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Data Analysis Model for Computed Tomography Usage

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ABSTRACT

Radiology medicine is one of the fields experiencing extremely rapid development in modern medicine. Among these fields, computed tomography (CT) plays a crucial role in medical clinical diagnosis. However, computed tomography have high medical costs due to expensive medical equipment, the use of contrast agents, professional radiographers operating the equipment, and the need for radiologists to interpret reports. In the current medical environment where Taiwan implements a global budget system, the rationality of the number of computed tomography examinations has always been a focus of concern. In this study, we employed Royce's waterfall model to develop a cloud-based and mobile bed dynamic model system. The primary research objective was to provide supervisors with the latest data analysis model for CT usage.

Keywords: computed tomography, waterfall model, cloud-based, electronic commerce, and dynamic model.

INTRODUCTION

CT examinations can be applied to almost the entire body, and their greatest advantages are speed, versatility, and affordability. Typically, CT scans are used to detect tumors or inflammations in organs. Whether it's screening for liver cancer, lung cancer, or brain cancer, CT proves to be a powerful diagnostic tool. CT's X-ray radiation carries a carcinogenic risk, but if performed only once or twice a year, the cumulative dose remains low, and the carcinogenic risk is minimal, Jalaber *et al.* (2020). However, if the number of examinations exceeds two times a year, a careful evaluation is advisable, and hospitals must also consider the cost of CT as an important factor. In this study, we analyzed whether the volume of computed tomography scans conducted by various medical departments or different patient types in a large hospital within a specific region is excessive or high. Subsequently, we provided the hospital management with insights for formulating cost-control policies.

LITERATURE REVIEW

Waterfall Model

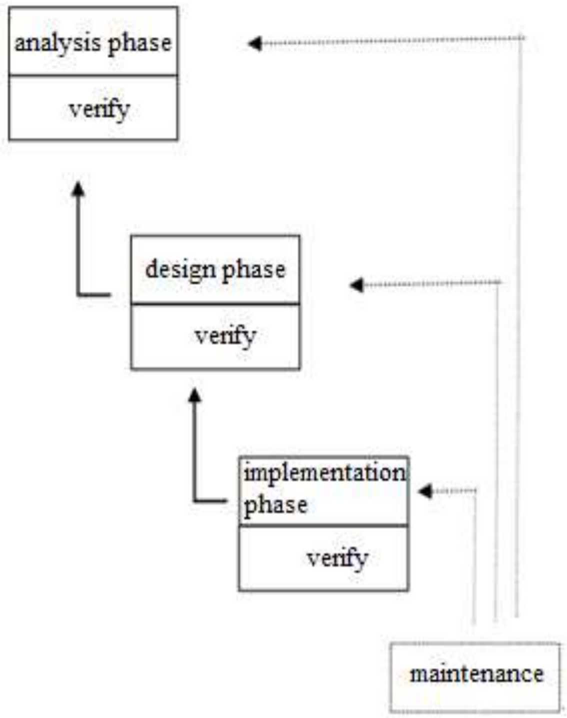
The Waterfall Model, sometimes referred to as the classical life cycle or linear sequence model, is also known as waterfall development. The original standard for most software development adheres to the Software Development Life Cycle (SDLC) process, requiring a comprehensive experience of each stage in the life cycle, Royce *et al*. (1970). This process involves systematic considerations, including time, resources, analysis, design, and technology. The analysis, design, and implementation phases are typically subdivided into at least three stages but are often expanded to encompass five to seven stages. (2022). The requirements analysis phase focuses on gathering requirements and understanding the characteristics of the software to be created. Once the user approves the requirements phase, the Specification team creates a Specification document. The design phase transforms requirements into software representations, providing insight into code quality before production. The implementation phase involves converting designs into machine-readable code, essentially the step of code generation. Following code generation, program testing begins, and after software delivery to the user, the maintenance phase addresses inevitable changes and updates, TRahayu *et al.* (2020).

