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Evaluation of Turnaround Time and the Associated Factors in CT at the Palestinian Hospitals: A Comprehensive Analysis

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Thesis Approval

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Declaration

I declare that, except where explicit reference is made to the contribution of others, this thesis is substantially my own work and has not been submitted for any other degree at the Arab American University or any other institution.

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Dedication

I dedicate this thesis to my beloved mother, whose love, support, and guidance have been the cornerstone of my accomplishments. Her memory will forever inspire me.

To my husband, Ahmad, who has been my steadfast partner on this journey.

To my son, Yanal, the light of my life.

To my sisters, Doha and Maha, whose love and support have shaped me into the person I am today.

To my father, Khaled, and my brothers, Omar and Mohammad.

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Abstract

Introduction: The rising demand for computed tomography scans has put pressure on radiology departments to optimize workflows and reduce turnaround times. Turnaround times encompass the entire process from scan order to report finalization. Optimizing the turnaround time is an important factor in improving patient satisfaction and facilitating the workflow at hospitals. This study examines the average turnaround time from the computed tomography order to accept, order to result, and from accept to result at Palestinian hospitals and determines the factors influencing these times.

Methods: A cross-sectional retrospective study, approved by the IRB, using data from 8,220 computed tomography scan orders from three Palestinian hospitals was carried out. Descriptive and non-parametric statistical analyses were employed to explore the association between turnaround times and variables such as order source (inpatient, outpatient, or emergency department), scan day and shift, and the utilization of contrast media.

Results: The median turnaround time for order to accept, from order to result, and from acceptance to result were 78, 837, and 462 minutes, respectively. The study identified notable differences in turnaround times among the studied hospitals. The Ibn Sina Specialized had generally shorter turnaround times compared to Specialized Arab Hospital and Istishari Arab Hospital. Turnaround times vary significantly depending on working shifts, the day of the week, encounter type, and the use of contrast media. Outpatient computed tomography scans had shorter turnaround times than inpatient or emergency scans, the use of contrast media increased turnaround times, and scans performed during the weekend showed increased turnaround times.

Conclusion: Computed tomography scan turnaround times are important indicators of the radiology department's productivity at the hospital. The turnaround times are significantly influenced by several factors including the order day, the working shift, the ordering source, and the use of contrast media. To enhance computed tomography scan efficiency and patient outcomes, strategies should focus on optimizing staffing, streamlining departmental processes, and addressing patient-related factors.

Keywords: Computed Tomography, Turnaround Time, Working Shift, Contrast Media, Radiology Workflow.

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List of Definitions of Abbreviations

Abbreviations	Title
3D	Three-Dimensional
AAUP	Arab American University of Palestine
AI	Artificial Intelligence
CCU	Cardiac Care Unit
CD	Compact Disc
CT	Computed Tomography
ED	Emergency Department
ERP	Enterprise Resource Planning
GFR	Glomerular Filtration Rate
HIS	Hospital Information System
IAH	Istishari Arab Hospital
ICU	Intensive Care Unit
IQR	Interquartile Range
IRB	Institutional Review Board
ISH	IbnSina Specialized Hospital
IV	Intravenous
JCI	Joint Commission International
LOS	Length of Stay
MRI	Magnetic Resonance Imaging
MSv	Millisievert
PACS	Picture Archiving and Communication System

SAH	Specialized Arab Hospital
SD	Standard Deviation
TAT	Turnaround Time

Chapter One: Introduction

1.1 Overview

Computed tomography (CT) is a vital tool in the field of modern diagnostic medicine. It produces high-quality three-dimensional (3D) images by rotating an X-ray tube around the patient from 180 to 360 degrees, which aids in the diagnosis of various clinical conditions. CT is the cornerstone of medical imaging; it has become the foundation of imaging across a range of clinical areas, such as acute care, stroke management, trauma evaluation, oncology, and other diagnostic applications(Dundamadappa et al., 2021; Hiriyannaiah, 1997; Schrevens et al., 2004).

The CT is important in managing chronic diseases and developing treatment recommendations. It provides immediate clinical guidance, aids in monitoring treatments, and gives a clear visual of a patient’s health. CT scans provide detailed images of the body's anatomical structures, which greatly impact differential diagnosis and treatment plans (Shefer et al., 2013).

CT scans utilize sophisticated X-ray equipment and computer processing to generate detailed internal images of the body. The technology encompasses several key components, including the X-ray machine, detectors, a circular gantry (which houses both the X-ray source and detectors), a patient table, and various electronic systems. By integrating foundational principles of X-ray physics, radiation exposure, and image acquisition mechanics, CT imaging provides a comprehensive approach to medical diagnostics (Goldman, 2007a).

The basic functioning of a CT scan involves the use of x-ray beams and computational techniques to create cross-sectional images or slices of the body. These images, composed of pixels forming a matrix, reflect varying levels of gray to depict different structures. The differences in shading arise due to the attenuation of X-ray beams, which depends on the density and atomic number of the tissues. For instance, higher-density tissues, which attenuate more X-rays, appear white, whereas less dense materials appear black. To enhance visibility, contrast agents like iodine may be used. The Hounsfield Unit (HU) scale quantifies attenuation values, aiding in tissue characterization and diagnosis (Seeram, 2018).

The CT scanning process involves three main phases: data acquisition, image reconstruction, and image display. In the first phase, data is collected by the detectors as X-ray photons interact with the body's tissues. During the second phase, the data acquisition system processes the collected data, assigning values to pixels and reconstructing the image. Finally, in the image display phase, these pixel values are represented as varying shades of gray on the monitor, allowing radiologists to analyze anatomical structures. To ensure accuracy and high-quality imaging, technical aspects such as selecting appropriate slice thickness, controlling X-ray beam intensity, and converting X-rays to electronic signals are meticulously managed (Seeram, 2010).

Detectors play a crucial role in CT imaging, whether as single elements or part of a larger array. The fan beam's size and the number of detector elements depend on the scan's field of view (Fuchs et al., 2000). Ideal detectors should efficiently capture transmitted photons, have minimal afterglow, effectively suppress scatter, and maintain stability to avoid frequent calibration interruptions. Their overall efficiency is influenced by factors such as the detector material's stopping power, scintillator efficiency, charge collection efficiency, geometric efficiency, and scatter rejection. Modern CT scanners mainly use solid-state crystal detectors, although older systems might utilize xenon gas detectors (Hsieh et al., 2000;Newell Jr et al., 2015;Kulkarni et al., 2021).

The gantry's Data Acquisition System converts analog signals to digital, with continuous X-rays creating rays that are read and processed to form images. Iterative reconstruction, a newer method, reduces noise and radiation dose by up to 50% by updating the image through comparisons with original data (Stiller, 2018).

The CT image quality is determined by several controllable factors, such as mA level, scan duration, slice thickness, field of view, reconstruction method, and kVp. These variables, often termed scanning parameters, significantly influence image quality, which relies on spatial resolution (the ability to discern fine details) and contrast resolution (distinguishing objects with similar densities) (Goldman, 2007b).

Spatial resolution is assessed using the modulation transfer function, while in-plane resolution depends on matrix size and display field of view. Pixel size affects accuracy, with smaller pixels enhancing spatial resolution. Voxel size, influenced by slice thickness and matrix dimensions, is also vital for spatial resolution. Different reconstruction algorithms can enhance or suppress specific data aspects, with some emphasizing data smoothing to reduce artifacts and others optimizing spatial resolution at the cost of low-contrast resolution (Nickoloff & Riley, 1985; Pan et al., 2005; Seeram, 2008).

Contrast resolution depends on object size and physical traits, such as the lung's air content. Temporal resolution is essential for capturing moving structures and dynamic contrast studies, influenced by factors like gantry speed and detector channels. To maintain high standards, quality control programs are designed to optimize CT image quality while minimizing patient radiation exposure. These programs involve systematic performance monitoring by CT technologists and medical physicists, with regular tests and documentation to ensure adherence to specified guidelines (Goldman, 2007b; Kemerink et al., 1996).

Artifacts in CT imaging can significantly degrade image quality and are typically classified as physics-based (related to data acquisition), patient-based, or equipment-induced. Identifying and understanding these artifacts is essential for their prevention, reduction, and timely correction, which can save both time and resources (Barrett & Keat, 2004). A thorough understanding of CT physics is essential for recognizing and managing artifacts that can affect image quality. For instance, an image may appear noisy when using a shallow technique, particularly in pediatric cases, but may still suffice for follow-up on significant abnormalities such as abscesses (Seeram, 2015).

Radiologists and radiographers must know the factors related to physics like beam hardening, partial volume effects, and metallic artifacts, to identify and reduce these issues (Mahmoudi et al., 2019). Mastery of CT physics enhances diagnostic precision, reduces repeat scans, limits radiation exposure, and expedites medical interventions, thereby significantly improving patient care.

The CT scans are ordered for a wide range of clinical indications across emergency, inpatient, and outpatient settings. They are used for cancer screening, staging, follow-up, and guiding biopsies and surgical procedures. Other uses include diagnosing lymphadenopathy, stroke, edema, skull fractures, calcifications, arteriovenous malformations, cysts, hydrocephalus, sinusitis, and empyema (Paulo et al., 2020).

The use of CT in medical practice needs protocols that balance test sensitivity and specificity, speed of diagnosis, and the risks associated with contrast media (Broder et al., 2013). Additionally, the need for CT scans should be well justified through a clinical examination and a review of the patient's medical history. This is important because CT scans involve exposing patients to high levels of radiation.

The CT scan can be done with or without contrast media, depending on clinical indications. The contrast agents, which are typically iodine-based, are administered intravenous (IV) or orally. Oral contrast helps visualize the gastrointestinal system, while IV contrast enhances the visibility of blood vessels, tumors, and infections. Comprehensive evaluations often involve multiple imaging phases, such as arterial, venous, and delayed phases (Patel & De Jesus, 2021). Although IV contrast agents provide valuable diagnostic information, they carry a risk of kidney injury, especially in patients with pre-existing renal impairment (van der Molen et al., 2018). Preventive measures include assessing kidney function before the scan and ensuring adequate hydration afterward (Weisbord et al., 2008).

Turnaround time (TAT) is a significant metric in healthcare, denoting the duration required for the completion of a process or task, from initiation to outcome (Goswami et al., 2010). For CT scans, the term ' Turnaround time ' (TAT) covers the entire workflow, from the patient's arrival to the final radiology report. This includes the initial image request, patient preparation, image acquisition, interpretation, and reporting. TAT has a direct impact on patient care and satisfaction, making it a pivotal consideration in healthcare settings (Flug et al., 2022).

Several issues directly relate to TAT factors. Some of them are technical issues, like machine and system downtime or malfunctions, equipment speed, contrast delay, data transfer and processing, calibration, and warm-up time. Also, there are human issues related to TAT: the shortage of technicians or radiologists, delays in interpreting results, and inadequate training affect TAT. In addition to administrative and workflow issues, like a lack of clear priorities between urgent and non-urgent cases. Also, there is a patient-related delay, such as the patient's late arrival at the department (Kalender, 2011).

Waiting time significantly impacts patient satisfaction, and the efficient and timely delivery of medical imaging services is crucial for patient care and diagnosis (Ferreira et al., 2023). With the rising demand for CT scans, even during on-call hours, radiology departments are under increasing pressure to optimize their workflow and reduce the TAT (Bruls & Kwee, 2020). Prolonged TAT for imaging tests like CT scans often leads to delays in treatment and patient disposition. Reducing TAT can help avoid unnecessary hospitalizations, shorten hospital stays, and lower costs, especially given the growing demand for radiology exams (Verma et al., 2020).

