major areas, the structure of RT, radiation treatment plan, RT dose, RT image, treatment records, and summary of treatment records) and interoperable systems, the analysis of the experts' opinions showed that there was a lack of compatibility between equipment and information systems with RT workflows. In addition, there was limited knowledge about the use of DICOM-RT, and finally, it was recommended to use this standard to enhance interactions between information systems in the RT department(4).

According to Moore et al. study (17), Four main areas of likely advancement in clinical radiation were cloud computing, aggregate data analyses, parallel computation, and automation. As these developments promised both new opportunities and new risks to clinicians and patients alike, the potential benefits were weighted against the hazards associated with each advance. Regarding the advancements in information technology in RT, the findings showed that economic constraints and insufficient support for information technology in the hospitals were the most important barriers to creating an RT documentation system (13). Determining the level of compliance of clinical activities with an RT information system provided some feedback to enhance RT information, IT infrastructure, and clinical functions(21).

In 2014, Shakeshaft et al (18) provided recommendations for achieving the appropriate level of quality in RT. Since, it is crucial to identify errors and to provide an appropriate approach in a disaster recovery plan, testing fail-over between servers, testing treatment plan delivery during a network or a server failure, and taking backup and restoring data should receive more attention. Regarding Creating a data exchange strategy for RT research, skripcak et al (16) emphasized paying more attention to issues such as data interoperability, utilization of standards, data quality and privacy concerns, data ownership, rights to publish, and data pooling architecture and storage.

Since Radiation oncology is a technology and computer-intensive medical specialty, it should lend itself ideally to data science methods, where computer science, statistics, and clinical knowledge are combined to advance state-of-the-art care. Velious et al (8) emphasized it should involve statistical capabilities, and computational and domain knowledge from clinical radiation oncology.

A review study conducted by Garcia et al (12) highlighted Using RADIANCE with preoperative images guarantees the documentation of the procedure, facilitates quality assurance as well as boosts the adoption of the technique by reducing the learning curve of the ROs and improving the communication with the surgical team. They mentioned that RADIANCE will be more useful when using intraoperative images. According to Pawlicki et al (10) study, Reporting and learning from incidents and near-misses was a key component of quality and safety in RT. A major benefit of the national or international systems was the potential for a larger database of incidents, supporting wider analysis and comparison, and sharing of knowledge across a larger community.

Discussion

To improve the quality of cancer care and clinical research, the use of information and communication technology seems to be inevitable in managing the increasing volume of health data. Therefore, the use of clinical information systems in the field of RT has been suggested to manage related data. The main advantages of using these systems include improving the quality of care, reducing medical errors, decreasing clinical documentation time, providing rich data for clinical research, and controlling health costs.

In the current study, papers related to the use of clinical information systems in the field of RT published between 2010 and 2022 were reviewed. Most of these studies were conducted in the USA (nine studies) and other developed countries such as Australia, Germany, India, Taiwan, Ireland, and Portugal. Therefore, considering the importance of these systems in improving the quality of care for cancer patients and facilitating clinical activities, the research in this area seems to be limited. In fact, given the complexity of care and workflows in the field of oncology, numerous studies can be conducted to explore the application of clinical information systems in RT. Besides, since most of these studies were conducted in developed countries, similar studies in developing countries seem to be necessary to be able to compare similarities and differences.

The findings indicated that a significant number of studies aimed at designing and implementing RT information systems (3, 7, 11, 14, 15, 19, 23). Designing a web-based Integrated Radiation Oncology Information Platform (IROIP) to grasp data from several independent information systems, such as Health Information System (HIS) and RT Information System (RIS) is preferred. Because this integration demonstrated a real-time manner, resulting in a more effective way to enhance treatment efficacy and increase patient safety. Staff safety was also guarded during RT by preventing intra-mural infections. Also, a web-based EDC system that integrated hospital-based EHRs with a radiation-specific record-and-verify system for routine clinical use is advised.