Computed Tomography

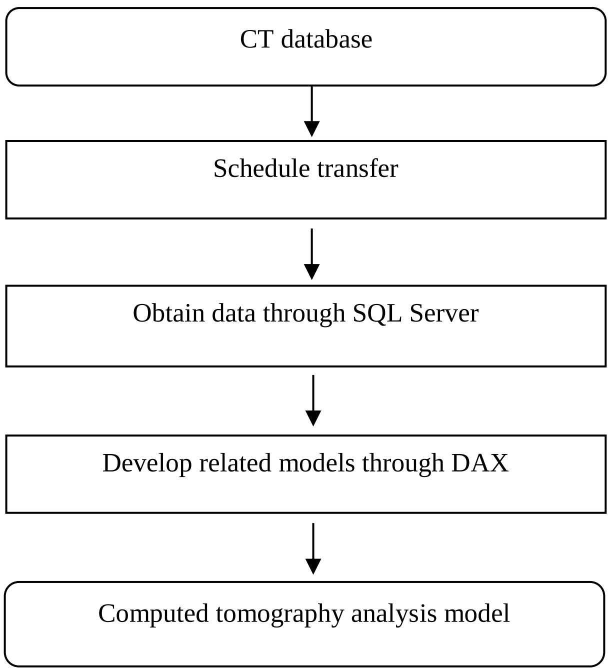
Computed Tomography (CT for short), also known as computerized tomography, is an imaging diagnostic examination. The technique used to be called Computed Axial Tomography (CAT). (2021). It employs computer-processed combinations of numerous X-ray measurements taken from various angles to generate cross-sectional (tomographic) images, often referred to as virtual 'slices,' of a specific scanned area of the object. This allows users to visualize the interior of the object without the need for physical dissection. In 1979, the Nobel Prize in Physiology or Medicine was jointly awarded to South African-American physicist Alan Cormack and British electrical engineer Godfrey Hounsfield for their pioneering work in the development of computer-assisted tomography, Narula *et al*. (2021).

METHODOLOGY

The research adopts the three-stage waterfall model proposed by Winston Royce (1970). The stages of analysis, design, and implementation are shown in Figure 1. The development model requires rigorous verification in each stage. After completing one stage, proceed to the next stage. In the initial phase of the study, we used the development tool PowerBI to develop models using DAX syntax and imported the computer tomography execution volume database of outpatients, emergency and inpatients into the Power BI system for data analysis, Beckeret al. (2019). We explored different medical disciplines and physicians. The number of CT examinations issued and the occurrence of more than two body parts examined by patients on the same day are used as the data basis for feedback to the medical department. The back-end uses C# syntax to match the MS-SQL Server database, through scheduling settings, regularly updates the data, and compiles the research structure of this study through the data warehouse data, as shown in Figure 2. The usage data analysis model of computed tomography in the study, the three stages of the waterfall model in the development process are as follows. And the analysis period: from January 15, 2023, to February 15, 2023, a total of 30 days. Design phase: From February 16, 2023, to March 31, 2023, the design phase took 1.5 months to develop. Implementation stage: The function of the patient return medical system will be implemented on May 1, 2023, on the hospital's webpage and mobile presentation, to achieve the research purpose of this study.



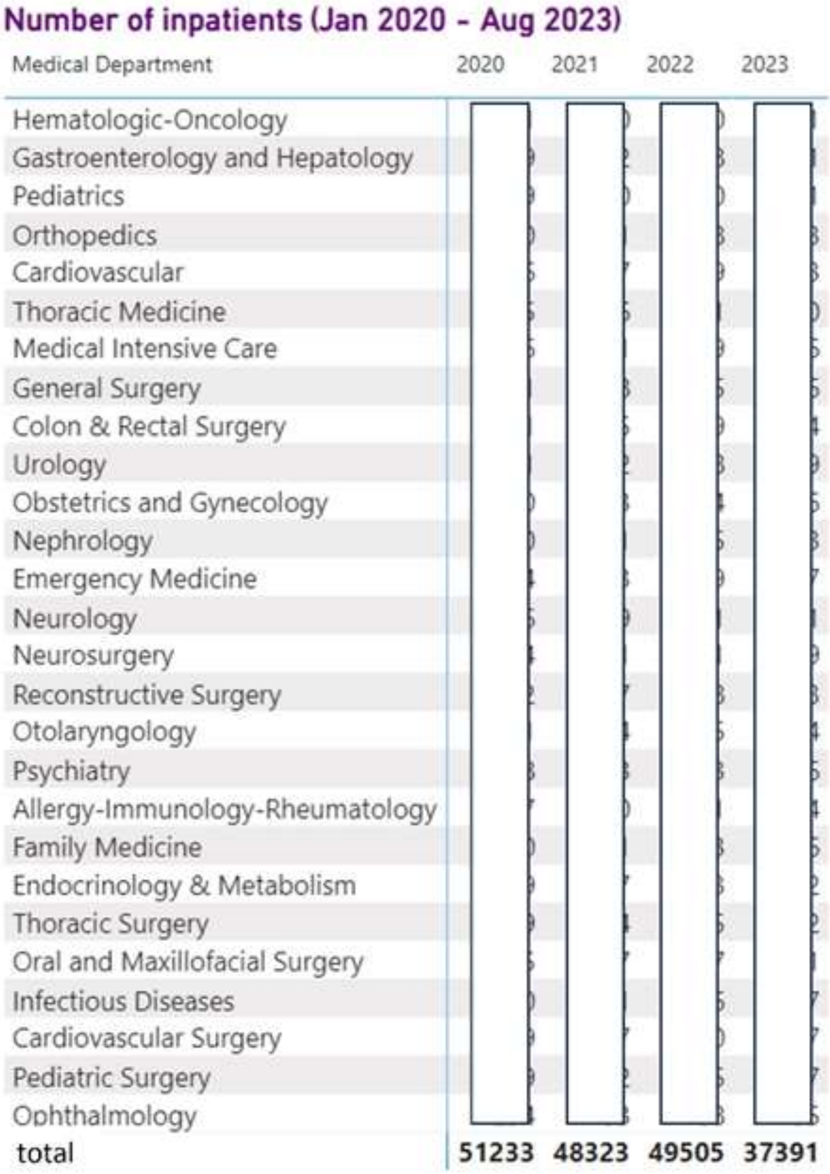
Source: Winston Royce (1970).
Figure 1: Development model.