However, inefficient processes and a lack of coordination among healthcare professionals involved in the CT scan process can lead to treatment delays. These delays can be from barriers in communication and information flow between different departments and personnel, low availability of resources, inadequate staffing levels,high patient volumes, a lack of organized workflows and standardized protocols, and technical problems with CT scan equipment or systems (Perotte et al., 2018).

Balancing patient demand with hospital capacity is very important for enhancing healthcare quality. Discrepancies between patient demand and hospital capacity may cause prolonged waiting times, patient dissatisfaction, and worn-out staff. On the other hand, a well-organized system can enhance patient experiences, improve the use of resources, and optimize healthcare outcomes(Turgay et al., 2023).

By identifying the main factors affecting TAT, radiology departments can improve their operational efficiency, resulting in faster diagnosis, improved patient satisfaction, reduced waiting times, and better management of increased patient volumes (Olisemeke et al., 2014). Therefore, this study aims to evaluate TAT and the associated factors in CT scans, providing useful findings that can help healthcare institutions balance the growing demand for CT scans with the need for timely and accurate diagnoses, which contributes to better healthcare.

Radiology technicians and radiologists play a critical role in the CT imaging process. They require technical knowledge to operate the CT device and interpret CT images accurately. However, their work does not exist in isolation (Boice et al., 1992).

Physicians must integrate CT findings with patients' medical histories and physical examinations to make precise diagnoses. To ensure optimal outcomes, strategic utilization of CT involves selecting appropriate protocols and minimizing radiation exposure, particularly for vulnerable populations such as pregnant women and children. Ethical practices further underscore the importance of obtaining informed consent and using the lowest effective radiation dose. The responsibilities are shared across the healthcare team: physicians order and interpret scans, nurses prepare patients and monitor them during procedures, especially contrast agents (Alhelayel et al., 2024; Alzahrani et al., 2024).

Effective communication among healthcare team members is vital for delivering high-quality CT imaging services. Clear, timely information exchange about critical findings, patient conditions, and medication needs is crucial. For instance, radiologists must convey their findings in a way that is understandable to non-specialist team members, ensuring that everyone involved in patient care is on the same page. Coordinated care is essential for a seamless patient experience, involving careful scheduling, ensuring technologist availability, and providing appropriate post-scan care (Poole & Real, 2003).

Additionally, physicians manage follow-up care based on CT results, involving specialists as needed to address complex cases. Patient-centered care is a cornerstone of this process, as it focuses on involving the patient in decision-making, addressing his concerns, and providing clear information about CT scans and possible subsequent treatments. Healthcare teams must verify patient identities, assess for contrast allergies, and monitor for adverse reactions during and after imaging to ensure patient safety(Stille et al., 2005; Symon et al., 1996).

High-quality CT imaging depends on continuous training and collaboration. Regular training and various specialization team meetings are essential for keeping healthcare professionals updated on best practices, safety protocols, and technological advancements. These platforms foster more effective and collaborative care, ensuring that all team members are aligned in their approach. Continuous education is particularly important, as it ensures that the healthcare team remains proficient in their roles, ultimately enhancing patient outcomes. By prioritizing teamwork, communication, and education, healthcare providers can deliver safer, more efficient, and patient-centered CT imaging services (Institute of Medicine, 2010).

1.2 Study Problem

The time between ordering the scan and reporting the results affects the diagnostic efficiency of the CT scans. Prolonged TAT for CT scans is a common issue that negatively affects patient care. Extended TAT causes stress and dissatisfaction for patients and increases healthcare costs due to prolonged hospital stays (Perotte et al., 2018).

Prolonged TAT on CT scans is influenced by a variety of factors, including operational inefficiencies, redundant processes, and slower CT scan times and image processing capabilities. Furthermore, inadequate staffing levels and varying staff experience can disrupt workflow and extend TAT (Dawande et al., 2022).

Other factors contributing to prolonged TAT include patient-related delays like preparation time and high patient volumes. Poor case prioritization and communication issues within and between departments worsen the problem. In addition, technical challenges such as poor image quality necessitating rescans and equipment maintenance periods can lead to prolonged TAT (Baccei et al., 2020; Lodge & Bamford, 2008).

Inappropriate scheduling of CT scans and the associated increase in TAT are real problems in the radiology department. A comprehensive evaluation of TAT in CT scans and the identification of factors that increase TAT would be of great benefit in developing applicable strategies to improve the process of CT scans in hospitals.

1.3 Research Questions

1. What factors are associated with variations in CT scan TAT at Palestinian hospitals?
2. What is the average TAT for a CT scan (from the order to the final report)?
3. What is the average time for a CT scan order to accept?
4. What is the average time from CT scan acceptance to the final report?
5. Do the variables (the encounter type, CT scan type, and ordering day and time) significantly affect the average TAT, the time from order to accept, and the time from acceptance to final report?

1.4 Study Justification

The research topic will provide new data on the time required for CT scans and the variables affecting them in three Palestinian hospitals in different cities. There is a lack of such evidence based on scientific research, and CT scans are in high demand in all hospitals, with observed delays in reporting. As a result, the research findings can be used by radiology departments and hospital quality control units to improve the quality of the healthcare system by adopting newly updated protocols to facilitate the CT scanning process based on the current study and further studies on the same topic in other hospitals.

Additionally, the current findings can be compared with data from studies in other countries to evaluate the healthcare system in Palestine relative to others. Thus, several measures can benefit from the study outcomes to improve the healthcare system in Palestine.

The TAT for CT scans has not been evaluated in Palestine. In addition, the TAT in Palestinian hospitals is considered long, and medical diagnoses are often delayed due to delayed medical reports. Patients must schedule their CT scans previously, leading to extended waiting times. This delay is often because of the high patient volume and the absence of competent protocols to achieve an efficient workflow in a short period. This study is considered to be the leading study in Palestine to identify the TAT of CT scans and the factors influencing it. The findings can be used to develop new CT protocols that allow for a greater number of scans to be taken in a shorter time by reducing the required TAT.

1.5 Research Objectives

1.5.1. Primary Objective

The main goal of this study is to assess the TAT and the associated factors in CT scans at privatePalestinian hospitals.

1.5.2. Secondary Objectives

1. To determine the average TAT from the time a CT scan is ordered to the final report.
2. To determine the average TAT from the time a CT scan is ordered to its acceptance.
3. To determine the average TAT from the acceptance of a CT scan to the final report.
4. To examine the relationship between encounter type, CT scan type, and the day and time of ordering with the average TAT, including TAT from ordering to the final report, ordering to acceptance, and acceptance to the final report.

1.6 Research Hypotheses

Hypothesis 1:The TAT of CT scans at Palestinian hospitals varies, and there is a statistically significant difference in the TAT of CT scans based on the type of CT scan, the ordering department, and the day and time the scan is ordered.

Hypothesis 2: The average TAT for CT scans using contrast media is significantly longer than the average TAT for CT scans without contrast media, due to the additional preparation and extended scan duration required.

Hypothesis 3: The average TAT for CT scans ordered from the Emergency ED is significantly shorter than the average TAT for scans ordered from inpatient or outpatient departments, due to the urgency of cases in the ED.

Hypothesis 4: The average TAT for CT scans performed during the morning shift is significantly shorter than the average TAT for scans performed during the night shift, due to the presence of a larger working team during the day.

Hypothesis 5: The average TAT for CT scans performed on weekdays is significantly shorter than the average TAT for scans performed on weekends.

Chapter Two: Literature Review

2.1 Overviews

There are several processes involved in the CT imaging process: ordering the scan, accepting it, and then obtaining the findings. CT scan orders are categorized into inpatient, outpatient, and ED orders. For inpatients and EDs, the image order requisition is placed in the hospital information system (HIS) by the ordering physician. The registration process for these patients is completed before the CT scan order. However, outpatient orders are entered into the HIS by a radiographer or receptionist in the radiology department. Subsequently, the patient completes the registration and the financial process for the imaging request.

Once the financial process is finalized, the CT orders are scheduled. Pre-scan instructions vary according to the type of CT imaging being performed; some patients may require fasting, oral contrast administration, kidney function tests, IV cannula placement, or pre-medication to prevent adverse reactions. Thus, the pre-CT exam phase 'order to accept' is concluded.

When the CT scan order is accepted, the patient is prepared for the scan in the CT room. They are dressed in a hospital gown and given instructions on positioning, breathing, and the sensation of contrast media as it enters their body. They are also informed about the scan's duration, the need for stillness, and the insertion of an IV line. The CT scan then begins, after the examination ends, the patient is given further instructions, and the CT images are transferred from the CT device to PACS. Then the radiologist begins to interpret the CT scan images and documents the results in the HIS system. With this, the CT exam and post-CT exam phases ‘accept to result' are concluded. Subsequently, the patient's physician starts patient management based on the documented findings from the radiology department. The activity model for the CT scan imaging process is shown in Figure 2.1.

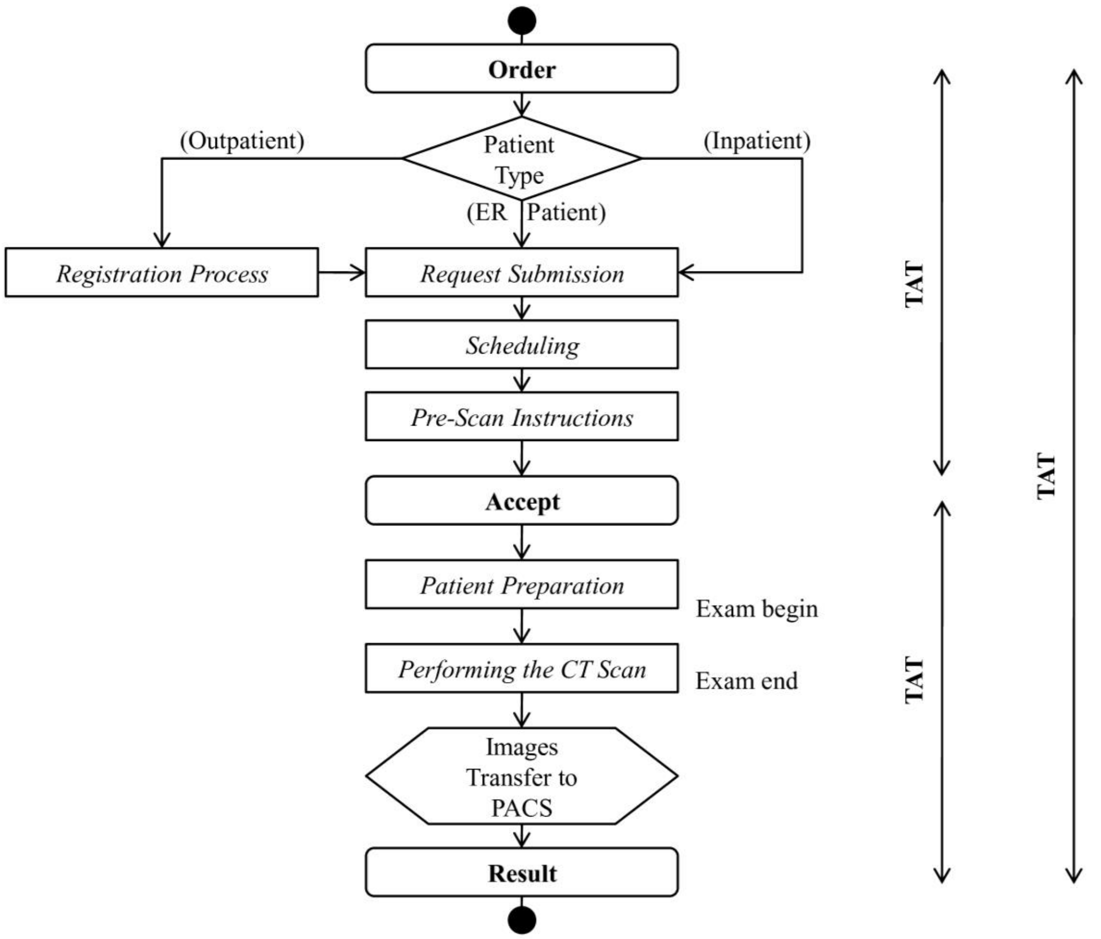

Figure 2.1: The activity model for the CT scan imaging process illustrates the various stages, starting with the entry of the CT request into the HIS and culminating in the generation of the final report.