Safety and quality are two important topics in RT. To share information on incidents and near-incidents in RT and to learn from these incidents in the context of departmental infrastructure and procedures, A web-based cross-organizational and international reporting and learning system is needed. Also, To identify deficiencies with simulation and treatment planning orders and to develop corrective measures to improve safety and quality, an intelligent simulation and treatment Planning Electronic (SIMPLE) order system was designed. The new Web-based order form, with custom fields and consistency checking based on site and simulation, results in a significant reduction in the number and severity of events and is quicker to complete. Since Patient registries have emerged as important tools for the collection of data on the quality, safety, effectiveness, and value of medical therapies, developing a national electronic registry for radiation oncology is suggested by the national registry of RT (NROR).

Based on the findings, since most of the RT information systems contain scattered data from other information systems, it is essential to pay more attention to the standardization and the clinicians' workflows. The application of the DICOM-RT standard has been suggested in various studies. DICOM-RT consists of six main objectives which are RT structure, radiation treatment planning, radiation dose, radiation image, radiation treatment documents, and a summary of RT documents. This standard offers a standard method for data transfer in the RT department (4). Therefore, such a standard approach can be adopted to manage RT departments more efficiently.

The finding showed that the presence of a team of varied professionals with specific skills and responsibilities, complex technologies, computer applications, multiple interphases, and the stressful and time-constrained milieu of modern medicine are some of the factors that may cause the errors in radiation oncology (2, 22). Therefore, electronic checklists have been introduced in simulation, treatment planning, treatment delivery, and audits of RT processes. Thus, the development and use of the electronic checklist help in reducing errors and also improving workflow in our department.

RT data are complex and longitudinal data sets which frequently collected to track both tumor and normal tissue response to therapy. Advances in computer storage, computing power, statistical methods, and the ability to electronically associate multiple types of data from disparate sources (e.g. demographic, genetic, imaging, treatment, and outcomes) have enabled “Big Data” research in RT. There is a clear need in radiation oncology, across multiple cancer sites, to use Big Data for research aimed at both improving cancer cure rates and reducing the incidence of normal tissue toxicity.

The study findings showed that although numerous clinical information systems have been developed in the field of RT (3, 7, 11, 14, 15, 19, 23), a limited number of these systems were evaluated and there is little evidence regarding the impact of these systems on cancer care. In fact, similar to other areas, these systems need to be evaluated based on certain criteria to maximize the benefits obtained from them.

Overall, this review study showed that clinical information systems in the field of RT can help to improve the readability of documents, to enhance the flow of information, to reduce the searching time, provide complicated treatments plans, eliminate errors in prescribing, assess clinical outcomes, to provide evidence-based activities, to reduce waiting time, and to control health costs. These benefits can be achieved following successful system implementation. Besides, the most important success factors of these systems were as follows: clinical leadership, paying attention to the clinical and organizational processes, workflow re-engineering, application of electronic protocols, system integration, the use of data analytical tools, the use of big data, the use of systematic quality assurance programs, user-friendly interface design, user satisfaction, user training, periodic evaluation and application of standards (18, 19).

In addition, the complexity of the system, considerable cost and time for implementation, the need for standardization, and concerns over patient safety, security, confidentiality, and quality of care were the main obstacles in front of using these systems. It seems that before designing and applying such systems, a thorough understanding of care processes and workflows is necessary to avoid any failure in the future. This approach can help to identify users' requirements before designing systems and increase the possibility of successful system implementation.

Conclusion

The deployment of clinical information systems in the field of RT seems to be useful to perform daily activities. Establishing and applying an integrated information platform is useful in not only effectively integrating data from different information systems, but also in alerting abnormal medical data to allow immediate intervention. These abilities enhance working efficiency and increase patient safety. A user-centered and participatory design method should be applied to achieve these benefits. The variety of workflows and information needs in different departments are the main reasons for designing different systems. Also, Data derived from biomedical research are diverse and complex as this includes imaging, phenotypic, genetic/genomic, molecular, exposure, health, behavioral, demographic, treatment, outcomes, toxicity, and so on. Big Data methods allow researchers to maximize the potential of existing data and enable new directions for research.

To ensure that the systems are successfully implemented, evaluation studies are inevitable. Future research may pay more attention to the evaluation of the systems' functions as well as the impact of the systems on patient care and daily activities. To prevent errors and improve performance in RT, electronic checklist should be used. The development and use of the electronic checklist help in reducing errors and also improving workflow in the radiation department.

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