Source: This study.
Figure 2: The reference styles in the tex.

RESULT

This study analyzed a total of 3,031,210 outpatients and 186,452 inpatients from January 2020 to August 2023 (Figure 2 & Figure 3). Data results indicate that in the outpatient department (Figure 4-1 & Figure 4-2), medical departments with a higher number of cancer patients, such as thoracic surgery, hematology and oncology, thoracic medicine, radiation oncology, colorectal surgery, etc., indeed exhibit a higher frequency of ordering computed tomography examinations as follow-up procedures. In the inpatient department (Figure 5-1 & Figure 5-2), departments with a significant population of critically ill patients, such as surgical intensive care, neurosurgery, neurology, cardiovascular surgery and general surgery, also demonstrate a greater proportion and repetition of computed tomography examinations for inpatients. Furthermore, when hospital management implemented specific measures, the rate of repeated scans decreased, successfully achieving the research objectives of this study. However, due to internal management requirements, we are currently unable to present the relevant data and information regarding the rate of repeated CT scans in various medical departments and the extent of their reduction. We apologize for any inconvenience this may cause.



Number of inpatients (Jan 2020 - Aug 2023)

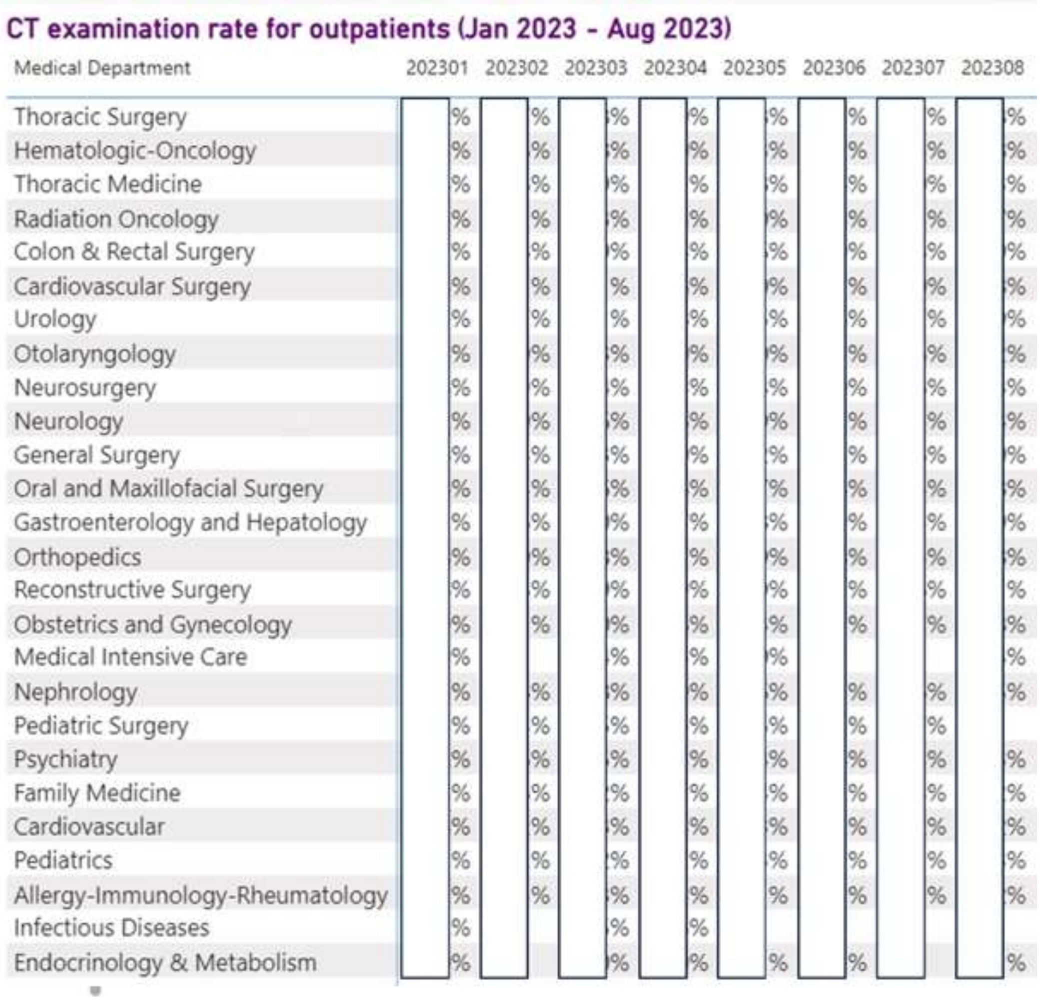
Medical Department	2020	2021	2022	2023
Hematologic-Oncology				
Gastroenterology and Hepatology				
Pediatrics				
Orthopedics				
Cardiovascular				
Thoracic Medicine				
Medical Intensive Care				
General Surgery				
Colon & Rectal Surgery				
Urology				
Obstetrics and Gynecology				
Nephrology				
Emergency Medicine				
Neurology				
Neurosurgery				
Reconstructive Surgery				
Otolaryngology				
Psychiatry				
Allergy-Immunology-Rheumatology				
Family Medicine				
Endocrinology & Metabolism				
Thoracic Surgery				
Oral and Maxillofacial Surgery				