Proper clinical care is always dependent on proper diagnosis, which is inevitably based on diagnostic techniques performed in medical imaging and medical laboratory outcomes (Cherryman, 2006). The significance of accurate and timely diagnosis cannot be overstated, as it forms the foundation upon which effective treatment plans are built. The poor performance of laboratories in hospitals is greatly affecting the patients' diagnosis and treatment. When laboratory services are suboptimal, there is a cascading effect on the entire healthcare delivery system(Holland et al., 2005).

Complex investigations such as magnetic resonance imaging (MRI) and CT are considered one of the most challenging diagnostic techniques due to the time requirement and the involvement of many departments from patient admission to report preparation.

These advanced imaging modalities require sophisticated equipment, highly skilled personnel, and seamless coordination among various hospital departments to ensure accurate results and timely reporting.

Moreover, the radiology department plays the cornerstone in the diagnosis of many challenging medical conditions, such as tuberculosis, cancer, and vascular disorders. Radiologists and imaging technologists must be proficient in interpreting a wide range of imaging studies, as their expertise directly impacts clinical decision-making. Achieving diagnosing accuracy besides reducing the TAT of testing is vital for beginning treatment, as reported in a previous study. Reducing the TAT is crucial because it minimizes the waiting period for patients, thereby expediting the initiation of appropriate treatment and improving patient outcomes (Kwak et al., 2013).

Imaging studies, including CT, are important in ovarian cancer and breast cancer diagnosis and staging and thus appropriate referral to a specialist in oncology and offer a significant survival advantage for patients and prognosis. Early detection and precise staging of cancers through imaging not only facilitate timely and targeted therapeutic interventions but also enhance the overall prognosis and survival rates of patients. The integration of advanced diagnostic techniques and efficient laboratory services is essential for delivering high-quality clinical care, improving patient outcomes, and ensuring the effective management of complex medical conditions (Paydary et al., 2019; Togashi, 2003; Yang et al., 2007).

High numbers of patients are frequently admitted to hospitals, which puts tremendous pressure on the healthcare system. The lack of a rapid streamlined flow of patients would lead to overcrowded departments, which would eventually lead to poor-quality medical care. Overcrowding can cause delays in treatment, longer waiting times, and increased stress for both patients and healthcare providers. This exponential increase in the number of requested scans forces the radiology department to improve its operations toward a more efficient output of reports.

Radiology departments must adapt to the growing demand by implementing innovative strategies and technologies to streamline their processes and reduce TAT.

Efficient management of radiology services is critical to ensuring timely and accurate diagnoses, which are essential for effective patient care. In a study conducted in the United

States, the average TAT for CT scans was 5.9 hours, and persistent dissatisfaction was reported; however, several measures were undertaken and significant reductions in the TAT were achieved (Perotte et al., 2018). An improvement in the ED throughputs was reported after using quality improvement techniques to lower the TAT of radiology reports. The quality improvement techniques include the use of data-driven approaches to identify process inefficiencies, improve resource utilization, and enhance the coordination between different departments(Flug et al., 2022; Towbin et al., 2013).

The treatment outcomes are time-limited in some urgent cases, like acute stroke, so decreasing CT scan TAT is critical in preventing life-long brain damage and improving patient prognosis. Because acute stroke is an emergency case, every minute counts, as delays in diagnosis and treatment can lead to irreversible brain injury. Rapid imaging is important for determining the appropriate action, whether it includes administering thrombolytic therapy, performing mechanical thrombectomy, or providing other interventions to restore blood flow to the affected area of the brain.

A previous study at the Baylor Saint Luke's Medical Center in Houston showed reduced TAT in brain CT scans for patients admitted for stroke compared with non-stroke patients. This finding indicates the importance of prioritizing stroke patients and ensuring that they receive immediate attention in the radiology department. The study highlighted the effectiveness of implementing streamlined protocols and dedicated stroke teams to expedite the imaging process and minimize delays. Such measures are crucial for achieving optimal outcomes in stroke care and reducing the long-term burden of stroke-related disabilities on patients and healthcare systems (Bershad et al., 2015). Consequently, a multidisciplinary approach can be developed to achieve reduced TAT for CT scans.

Longer TATs can be a determining factor in the overall efficiency of a hospital and the quality of patient management. So some radiology departments utilize Lean process improvement methodology. Lean methodology, originally developed in the manufacturing industry, focuses on identifying and eliminating waste in processes to create more value with fewer resources (Walker & Dunn, 2006).

By applying Lean principles, radiology departments eliminate wasted time, reduce costs, and enhance productivity, leading to increased staff satisfaction. When radiology staff can perform their tasks more efficiently and effectively, it reduces their workload and stress, leading to a more positive work environment and higher job satisfaction (Baccei et al., 2020). As a result, patients are diagnosed more quickly, and treatments commence sooner (Lodge & Bamford, 2008).

Globally, healthcare systems have implemented a range of strategies to address inefficiencies in hospital TAT, In the United States and several European countries, many hospitals have adopted lean management methodologies aimed at streamlining clinical workflows, minimizing operational waste, and enhancing patient throughput. For example, one United States hospital successfully reduced radiograph TAT in the emergency department by introducing daily performance feedback mechanisms, optimizing radiology staffing schedules, and redesigning internal processes (Lam et al., 2021).

Technological integration has also played a critical role in improving TAT. Countries such as the Netherlands and South Korea have invested in comprehensive electronic health record systems and automated order-entry platforms, which have significantly reduced delays in test ordering and result dissemination.

Additionally, healthcare institutions in Canada and the United Kingdom frequently utilize national performance benchmarks and public reporting frameworks to monitor and enhance TAT. These systems establish clear targets for the timely delivery of imaging and laboratory results (Hu et al., 2011; Verma et al., 2020).

Although TAT in diagnostic imaging has been widely studied in many parts of the world, there is still a noticeable lack of research on this topic within the Palestinian healthcare system. Most existing studies come from countries with advanced healthcare bases, where hospitals have advanced digital systems. These conditions differ significantly from the health status in Palestine, where hospitals often operate under difficult conditions and occupation restrictions, which prevent them from adopting electronic systems in all hospitals and then expanding the research.

As of now, there is no comprehensive study specifically about CT scan TAT or the factors that influence it in Palestinian hospitals. This absence of local studies creates a significant gap in the literature and affirms the need for research to show the realities of the Palestinian healthcare environment.

2.2 The Pre-CT Exam Phase

The pre-exam phase spans from the CT scan order to its acceptance. This phase is important and includes all activities from the moment a CT scan is requested until it is accepted by the radiology department in the system. The department accepts the CT order when the patient is ready for the scan. Efficient management of this phase is important to minimize delays in workflow. This phase includes the request submission and registration process (specifically for outpatients), scheduling, and pre-scan instructions. `

2.2.1. Registration Process and Request Submission

The registration process involves creating a medical record, which includes verifying patient demographics, and health insurance details, and completing financial procedures. The duration of this process can vary, depending on the complexity of the financial and insurance approvals required (Sloan & Steinwald, 1980). Efficient registration procedures are crucial to ensure that patients are correctly identified and that all necessary administrative tasks are completed before the scan is scheduled.

During the registration process, hospitals collect essential information like the patient's name, date of birth, address, phone number, email, and emergency contact details. This information is used to create a unique medical record number for each patient, which helps in accurately linking all medical records and encounters to the correct individual. Additionally, the registration process involves verifying the patient's insurance coverage and obtaining necessary pre-authorizations or referrals for the scheduled procedure (Berlin, 1997).

Hospitals, as complex institutions, handle critical medical information and processes through electronic, manual, or hybrid systems. Manual systems consist of paper-based records and physical files. However, these systems are prone to errors, such as illegible handwriting, misplaced files, and inconsistencies in data entry. Electronic systems in hospitals utilize computerized methods to store and manage patient medical information. These systems, referred to as Electronic Health Records (EHRs), provide real-time access to detailed patient information, encompassing medical history, test results, and treatment plans.

EHRs enhance communication between departments, reduce errors, and streamline workflows, leading to improved patient care and operational efficiency (Gooch & Roudsari, 2011).

Hybrid systems combine elements of both manual and electronic systems, offering a balanced approach to managing hospital operations. These systems can integrate digital records with traditional paper files, providing flexibility and ensuring continuity of care during the transition to fully electronic systems (Jha et al., 2009; Weeks, 2013).

Healthcare providers, whether they are physicians or radiology departments, submit radiology requests either electronically or manually, according to the hospital's system. Electronic submissions can simplify the radiology process, reduce errors, ensure timely receipt of the request, and improve communication between the radiology department and other departments, leading to a more streamlined workflow (Vishwanath et al., 2010). Manual submission of requests is still used in some radiology departments; it can cause errors and delays, so it is recommended to transition to electronic systems to enhance accuracy and efficiency (Desai et al., 2018).

The CT scan requests can be submitted directly to the HIS by a physician from the hospital for ED patients, inpatients, or those referred from an external clinic in the same hospital. Additionally, the radiology department, whether a radiographer or department secretary, can add a CT order for outpatients who need a scan as ordered by an external physician (Ahmad & Anjum, 2016).

The process of submitting a CT scan request involves several steps to ensure accurate communication between the referring physician and the radiology department. Initially, the referring physician must collect clinical information about the patient, such as medical history, symptoms, previous surgeries, and any prior imaging studies. This information is crucial for the radiologist to interpret the CT scan accurately and provide suitable recommendations (Fatahi et al., 2019).

The physician then fills out a request form. The form includes details such as the patient's name, identification number, clinical indication for the scan, and any specific instructions for the radiology department. The request form is submitted to the HIS, then it is reviewed and prioritized based on the urgency of the scan. For urgent cases, such as suspected strokes or trauma, the request is flagged by an urgency sign. This is shown in the radiology request, then the radiology department schedules the scan immediately (Dixon & Culpan, 2008).

Before submitting the outpatient CT scan order to the hospital system, radiographers must ensure that the CT request is appropriate for the patient's condition and to avoid unnecessary radiation exposure. They may need to consult with radiologists to confirm that the CT scan is an appropriate and justifiable diagnostic tool based on patient clinical indications and consider alternative imaging modalities that can give the diagnostic information with reduced or no radiation exposure, such as MRI or ultrasound (Rosenthal & Pianykh, 2021).

Additionally, some patients may not be familiar with which type of medical imaging is best for their condition, and they might come to the radiology department before consulting their physician. This can lead to confusion or anxiety when they're faced with several imaging options. Therefore, healthcare providers need to communicate clearly with patients and explain why a specific scan is recommended and how it relates to their medical status (Ford et al., 2021).

A recent study at Hebron Governmental Hospital highlighted this issue, showing that 78% of brain CT scans were deemed unnecessary. Many of these requests came from non-specialized physicians who lacked sufficient knowledge about when such imaging is appropriate (Sabarna et al., 2023).

Accurate patient information, including medical history, medical condition, and previous imaging studies, is essential for planning a CT scan effectively. This information helps determine whether the patient needs oral contrast, IV contrast media, or both during the same scan (Beckett et al., 2015).

Different CT order times and days of the CT scan orders (weekend and weekday) affect the TAT for CT scans in trauma cases (Sobrian-Couroux et al.). A previous study at a tertiary center involving 17,709 CT trauma scans aimed to identify factors contributing to TAT variability. It found that differences among imaging technologists and the specific hours and days during which trauma imaging was conducted influenced the CT trauma TAT (Wood et al., 2023).

2.2.2. Scheduling

The third step in the pre-exam phase is scheduling appointments. In most hospitals, scheduling includes coordinating with the patient's availability and the urgency of the scan. Efficient scheduling of CT scans is important for optimizing patient care. Multiple factors must be considered when scheduling CT scans, including patient characteristics, technical considerations, and operational factors (Reiner et al., 2002).

Patients with critical and urgent medical conditions requiring immediate diagnosis often need CT scans to ensure timely and accurate diagnosis, which can be life-saving in emergency cases, so these patients need priority in scheduling (Hilbert et al., 2007). For example, in cases of acute trauma, stroke, and severe internal injuries, rapid CT imaging is essential to facilitate intervention and treatment. Delays in imaging can lead to a worsening of the patient's condition and potentially life-threatening outcomes (Volders et al., 2019).

Previous patient history, allergies to contrast agents, and other health conditions can influence scheduling decisions (Lusic&Grinstaff, 2013). Preparation for patients with allergies to contrast agents is very important to ensure their safety during the scan. Patients who have a known allergy to contrast must take specific precautions to prevent or reduce an allergic reaction. This involves premedication with steroids and antihistamines, which takes time, thus delaying the patient's schedule. For example, a common protocol includes taking 50 mg of prednisone 13 hours before the scan, another 50 mg 7 hours before, and a final 50 mg 1 hour before the scan, along with an antihistamine 1 hour before the scan (Kang et al., 2022).

Additionally, age considerations are important. Children and the elderly have challenges in scheduling (Kasper &Hohenberger, 2020). Pediatric patients need focused care to minimize radiation exposure. Children may need sedation or anesthesia to remain still during the scan, which requires additional preparation time (Callahan et al., 2018; Gottumukkala et al., 2019). Elderly patients may face movement difficulties, cognitive dysfunction, or difficulty following instructions, so elderly patients need additional time and assistance during the scan (Brown & Flood, 2013; Caplan et al., 2016).

The CT scan that requires contrast media and laboratory tests requires more pre-scan times (Marin et al., 2011). Patients need to drink the oral contrast 1.5 to 2 hours before the scan, and this preparation adds time to the overall CT procedure (Kepner et al., 2012). Additionally, laboratory tests such as blood urea nitrogen (BUN) and creatinine levels are required to assess kidney function before administering contrast agents to ensure the kidneys' ability to purify the blood from the contrast. These tests increase the duration required to Arrange the CT scan, and consequently, delay scheduling the scan (Kamal, 2014).

Moreover, the quantity and type of CT scanners available in a facility impact scheduling capacity (Herts et al., 1998). The quantity of CT scanners impacts the capacity to image patients within a specific time; A higher number of CT scanners in the same facility allows for more CT imaging at the same time, shortening wait times, and increasing the total number of patients imaged (Boland, 2008).

Additionally, regular maintenance and downtime for CT scanners are necessary and available for all CT devices. Hospitals equipped with multiple scanners can effectively handle such disruptions by reallocating patients to other CT scanners, minimizing the impact on scheduling (Omar et al., 2024). Also, different types of CT offer varying levels of speed, accuracy, and capabilities.Advanced multi-slice CT scanners can capture images faster, shortening scan times and imaging more patients, thereby improving scheduling capacity (Boland, 2008).

An adequate amount of contrast agents for the CT scan is very crucial. CT scans will be delayed or rescheduled if contrast agents are insufficient. Additionally, the availability of radiology technicians is also a very important factor and essential for imaging. A shortage of trained technicians can lead to longer wait times and a decrease in the speed of workflow (Chernov et al., 2021).

Another important thing to organize radiology workflow, reduce waiting times, and schedule for long periods is to use advanced scheduling software. The use of online booking systems significantly improved appointment scheduling, decreased waiting times, and increased patient satisfaction by offering greater flexibility and efficiency in appointments (Seyedi et al., 2024). Technology is also crucial in organizing appointment durations and maintaining patient information (Camgoz-Akdag&Beldek, 2020). Additionally, notification and automated reminders tools help ensure patients arrive on time and don’t miss their appointments (Roseland et al., 2022).

Effective communication between departments is essential to avoid misunderstandings and ensure timely preparations of patients for imaging and reduce order to accept time (Harrington, 2022). Improved effective communication could enhance patient care, satisfaction, and staff morale. The best way to enhance CT scan efficiency is to eliminate non-value-adding activities and unnecessary waiting (Shou et al., 2020).

2.2.3. Pre-Scan Instructions

Pre-scan instructions depend on the type of CT imaging ordered; the preparation may involve fasting, taking oral contrast, performing kidney function tests, and inserting an IV cannula. Also, Patients with known allergies to contrast media may require pre-medication to avoid adverse reactions (McCullough, 2008). Clear and comprehensive pre-scan instructions are vital to ensure patient compliance and optimal image quality. Studies have shown that providing patients with detailed instructions and answers about their questions and concerns before the scan can significantly reduce the incidence of scan cancellations or rescheduling due to inadequate preparation.

According to Fischbach& Dunning (2009), radiology department healthcare providers must ensure that patient preparation instructions are clear and easy to understand. This is to minimize errors and decrease waiting times for patients and staff. It is also essential to offer pre-scan instructions in multiple languages and consider cultural differences in communication to ensure that all patients receive clear instructions, regardless of their language or cultural background (Zhura&Utesheva, 2020).

Furthermore, it is crucial to deal with the need for customized pre-scan instructions for pediatric or elderly patients, who may have unique considerations (Bray et al., 2022).

Inappropriate inpatient preparation for CT scans is a prevalent issue, usually because of inadequate nursing knowledge. Inappropriate preparation includes insufficient fluid intake, suboptimal bowel cleaning, and improper management of patients with potential pulmonary embolism. To address these shortcomings, a comprehensive educational program for nursing staff is essential. This program should focus on CT scan procedures and patient preparation requirements (Mohammed et al., 2025).

A research study conducted in England underscored the knowledge gap among ward nurses regarding CT scans. Only 17% of participants correctly identified CT as an X-ray-based imaging modality. While the majority recognized the need for oral contrast in abdominal CT scans, less than 10% accurately identified the contrast agent as water-soluble iodine (Podkletnova, 2012). These findings highlight the critical need for enhanced CT-related education for nursing personnel.

Different patients' preparation for CT scans is performed before the actual scanning. Depending on the patient's condition and indications for CT scanning (Podkletnova, 2012). If the preparatory steps are not executed properly, the CT scan may not provide useful data and the health of the patient could be compromised.

The IV contrast media are used to enhance the visualization of blood vessels and tissues, but they can be harmful to the kidneys and may cause contrast-induced acute kidney injury or contrast-induced nephropathy. Thus, patients scheduled for contrast administration should undergo serum creatinine assessment especially if they exhibit or are suspected of renal impairment, diabetes mellitus, or other relevant risk factors (Bae, 2010; Podkletnova, 2012).

Established risk factors for contrast-induced nephropathy encompass pre-existing renal insufficiency, diabetic nephropathy, excessive contrast media usage, and dehydration. Patients with congestive heart failure, a history of recurrent contrast procedures, and multiple myeloma in a dehydrated state are considered at relative risk. While CT with contrast enhancement is generally safe for individuals with normal renal function, Individuals categorized as having a moderate or high risk require specialized protocols to reduce the likelihood of contrast-induced nephropathy. (Owen et al., 2014).

To prevent the occurrence of contrast-induced nephropathy, non-steroidal anti-inflammatory drugs, and dipyridamoleneed to be stopped 48-72 hours before the procedure. Diuretics and angiotensin-converting enzyme inhibitors should be withheld for 24 hours before the contrast administration (Vercellino et al., 2009). High-risk patients should receive IV hydration using 0.9% saline, administered at a flow rate of 1.0-1.5 ml/kg/hr, adjusted according to volume status, initiated 12 hours before the procedure, and continued for 12-24 hours post-procedure (Mirza, 2023).

The previous study conducted a retrospective analysis of all CT imaging performed at an urban, tertiary care ED between May 1 and July 31, 2021. Over this timeframe, a total of

5,685 CT scans were completed for 4,344 patients, with a median interval of 108 minutes from the time of order to scan completion. To determine factors associated with delay and identify five factors: patients who were medically unstable or non-compliant; IV line issues; contrast allergies; concerns related to glomerular filtration rate (GFR); and delays related to imaging protocol (such as the need for IV contrast or requests for oral and/or rectal contrast).

There are both adjustable and unchangeable factors associated with significantly delayed CT in the emergency department (ED). Patient factors such as behavior, allergies, and medical acuity are beyond control. However, institutional guidelines concerning difficult IV access, administering contrast media in low GFR settings, and study protocols can be altered. (Dhanik et al., 2024).

The CT scan with oral contrast agents is vital for improving diagnostic accuracy across various clinical situations, particularly in abdominal imaging. Oral contrast agents improve the visibility of bowel structures, helping to identify conditions like adhesive small bowel obstruction (Khattab et al., 2024).

Studies indicate that CT with oral contrast can guide treatment decisions, with a significant percentage of patients successfully managed conservatively. Innovations in oral contrast agents, such as Lumentin, a per-oral HU-negative contrast agent that, enables the small bowel void to appear black against the mucosa, provide improved distribution and contrast in the small intestine, yielding diagnostic images comparable to MRI (Fork et al., 2023).

Despite the benefits, the use of oral contrast can delay diagnosis and increase aspiration risk, particularly in trauma cases. Some studies suggest that IV contrast alone may suffice for certain diagnoses, indicating a need for careful consideration of contrast use. While oral contrast agents significantly enhance CT imaging, their application must be balanced with potential risks and the evolving landscape of imaging technologies.(Golikhatir et al., 2023; Nastanski et al., 2001).