Infectious Diseases				
Cardiovascular Surgery				
Pediatric Surgery				
Ophthalmology				
total	**51233**	**48323**	**49505**	**37391**

Figure 2: Number of inpatients (Jan 2020 - Aug 2023).

Number of outpatients (Jan 2020 - Aug 2023)

Medical Department	2020	2021	2022	2023
Gastroenterology and Hepatology				
Neurology				
Cardiovascular				
Endocrinology & Metabolism				
Orthopedics				
Ophthalmology				
Psychiatry				
Urology				
Hematologic-Oncology				
Pediatrics				
Allergy-Immunology-Rheumatology				
Reconstructive Surgery				
General Surgery				
Neurosurgery				
Thoracic Medicine				
Obstetrics and Gynecology				
Nephrology				
Otolaryngology				
Family Medicine				
Rehabilitation				
Colon & Rectal Surgery				
Dermatology				
Radiation Oncology				
Oral and Maxillofacial Surgery				
Thoracic Surgery				
Infectious Diseases				
Cardiovascular Surgery				
total	**837408**	**811657**	**813139**	**569006**

Figure 3: Number of outpatients (Jan 2020 - Aug 2023)



CT examination rate for outpatients (Jan 2023 - Aug 2023)

Medical Department	202301	202302	202303	202304	202305	202306	202307	202308
Thoracic Surgery	%	%	%	%	%	%	%	%
Hematologic-Oncology	%	%	%	%	%	%	%	%
Thoracic Medicine	%	%	%	%	%	%	%	%
Radiation Oncology	%	%	%	%	%	%	%	%
Colon & Rectal Surgery	%	%	%	%	%	%	%	%
Cardiovascular Surgery	%	%	%	%	%	%	%	%
Urology	%	%	%	%	%	%	%	%
Otolaryngology	%	%	%	%	%	%	%	%
Neurosurgery	%	%	%	%	%	%	%	%
Neurology	%	%	%	%	%	%	%	%
General Surgery	%	%	%	%	%	%	%	%
Oral and Maxillofacial Surgery	%	%	%	%	%	%	%	%
Gastroenterology and Hepatology	%	%	%	%	%	%	%	%
Orthopedics	%	%	%	%	%	%	%	%
Reconstructive Surgery	%	%	%	%	%	%	%	%
Obstetrics and Gynecology	%	%	%	%	%	%	%	%
Medical Intensive Care	%		%	%	%			%
Nephrology	%	%	%	%	%	%	%	%
Pediatric Surgery	%	%	%	%	%	%	%	
Psychiatry	%	%	%	%	%	%	%	%
Family Medicine	%	%	%	%	%	%	%	%
Cardiovascular	%	%	%	%	%	%	%	%
Pediatrics	%	%	%	%	%	%	%	%
Allergy-Immunology-Rheumatology	%	%	%	%	%	%	%	%
Infectious Diseases	%		%	%				
Endocrinology & Metabolism	%		%	%	%	%		%