Removing the oral contrast preparation from abdominal and pelvic CT scans shortens the TAT. The process of consuming oral contrast can take 60–120 minutes before the CT scan, with the complete duration from test request to report completion extending for 3 to 4 hours (Schuur et al., 2010). Current consensus indicates that oral contrast does not provide an additional advantage in CT scans for renal colic. (Rao, 2004; Williams Jr et al., 2004), and blunt abdominal trauma (Miller & Shanmuganathan, 2005). Recent research indicates that abdominal and pelvic CT scans, whether using oral contrast or not, are equally effective in diagnosing patients with suspected appendicitis or nonspecific abdominal pain (Lee et al., 2006; Mun et al., 2006).

2.3 The CT Exam and Post-CT Exam Phases

The exam and post-exam phases span from acceptance to CT scan report preparation. This phase consists of performing the CT scan and writing the report.

2.3.1. Performing the CT Scan

The CT imaging involves a patient being positioned on a motorized table and moved through a circular aperture within the scanner. As the patient traverses this opening, an X-ray source and detector assembly rotate around them, completing one revolution in approximately one second. Rapid rotation is crucial for capturing high-resolution images while minimizing motion artifacts (Kalender, 2011).

The X-ray source produces a narrow, fan-shaped beam that penetrates a portion of the patient's body, allowing for detailed imaging of specific anatomical areas. A detector situated opposite the source captures the attenuated X-ray beam, generating a projection image. This process is repeated multiple times during a single rotation, acquiring data from various angles. The collected projection data are transmitted to a computer for reconstruction into cross-sectional images representing the internal anatomy. Advanced algorithms and computational techniques enhance the clarity and accuracy of these images, providing valuable diagnostic information for various medical conditions (Buzug, 2011; Shyu & Sodickson, 2016)

A CT scan is associated with significant radiation exposure, which is a recognized risk factor for cancer development (Suzuki & Yamashita, 2012). The ionizing radiation from CT scans can damage cellular DNA, potentially causing mutations that may develop into cancer over time (Iyer & Lehnert, 2000).

As outlined by the U.S. Food and Drug Administration, the carcinogenic effects of ionizing radiation depend on the radiation dose. The effective dose, measured in millisievert (mSv), is a standard way to measure effective radiation dose in CT imaging. It considers how sensitive each organ is to radiation and helps compare different types of scans. For example, organs like the thyroid gland and breast tissue are more sensitive to radiation, requiring careful consideration during imaging procedures (Clifton, 1986; Schonfeld et al., 2011).

Technological advancements, like automated exposure control and iterative reconstruction algorithms, led to reduced radiation exposure while preserving image quality (Greffier et al., 2016). Despite these advancements, ongoing research is essential to further enhance these techniques and develop new approaches for reducing radiation doses in CT imaging.

A comparative risk assessment places an effective dose of 10 mSv in perspective: it is linked to an approximate 1 in 2000 increased risk of fatal cancer. Without radiation exposure, the risk of developing a fatal cancer in the general population is 1 in 5. While effective doses from diagnostic CT examinations range from 1 to 10 mSv, depending on the scanned region, procedure, and equipment, the variation among patients is considerable. (Shyu&Sodickson, 2016).

Factors such as body size, age, and specific clinical indications affect the required radiation dose in CT scans. For example, pediatric patients are more sensitive to radiation and require lower doses to achieve optimal imaging results. Also, some CT images need thin-cut CT slices, which have more radiation. Radiologists and radiographers play a critical role in managing the requirement for diagnostic accuracy with the imperative to minimize radiation exposure. Ongoing education and compliance with optimal dose management practices are crucial for the safe and effective application of CT imaging in clinical practice (Huda & Vance, 2007; Kalra et al., 2015; Smith-Bindman et al., 2009).

Small changes in a workflow can achieve improvement in the radiology department and optimization of health records; through training, teamwork, effective communication, standardized workflows, and preventing the movement of work among employees (Kruskal et al., 2012).

Emphasizing the importance of teamwork fosters a collaborative environment where staff members can share knowledge, support each other, and work efficiently towards common goals. Effective communication is crucial for coordinating patient care and minimizing errors. Additionally, standardized workflows help streamline processes, reducing variability and improving consistency in patient care. Standardization also prevents the movement of work among employees, ensuring that tasks are completed efficiently and accurately (Kruskal et al., 2009; Mahmeen et al., 2024; Rachh et al., 2022).

The key factor that contributed most to the reduction in TATs was increasing the number of technologists (Mostafa & El-Atawi, 2024). Additionally, having an excess radiology staff number can minimize delays in performing CT scans (Flug et al., 2022). Maintaining an adequate count of radiology staff is crucial to prevent patient overbooking or rescheduling due to staff absences and leave, which contributes to reduced waiting times, enhances patient satisfaction, and improves the overall efficiency of the department (Gupta & Denton, 2008; Odhiambo et al., 2015). Continuous 24/7/365 radiology coverage for emergencies is linked to shorter TAT for imaging in both trauma and non-trauma cases (Jalal et al., 2021).

Therefore, recent studies and efforts have concentrated on reducing the time patients spend in the radiology department. These include reducing transport time to the radiology department, optimizing staffing and the location of the department, and optimizing examination protocols (Levenson et al., 2012). Additionally, reduces the time required for image interpretation (Kruskal et al., 2012).

Many delays in TAT because of the distance of the radiology department's location from the emergency and inpatient departments, also unavailability or lack of personnel assigned to patient movement, and the time nurses need to arrange transportation (Worster et al., 2006).

When nurses have to make repeated calls to find someone to transport patients to the radiology department, it takes time away from patient care. These delays can lead to dissatisfaction among patients and staff. Furthermore, the additional time patients spend waiting for tests and decisions on their disposition may heighten the risk of patient deterioration. Some patients require prompt attention in the radiology department to aid in clinical management, as any delay can adversely affect their health, as any delay can impact their health (Adams et al., 2007).

Implementing dedicated transport teams and optimizing the spatial layout of hospital departments can significantly mitigate these issues. For example, creating direct pathways between the emergency and radiology departments can enhance efficiency and reduce TAT (Ligtenberg et al., 2005; Rachuba et al., 2018).

Furthermore, shortages of scanning equipment, like contrast media or extension tubes, lead to longer TAT, increased patient waiting times, and resulting in a backlog of pending scans (Hall, 2013).

Hospitals must have backup electrical generators in case of frequent power outages and insufficient power supply during CT scans. This ensures that waiting times for patients and healthcare providers conducting the examinations are not prolonged (Capolino et al., 2015). Power interruptions can abruptly halt imaging procedures, leading to incomplete scans, data loss, and the need for rescheduling (Rosenthal & Pianykh, 2020).

Implementing inventory management systems and contingency plans can help mitigate the impact of equipment shortages and power outages. By monitoring stock levels, anticipating demand, and maintaining adequate reserves of essential supplies, radiology departments can reduce the risk of shortages and maintain seamless care (Meeme et al., 2015; Oballah et al., 2015).

The study recommends separating inpatient and outpatient CT services to tackle the issue of increasing CT waiting lists. The current system, where both inpatients and outpatients share a single CT scanner, experiences significant daily fluctuations in resource utilization and process delays. Inpatient examinations were found to require, on average, 23% more staff time than outpatient ones. For non-contrast CT scans, outpatients used 63% less time compared to inpatients (Conlon & Molloy, 2023).

This disparity can be attributed to the complexity and urgency of inpatient cases, which often require additional preparation and coordination. A study by (Murray et al., 2017) supports the recommendation for separate diagnostic imaging centers for inpatients and outpatients, citing improved efficiency and patient experience. Similarly, (Bates et al., 2016) found that separating inpatient and outpatient duties enhanced patient safety and the learning environment.

The ER overcrowding is a big problem, and it is associated with lower quality of care, reduced patient throughput, and limited access to ED services. The most important cause of this overcrowding is the integral role that diagnostic imaging plays in the process of diagnosing and evaluating patients (Worster et al., 2006). Research indicates that extended waiting periods and delays in treatment can result in negative patient outcomes, including higher rates of morbidity and mortality (Morley et al., 2018). The congestion in EDs results in decreased patient throughput, meaning that fewer patients can be seen and treated within a given timeframe.

This inefficiency not only affects patient satisfaction but also strains hospital resources and staff (Sartini et al., 2022). Restricted access to ED services due to overcrowding can prevent patients from receiving timely and appropriate care. This is distinctly concerning for urgent conditions like stroke or trauma, where any delays in diagnosis and treatment can lead to severe consequences (Giamello et al., 2023). Diagnostic imaging is essential for assessing and diagnosing patients in the ED. However, the substantial demand for these imaging services significantly extends the length of stay (LOS) in the ED. Efficient management of performing CT imaging is essential to mitigate this issue (Worster et al., 2006).

The implementation of a picture archiving and communication system (PACS) for radiology images, as opposed to using compact disc (CD) copies, significantly reduces the time needed for doctors to access CT scans. Physicians can review the CT images immediately after they are archived, even before the patient returns to their department (Khaleel et al., 2018).

The PACS enhances efficiency by allowing instant access to digital images, eliminating the need for physical transport of CDs. This immediate availability of images facilitates quicker decision-making and improves patient care. The cost savings associated with PACS implementation are significant. By eliminating the need for physical storage and transport of CDs, healthcare facilities can reduce expenses related to materials, labor, and storage space. Additionally, PACS minimizes the risk of lost or damaged images (Schenkel, 2000).

Odhiambo et al. (2015) found that integrating PACS into radiological services shortens TAT and provides substantial cost savings. The study highlighted that PACS reduces the time required for image retrieval, interpretation, and reporting, leading to faster diagnosis and treatment (Odhiambo et al., 2015).

The PACS streamlines workflow by enabling seamless sharing of images among healthcare professionals. This allows for more efficient multidisciplinary consultations. The digital nature of PACS allows for advanced image processing and analysis. Radiologists can utilize tools such as 3D reconstructions and image overlays to better visualize and interpret complex cases. PACS supports remote access and teleradiology, allowing radiologists to examine and interpret images from any location. This capability is especially advantageous in rural or underserved regions, where access to specialized radiology services may be limited (Berkowitz et al., 2018; Chandramohan et al., 2024; Society for Imaging, 2009).

2.3.2. Writing the Report

The increasing number of imaging exams presents a challenge for radiology departments to enhance their operations and efficiently produce reports. Improving the TAT of radiology reports is essential for maintaining productivity and providing timely patient care (Stern et al., 2018). This improvement also helps reduce healthcare costs by shortening hospital stays and accelerating treatment(Boland, 2007). Moreover, increasing the efficiency of radiology report production and encouraging early diagnosis in outpatient settings can lead to fewer hospital admissions and further cost savings (Zhang et al., 2013). Previous research suggests that the TAT for an inpatient radiology exam report should be under eight hours (Boland, 2006).

One effective strategy to enhance CT reports TAT is using technology, such as voice recognition software, so radiologists can dictate their findings directly into the system, which transcribes the speech into text (Osiemo, 2023). Examples of Voice Recognition Software in Radiology are Nuance Dragon Medical One17, PowerScribe 360, and Augnito(Gali & Dave, 2017; Onitilo et al., 2023). Another example is implementing standardized reporting templates for report generation (Larson, 2018). These templates ensure that all essential information is included and presented in a consistent format.

Furthermore, automated reporting systems, these systems use advanced algorithms and artificial intelligence (AI) to analyze medical images and provide initial findings. By leveraging AI, these systems can quickly identify abnormalities, measure anatomical structures, and highlight areas of concern, thereby reducing the time radiologists spend on manual analysis (Obuchowicz et al., 2024).

The initial findings generated by these systems serve as a preliminary report that radiologists can review and finalize. Furthermore, automated CT scan reporting systems can be particularly beneficial in resource-constrained settings or during peak times when the need for radiology services is high. By reducing the burden on radiologists, these systems help maintain high standards of care even under challenging circumstances. The integration of AI-driven automation in radiology holds great promise for advancing the field. (Reiner et al., 2007; Sistrom & Langlotz, 2005)

Sub-specialization enhances reporting TATs and productivity, as radiologists trained in subspecialties can more quickly recognize common findings, normal variants, and specific pathologies compared to general radiologists (Meyl et al., 2019; Rosenkrantz et al., 2018).

Implementing a subspecialized reporting workflow can significantly boost the efficiency and productivity of radiology departments. Studies have shown that the median TAT decreased from 17:04 hours with general reporting to 3:38 hours with subspecialized reporting. This remarkable reduction in TAT is attributed to the focused expertise of subspecialized radiologists, who can quickly identify and diagnose conditions within their area of specialization (Stern et al., 2018).

The percentage of radiology reports released within 24 hours improved from 65% to 87%, indicating a substantial enhancement in report availability speed. The productivity of radiologists increased from a median of 301 reports per full-time radiologist per month to 376 reports, indicating that subspecialized reporting not only sped up report generation but also enabled radiologists to produce a higher volume of reports (Stern et al., 2018).

Moreover, subspecialization encourages a culture of continuous education and professional development within radiology departments. Radiologists who focus on specific subspecialties can stay up-to-date with the newest advancements and research in their field, further enhancing the quality of their interpretations and reports (Friedberg et al., 2018).

In the Centralized Radiology Reporting System, radiologists are organized into subspecialty groups and work from a central location. This setup allows for more focused expertise, leading to improved report quality, reduced report TAT, and enhanced collaboration and AI integration. The study found that this system significantly decreased TAT for both MRI and conventional radiographs, showing better performance compared to a decentralized system. The MRI report TAT dropped from 1051 to 401 minutes. Also, the study indicated that 98.1% of radiologists felt the quality improved post-centralization compared to 91.3% before the change (Zabel et al., 2020).

Centralized reporting systems leverage advanced digital platforms to streamline the workflow, ensuring that radiologists can access and interpret images more swiftlyand accurately. By centralizing the reporting process, radiologists can collaborate more effectively, share insights, and provide second opinions without the delays associated with physical distance (Law et al., 2024; Pesapane et al., 2023).

Moreover, centralized systems integrate with HIS and PACS, allowing for seamless data sharing and storage. This integration improves the speed of report generation and enhances the security and accessibility of patient information. The centralized approach also supports continuous quality improvement initiatives by enabling the collection and analysis of performance metrics (Benjamin et al., 2010; Liu & Wang, 2010).

Centralized systems facilitate the integration of AI and machine learning, improving report generation and monitoring. This includes using natural language processing to enhance report accuracy and efficiency. AI-generated reports have shown a potential to match or exceed human-generated reports in certain contexts, suggesting a collaborative future for radiologists and AI systems (Chaves et al., 2024; Yang et al., 2024; Zhou et al., 2023).

The challenge of centralized reporting systems is the need for training and adaptation among radiologists, particularly older practitioners who may resist changes in reporting practices (Pepe et al., 2023).

The implementation of 24/7 radiologist coverage in emergency CT services significantly reduced imaging report TAT (Medeiros, 2019). This reduction was achieved through several strategies, including streamlining examination protocols, adjusting staff schedules, and refining examination booking procedures. These changes not only reduced the overall TAT for CT scans but also led to improved patient care.

One notable improvement was the reporting of overnight exams during the night shift, which relieved morning-shift radiologists from processing the previous night's exam backlog. This resulted in decreased report TATs for most imaging studies conducted between 08:00 and 12:00. Consequently, emergency physicians now benefit from more prompt access to precise imaging results, which supports effective patient care management (Alshabibi et al., 2020).

Moreover, the incorporation of advanced technologies, such as AI and machine learning, can significantly improve the efficiency of round-the-clock radiologist coverage. These technologies can assist in preliminary image analysis, flagging critical findings for immediate review, and optimizing workflow efficiency (Van Leeuwen et al., 2022).

The TAT for reports is expected to increase when the volume of radiology studies conducted within a certain period exceeds the radiologist's capacity to interpret them during that same timeframe. Solutions include providing an additional radiologist to cover busy periods, having a resident assist with report writing, and considering the time elapsed since the start of a radiologist's shift (Rathnayake et al., 2017).

The speed of radiology report TAT is a very important indicator for radiologists. It has been recognized as a vital component of departmental quality management programs by the Joint Commission for the Accreditation of Health Care Organizations. This commission is a globally recognized leader in healthcare quality and patient safety, providing accreditation to healthcare organizations that meet performance standards.

Their accreditation process involves a thorough evaluation of an organization's compliance with these standards, which are designed to inspire and improve quality and safety for patients. Two essential steps in achieving quick report TAT are allocating sufficient departmental resources for swift transcription and modifying physician practices to accelerate the editing and signing of reports (Seltzer et al., 1997).

Previous research indicates that training sessions for staff radiologists on the significance of quick TAT, along with the provision of report templates for faster report generation, can prevent prolonged TAT (Seltzer et al., 1997). On one hand, the effort to minimize report TAT must be balanced against its implications for report quality. That longer TAT may reflect radiologists' lengthiness in viewing images and writing a detailed report, and hence the quicker production of the report may fail to include clinically relevant information or clarity in its style and structure (Seltzer et al., 1994).

Research by (Verma et al., 2020) suggests that radiologists who take more time to interpret imaging studies are less likely to make diagnostic errors.

Achieving a low TAT is a critical priority for radiology practices. The Joint Commission's Hospital National Patient Safety Goals include the timely reporting of critical diagnostic test results. In alignment with these principles, Joint Commission International

(JCI), a globally recognized organization, accredits healthcare institutions to ensure they meet high standards of quality and patient safety.

In radiology, JCI standards focus on several key areas. Patient Safety Goals include accurate patient identification, effective communication of critical test results, and adherence to evidence-based practices to minimize risks. Quality assurance plays a vital role, with radiology departments required to implement protocols for equipment maintenance, staff training, and regular audits to maintain diagnostic accuracy and safety.

Additionally, JCI emphasizes continuity of care, necessitating seamless coordination between radiology and other departments to guarantee timely and effective patient care. Proper documentation of imaging procedures and the timely reporting of results are also critical for compliance with JCI standards. Furthermore, the American College of Radiology's practice guidelines emphasize the importance of prompt communication of imaging results to ensure the delivery of high-quality patient care (Myers, 2011; Rosenkrantz et al., 2014; Schyve, 2000).

The difficulty of accessing an on-call radiologist during the night shift can significantly increase the risk of delayed diagnosis, misdiagnosis, and inappropriate treatment for patients. This is particularly concerning for urgent or emergency cases that require immediate radiological evaluation (Hall, 2013).

The risk of delayed diagnosis is exacerbated when the reliance on on-call residents and teleradiology. Radiology residents are available at the hospital during their on-call shifts. They handle urgent imaging cases, often during nights or weekends, and provide preliminary interpretations of imaging studies.

Teleradiology involves remote radiologists who interpret imaging studies from a different location, often using digital platforms like PACS, providing final interpretations rather than preliminary ones. It enables hospitals to access radiology expertise 24/7, especially in areas with a shortage of on-site radiologists.

While it offers flexibility and broader access to subspecialty expertise, teleradiology may face challenges in communication and integration with the on-site clinical team. On-call residents and teleradiology have shown differing accuracy rates. On-call residents demonstrated faster TAT compared to teleradiologists. Many healthcare systems use a combination of on-call residents and teleradiology to ensure comprehensive radiology coverage (Pierson et al., 2024; Yeates et al., 2022).

Quicker delivery of radiology reports can significantly reduce the patient's psychological distress. A study examining patient complaints across various service departments found that 104 patients lodged complaints against the radiology department, 89 against laboratory services, and 21 against the pharmacy (Odhiambo et al., 2015). The most common grievance expressed in patient satisfaction surveys is the excessive waiting time (Carr-Hill, 1992). So some patients may find alternative hospitals for their diagnostic imaging or leave dissatisfied with the services provided.

Effective communication through formal radiology reporting practices between radiologists and ED physicians is deemed a vital element of high-quality patient care (Rosenkrantz et al., 2014). Nevertheless, reporting exam results in the ED faces multiple obstacles, including delays in radiologist interpretation, time limitations owing to the rising demand for imaging, lack of complete information from the ordering provider, and communication issues between the ED physician and the radiologist (Gunn et al., 2013). Extended shift hours and misinterpretation of imaging studies have been identified as major sources of clinical errors, especially in ED settings (Hanna et al., 2016).

Chapter Three: Methodology

3.1 Ethical Consideration

The Institutional Review Board (IRB) at the Arab American University of Palestine (AAUP), with the code number "R-2024/A/48/N," officially approved this study. The IRB's approval signifies that the research adheres to the highest standards of ethical conduct. The institutional research committee's ethical guidelines were followed in all the study procedures. All data collected during this study were used anonymously, and data confidentiality will be maintained throughout the study and used only to achieve the aims of the study.

The participants' information did not include any identifying details such as names, departments, or other personal information, thereby ensuring that the information was not misused in any way. In addition, the hospitals involved in the study were notified of its intent through an official letter from the university. The research was also approved by the hospitals' respective Ethics Committees, further underscoring the importance placed on ethical considerations throughout the study.

3.2 Study Design and Sampling Method

The cross-sectional retrospective design was used to perform the current study, chosen for its ability to provide a snapshot of the data at a specific point in time. This design is particularly advantageous when resources are limited and when the primary aim is to analyze the prevalence or associations between variables without manipulating the study environment.

The study used a convenient non-probability sampling method. The hospitals were chosen intentionally based on accessibility and willingness to provide data (convenient sampling). Within each selected hospital, all CT scan cases during the study period were included (non-probability sampling). This approach was selected due to its practicality and ease of access to subjects (Pace, 2021).

The study included all CT scan examinations completed from July 2023 to December 2023 at three hospitals in Palestine: IbnSina Specialized Hospital (ISH), Specialized Arab Hospital (SAH), andIstishari Arab Hospital (IAH).All three mentioned hospitals are equipped with 128-slice Philips CT scanners manufactured in the years 2021, 2022, and 2015, respectively.

The timeframe was chosen to ensure a comprehensive collection of data within a consistent period. A total of 8220 CT scans were included in the current study, with 2479 CT scans from ISH, 3420 CT scans from IAH, and 2321 CT scans from SAH. These numbers reflect the extensive scope of the study and the significant amount of data analyzed, contributing to the robustness of the study's findings.

3.3 Data Collection

Following official approval by the IRB) with the code number “R-2024/A/48/N,” data from the medical records stored in the Enterprise Resource Planning (ERP) system were collected. These records are connected to the HIS, which is used in selected hospitals and accessed through the quality departments at the above-mentioned hospitals. It is worth noting that the electronic recording system is not available at all hospitals in Palestine. Thus, hospitals were selected based on whether they have the electronic recording system protocol or not. This selection criterion ensured the consistency and accuracy of the data collected for this study.