Figure 4-1: Average monthly CT examination rate for outpatients (Jan 2020 - Aug 2023)

Average monthly CT examination rate for outpatients (Jan 2020 - Aug 2023)

Medical Department	2020	2021	2022	2023
Thoracic Surgery	%	%	%	%
Hematologic-Oncology	%	%	%	%
Nuclear Medicine	%	%		
Radiation Oncology	%	%	%	%
Thoracic Medicine	%	%	%	%
Colon & Rectal Surgery	%	%	%	%
Otolaryngology	%	%	%	%
Urology	%	%	%	%
Neurosurgery	%	%	%	%
Cardiovascular Surgery	%	%	%	%
General Surgery	%	%	%	%
Neurology	%	%	%	%
Oral and Maxillofacial Surgery	%	%	%	%
Gastroenterology and Hepatology	%	%	%	%
Medical Intensive Care	%	%	%	%
Geriatric Medicine		%	%	
Orthopedics	%	%	%	%
Reconstructive Surgery	%	%	%	%
Pediatric Surgery	%	%	%	%
Obstetrics and Gynecology	%	%	%	%
Nephrology	%	%	%	%
Infectious Diseases	%	%	%	%
Psychiatry	%	%	%	%
Family Medicine	%	%	%	%
Pediatrics	%	%	%	%

Figure 4-2: CT examination rate for outpatients (Jan 2023 - Aug 2023)

Average monthly CT examination rate for inpatients (Jan 2020 - Aug 2023)

Medical Department	2020	2021	2022	2023
Surgical Intensive Care		%	%	%
Neurology	%	%	%	%
Neurosurgery	%	%	%	%
Cardiovascular Surgery	%	%	%	%
General Surgery	%	%	%	%
Medical Intensive Care	%	%	%	%
Infectious Diseases	%	%	%	%
Gastroenterology and Hepatology	%	%	%	%
Thoracic Surgery	%	%	%	%
Colon & Rectal Surgery	%	%	%	%
Oral and Maxillofacial Surgery	%	%	%	%
Thoracic Medicine	%	%	%	%
Endocrinology & Metabolism	%	%	%	%
Urology	%	%	%	%
Nephrology	%	%	%	%
Orthopedics	%	%	%	%
Allergy-Immunology-Rheumatology	%	%	%	%
Otolaryngology	%	%	%	%
Pediatric Surgery	%	%	%	%
Hematologic-Oncology	%	%	%	%
Ophthalmology	%		%	
Reconstructive Surgery	%	%	%	%
Cardiovascular	%	%	%	%
Family Medicine	%	%	%	%
Psychiatry	%	%	%	%

Figure 5-1: Average monthly CT examination rate for inpatients (Jan 2020 - Aug 2023)