The collected data includes the following parameters: time of CT scan order, time of CT scan acceptance, time of the CT scan final report, order status, encounter type, the ordering day and time, and whether CT scans were with or without contrast media. These specific parameters were chosen to provide a thorough understanding of the CT scanning process and its efficiency. Then, the order to accept TAT, the order to result TAT, and the accept to result TAT were calculated in minutes.

The encounter type refers to the department ordering the CT scans, which are divided into inpatient, outpatient, and EDs. The ordering day is divided into weekdays and weekends; the ordering time is divided into A shift (from 8:00 am to 3:00 pm), B shift (from 3:00 pm to

10:00 pm), and C shift (from 10:00 pm to 8:00 am), to assess the influence of different periods on the efficiency of the CT scan process.

3.4 Statistical Analysis

Data were analyzed using Statistical Package for the Social Sciences version 21 (SPSS 21) by IBM Corp., Armonk, N.Y., USA. Descriptive statistics were used to report the TAT mean, standard deviation, median, and quartiles. The sample was tested for normality using the Kolmogorov-Smirnov test, and it was found to be non-normally distributed($p < 0.05$).Thus, non-parametric tests were used to determine the association of the order to accept TAT of the CT scans with the working day, working shift, the CT scan encounter type, and the use of contrast media.

Additionally, the association of the order to result TAT of the CT scans with the working day, working shift, the CT scan encounter type, and the use of contrast media and the association of the accept to result TAT of the CT scan with the working day, working shift, the CT scan encounter type, and the use of contrast media were also evaluated using the non-parametric tests.

The Kruskal-Wallis test was used to determine the association between the TATs and the encounter type and between the TATs and the working shift (A, B, and C shifts) because encounter type and working shift are trimeric variables.

The Mann-Whitney U test was used to determine the association between TATs and the use of contrast media and between TATs and the working day of the CT scan (weekdays or weekends) because these variables are dimeric.

In addition, the variations in the order to accept TAT, order to result TAT, and accept to result TAT of CT scans were evaluated between the three studied hospitals using the Kruskal-Wallis test. Variables that were significant in the Kruskal-Wallis test were introduced into Dunn’s post hoc test to determine the difference between every two groups. A p-value of less than 0.05 was considered statistically significant.

Chapter Four: Results

Descriptive statistics of the order to accept TAT, order to result TAT, and accept to result TAT of CT scans in the total sample and each hospital separately.

The descriptive statistics, including the mean, standard deviation (SD), median, and interquartile range (IQR) for the TATs in the study sample, are shown in Table 4.1 and Figure 4.1. The median of the order to accept TAT in minutes was 78, 60, 121, and 58 minutes for the total sample, the ISH sample, the IAH sample, and the SAH sample, respectively. The median of the order to result TAT in minutes was 837, 616, 874, and 964 minutes for the total sample, the ISH sample, the IAH sample, and the SAH sample, respectively. The median accept to result TAT in minutes was 462, 165, 648.5, and 484 minutes for the total sample, the ISH sample, the IAH sample, and the SAH sample, respectively. The order to accept TAT and the accept to result TAT were higher for the IAH than for ISH and SAH. The order to result TAT was higher for the SAH compared with the other two hospitals.

Table 4.1: Descriptive statistics of the order to accept TAT, order to result TAT, and accept to result TAT of CT scans in the total sample and each hospital separately

Variable	Hospital	Mean	SD	Median	IQR [Q1-Q3]
Order to accept TAT (min)	ISH (n=2479)	294.77	483.64	60	[22-298]
	IAH (n=3420	351.4	739.43	121	[35-557]
	SAH (2321)	358.33	491.1	58	[15-734]
	Total (n=8220)	336.28	605.64	78	[24-571]
Order to result TAT (min)	ISH (n=2479)	4488.46	18164.5	616	[103-1497]
	IAH (n=3420	1082.62	1169.07	874	[306.25-1461.75]
	SAH (2321)	2266.76	5734.2	964	[220-2120]
	Total (n=8220)	2444.12	10553.2	837	[189-1548]
Accept to result TAT (min)	ISH (n=2479)	4193.69	18145.5	165	[27-1024]
	IAH (n=3420	731.24	878.22	648.5	[94-1022.75]
	SAH (2321)	1908.43	5694.56	484	[0-1351]
	Total (n=8220)	2107.84	10529.6	462	[55-1096]

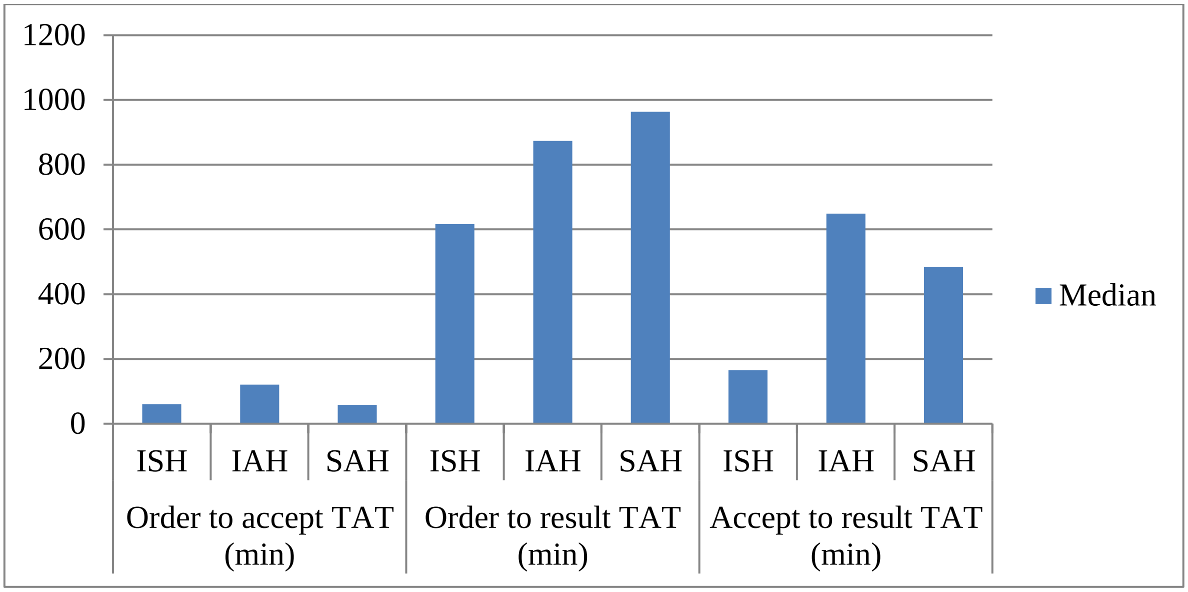

Figure 4.1: Description of the order to accept TAT, order to result TAT, and accept to result TAT (median) in the three hospitals.

Variation in the order to accept TAT based on the predictors in the total sample, the ISH, the IAH, and the SAH.

The association between the order to accept TAT and the use of contrast media in the CT scan, the working day, the working shift, and the CT scan encounter type was evaluated. Table 4.2 reveals that the order to accept TAT in minutes is significantly associated with the working shift and the encounter type in the total sample as well as in each hospital separately (p-value < 0.001). For the total sample of 8220 CT scans, a significantly lower order to accept TAT was found in the B shift, followed by the A shift, while it was longest in the C shift (B shift < A shift < C shift). Regarding the encounter type for the total sample, a significantly lower order to accept TAT was found for outpatient CT scans, while it was longer for emergency CT scans and even longer for inpatient CT scans (outpatient < emergency < inpatient).

Regarding the CT scans from ISH, a significantly higher order to accept TAT was in the C shift compared with the A and B shifts; however, there was no significant difference in the order to accept TAT between the A and B shifts. Similar to the pattern observed for the total sample, the order to accept TAT for CT scans from ISH was significantly shorter for outpatient CT scans, followed by emergency CT scans and then inpatient CT scans (outpatient < emergency< inpatient).

For the CT scans from IAH, the order to accept TAT was significantly lowest in the B shift followed by the A shift, and significantly higher in the C shift (B shift < A shift < C shift) and it was significantly lowest for outpatient CT scans compared with emergency and inpatient CT scans, there was no significant difference the order to accept TAT between the emergency and inpatient CT scans.

For CT scans from SAH, the order to accept TAT was significantly lowest in the B shift, followed by the A shift, and significantly higher in the C shift (B shift < A shift < C shift). Moreover, a significantly lower order to accept TAT was found for outpatient CT scans, while it was longer for emergency CT scans and longer for inpatient CT scans (outpatient < emergency < inpatient).

The order to accept TAT was not significantly affected by the working day in the total sample from the three studied hospitals and in CT scans from IAH and SAH separately.

However, a significantly higher order to accept TAT was observed in the CT scans performed during the weekends compared with CT scans performed during the weekdays from ISH (p-value = 0.003). Furthermore, using contrast media significantly increased the order to accept TAT in the total sample and CT scans from IAH (p-value < 0.001). However, the order to accept TAT for CT scans from ISH and SAH was not affected by using contrast media as a predictor variable. Results are shown in Table 4.2.

Table 4.2.Variation in the order to accept TAT based on the predictors in the total sample, the ISH, the IAH, and the SAH.

Order to accept TAT (min)	**ISH (n=2479)**			**IAH (n=3420)**			**SAH (n=2321)**			**Total sample (n=8220)**		
	n	Mean rank	p-value	n	Mean rank	p-value	N	Mean rank	p-value	N	Mean rank	p-value
Contrast media^{+}												
No	1783	1240.9	0.925	1990	1621.4	**<0.001**	1869	1150.4	0.12	5642	4001.4	**<0.001**
Yes	696	1237.8		1430	1834.5		452	1205		2578	4349.3	
Working day^{+}												
weekday	2175	1224.1	**0.003**	3119	1717.7	0.172	2043	1160.5	0.917	7337	4107.2	0.717
weekend	304	1353.7		301	1636.3		278	1164.9		883	4137.8	
Working shift^{++}												
A shift	948	1014.3^{a}	**<0.001**	1639	1468.9^{a}	**<0.001**	734	882.2^{a}	**<0.001**	3321	3443.6^{a}	**<0.001**
B shift	662	931.7^{a}		611	1052.8^{b}		596	688.6^{b}		1869	2606.6^{b}	
C shift	869	1721.2^{b}		1170	2392.5^{c}		991	1651.6^{c}		3030	5769^{c}	
Encounter type^{++}												
Inpatient	1561	1340.1^{a}	**<0.001**	1911	1769.9^{a}	**<0.001**	1492	1241.6^{a}	**<0.001**	4964	4332.7^{a}	**<0.001**
Outpatient	340	856.8^{b}		1020	1571.6^{b}		278	816.8^{b}		1638	3560.7^{b}	
Emergency	578	1195^{c}		489	1768.2^{a}		551	1116.4^{c}		1618	3985.4^{c}	

$^{+}$Predictors for which the *p*-value is calculated using the Mann-Whitney U test.

$^{++}$ Predictors for which the *p*-value is calculated using the Kruskal-Wallis test.

Superscripts (a,b, and c) correspond to the results of Dunn's post hoc test.

Variation in the order to result TAT based on the predictors in the total sample, the ISH, the IAH, and the SAH.