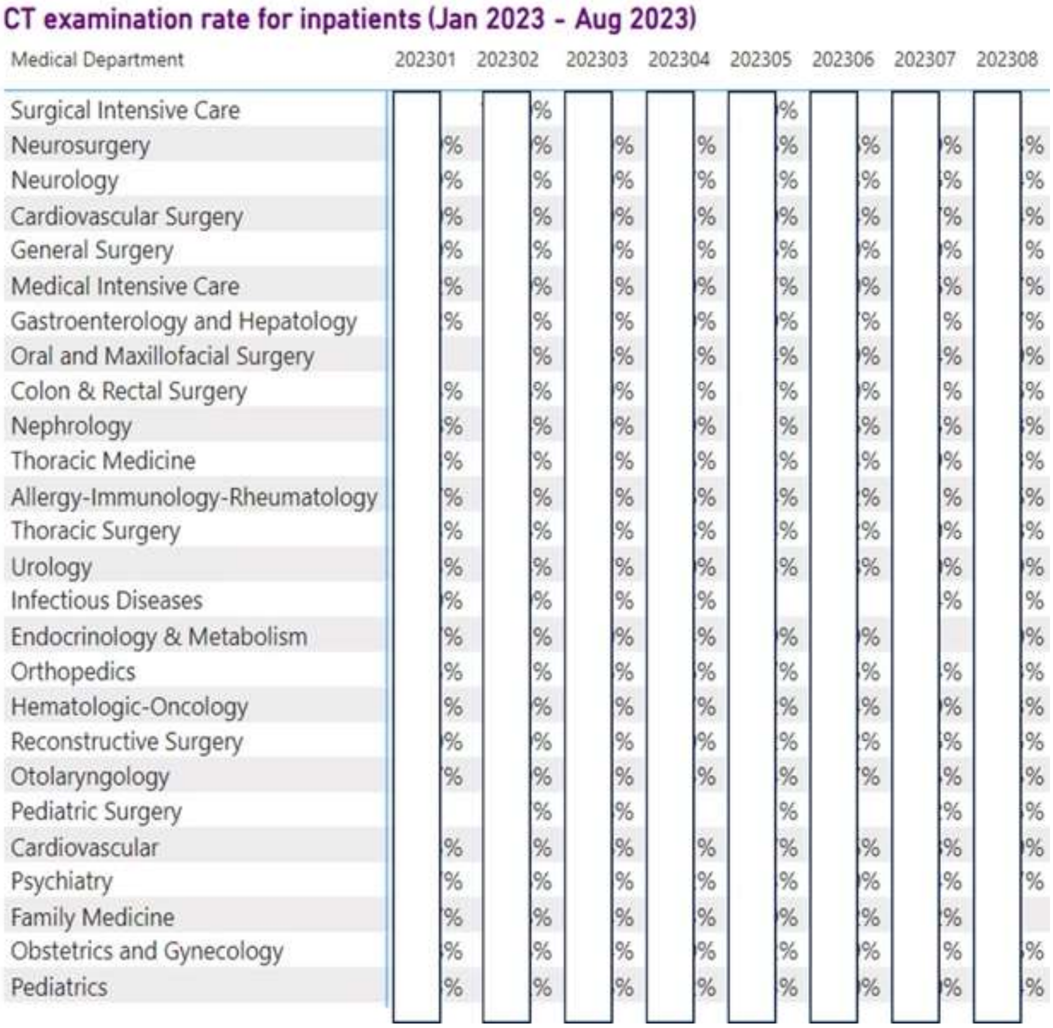


Figure 5-2: CT examination rate for inpatients (Jan 2023 - Aug 2023)

CONCLUSION

In conclusion, the alignment of computed tomography (CT) utilization with the genuine medical requirements of patients represents a critical nexus that hinges on meticulous considerations of both patient safety and medical costs. The comprehensive exploration of this relationship necessitates an ongoing commitment to observing and analyzing the long-term implications of CT utilization. The incorporation of a database for data analysis and medical management communication has proven instrumental in illuminating patterns and trends within specific patient categories. Notably, a discernible reduction in the frequency of examinations has been observed among certain patient cohorts. This observed trend highlights the dynamic nature of healthcare practices and the need for adaptive strategies that can be informed by robust data analytics. Assessing the appropriateness of examination frequency is a multifaceted endeavor requiring a nuanced understanding of evolving patient needs, technological advancements, and healthcare best practices. The feedback loop established through systematic observation allows for insights into the evolving landscape of medical imaging utilization. Continuous refinement of protocols and guidelines is essential to align CT utilization with the ever-changing landscape of patient care. Moreover, the provision of feedback to the medical department serves as a crucial component of healthcare management. The insights gained from long-term observation and analysis enable informed decision-making, facilitating proactive adjustments to examination protocols, resource allocation, and overall healthcare strategies. This iterative process ensures that CT resources are efficiently allocated and utilized, contributing to both optimal patient care and effective healthcare resource management. In summary, the integration of computed tomography into medical practices demands a vigilant and adaptive approach, with a continuous feedback loop that considers patient safety, evolving medical needs, and the economic implications of healthcare decisions. This study underscores the importance of ongoing research, data-driven insights, and collaborative efforts to enhance the alignment of CT utilization with the dynamic landscape of healthcare delivery.

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