The association between the order to result TAT and the use of contrast media in the CT scan, the working day, the working shift, and the CT scan encounter type was evaluated. Table 4.3 illustrates that the order to result TAT in minutes is significantly associated with the working shift and the encounter type in the total sample as well as in each hospital separately (p-value < 0.05). For the total sample of 8220 CT scans, a significantly higher order to result TAT was found for the CT scans from the C shift compared with that from the A and B shifts, however, no significant difference was observed in the order to result TAT for CT scans between the A and B shifts. Regarding the encounter type for the total sample, a significantly lower order to result TAT was found for emergency CT scans compared with outpatient CT scans, however, no significant differences were observed between inpatient CT scans and the other encounter sources.

Regarding the CT scans from ISH, the order to result TAT was significantly lowest in the B shift, followed by the A shift, and significantly higher in the C shift (B shift<A shift<C shift). Similar to the pattern observed for the total sample, a significantly lower order to result TAT was found for emergency CT scans compared with outpatient CT scans, however, no significant difference was observed between inpatient CT scans and the other encounter sources.

For the CT scans from IAH, the order to result TAT was significantly lowest in the A shift and significantly higher in the B shift, followed bythe C shift (A shift<B shift<C shift). Additionally,the order to result TAT was significantly lower for inpatient CT scans compared with outpatient CT scans, however, there was no significant difference between emergency CT scans and the other encounter types.

For CT scans from SAH, a significantly higher order to result TAT was found in the CT scans from the C shift compared with that from the A and B shifts. However, no significant difference in the order to result TAT was observed between CT scans from the A and B shifts. Moreover, no significant difference in the order to result TAT was found in the CT scan based on the encounter types according to the post hoc test outcomes.

The order to result TAT for CT scans was significantly affected by the working day in the total sample and in CT scans from IAH; significantly higher orders to result TAT were observed for CT scans performed on the weekends compared with the CT scans performed on weekdays (p-value <0.001). Furthermore, using contrast media was significantly associated with a higher order to result TAT for CT scans in the total sample and CT scans from ISH and IAH. However, the order to result TAT for a CT scan from SAH was not affected by using contrast media in a CT scan. Results are shown in Table 4.3.

Table 4.3.Variation in the order to result TAT based on the predictors in the total sample, the ISH, the IAH, and the SAH.

Order to result TAT (min)	ISH (n=2479)			IAH (n=3420)			SAH (n=2321)			Total sample (n=8220)		
	N	Mean rank	p-value	N	Mean rank	p-value	N	Mean rank	p-value	N	Mean rank	p-value
Contrast media+												
No	1783	1212.3	**0.002**	1990	1530.8	**<0.001**	1869	1160.3	0.912	5642	3949.6	**<0.001**
Yes	696	1310.9		1430	1960.6		452	1164.1		2578	4462.7	
Working day+												
weekday	2175	1235.9	0.442	3119	1690.3	**<0.001**	2043	1152.1	0.082	7337	4078.4	**<0.001**
weekend	304	1269.6		301	1920.1		278	1226.6		883	4377.3	
Working shift++												
A shift	948	1157.4a	**<0.001**	1639	1445.7a	**<0.001**	734	982.1a	**<0.001**	3321	3593.3a	**<0.001**
B shift	662	1042.6b		611	1747.4b		596	928.1a		1869	3571.8a	
C shift	869	1480.5c		1170	2062.2c		991	1433.6b		3030	5009.6b	
Encounter type++												
Inpatient	1561	1246ab	**0.006**	1911	1669.6a	**0.024**	1492	1185.1a	**0.04**	4964	4109.2ab	**0.038**
Outpatient	340	1327.4a		1020	1765.5b		278	1084.4a		1638	4218.3a	
Emergency	578	1172.4b		489	1755.6ab		551	1134.5a		1618	4005.5b	

[+] Predictors for which the *p*-value is calculated using the Mann-Whitney U test.

[++] Predictors for which the *p*-value is calculated using the Kruskal-Wallis test.

Superscripts (a,b, and c) correspond to the results of Dunn's post hoc test.

Variation in the accept to result TAT based on the predictors in the total sample, the ISH, the IAH, and the SAH.

The association between the accept to result TAT and the use of contrast media in the CT scan, the working day, the working shift, and the CT scan encounter type was evaluated.

Table 4.4 elucidates that the accept to result TAT in minutes is significantly associated with the CT scan encounter type in the total sample as well as in the ISH and IAH (p-value < 0.001). The accept to result TAT of outpatient CT scans was significantly high compared with inpatient and emergency CT scans in the total sample and within CT scans from ISH and IAH. However, no significant difference was observed in the accept to result TAT of CT scans encountered as inpatient or emergency orders. On the other hand, the accept to result TAT of CT scans from SAH showed no significant variation according to the encounter type.

In addition, the accept to result TAT of CT scans was significantly influenced by the working shift in the total sample, the IAH, and SAH, but not for CT scans from ISH. For the total study sample from the three hospitals, the accept to result TAT of CT scans from shift B was significantly higher than that of CT scans from shift A, however, no significant difference was observed in the accept to result TAT of CT scans from shift C compared with CT scans from the other shifts. The variation in the accept to result TAT of CT scans based on the working shift from each hospital separately was not constant. Significantly higher accept to result TAT of CT scans was observed for CT scans from shift C compared with those from shift A at the SAH.

Moreover, significantly higher accept to result TAT was observed for CT scans from shift B compared with those from shift A and shift C at the IAH, with no significant difference between CT scans from shift A and shift C. However, the accept to result TAT for CT scans at the ISH was not significantly variable based on the working shift.

The accept to result TAT was significantly affected by the working day in the total sample and in CT scans from IAH and SAH, where significantly higher accept to result TAT was observed for CT scans performed on weekends compared with CT scans performed on weekdays. However, the accept to result TAT of CT scans from ISH was not significantly variable based on the working day. Furthermore, using contrast media in CT scans was significantly associated with a higher accept to result TAT compared with CT scans without contrast media in the total sample and CT scans from ISH and IAH. However, the accept to result TAT for CT scans from SAH was not affected by using contrast media in CT scans.

Results are shown in Table 4.4.Additionally, accept to result TAT association with the predictors for the total sample is presented in Figure 4.1.

Table 4.4. Variation in the accept to result TAT based on the predictors in the total sample, the ISH, the IAH, and the SAH.

Accept to result TAT (min)	ISH (n=2479)			IAH (n=3420)			SAH (n=2321)			Total sample (n=8220)		
	n	Mean rank	p-value	n	Mean rank	p-value	N	Mean rank	p-value	N	Mean rank	p-value
Contrast media[+]												
No	1783	1200	**<0.001**	1990	1478.3	**<0.001**	1869	1156	0.459	5642	3877.1	**<0.001**
Yes	696	1342.5		1430	2033.7		452	1181.8		2578	4621.3	
Working day[+]												
weekday	2175	1244	0.458	3119	1684.5	**<0.001**	2043	1150.7	**0.043**	7337	4081.2	**0.001**
weekend	304	1211.5		301	1980.1		278	1236.7		883	4353.9	
Working shift[++]												
A shift	948	1276.8	0.075	1639	1630[a]	**<0.001**	734	1108.7[a]	**0.003**	3321	4029.8[a]	**0.011**
B shift	662	1195.1		611	2059.3[b]		596	1136.8[ab]		1869	4233.6[b]	
C shift	869	1234		1170	1641.2[a]		991	1214.3[b]		3030	4123[ab]	
Encounter type[++]												
Inpatient	1561	1204.6[a]	**<0.001**	1911	1634[a]	**<0.001**	1492	1160.5	0.422	4964	4003.4[a]	**<0.001**
Outpatient	340	1508.1[b]		1020	1900.7[b]		278	1204.5		1638	4619[b]	
Emergency	578	1178[a]		489	1612.8[a]		551	1140.3		1618	3924.3[a]	

[+] Predictors for which the *p*-value is calculated using the Mann-Whitney U test.

[++] Predictors for which the *p*-value is calculated using the Kruskal-Wallis test.

Superscripts (a, b, and c) correspond to the results of Dunn's post hoc test.

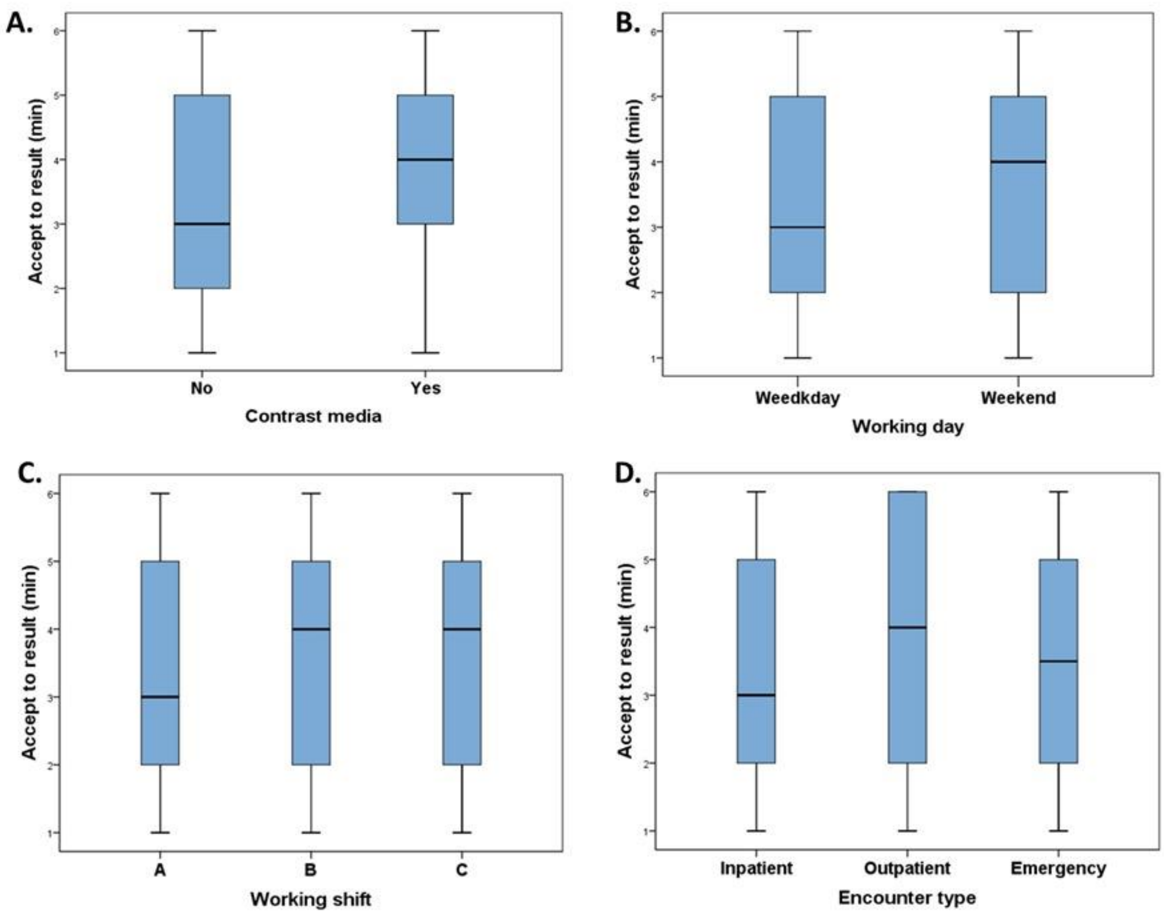

Figure 4.2: Boxplot presentation of the association between the accept to result TAT (min) and the predictors in the total sample.(A) Contrast media usage, (B) Working day, (C) Working shift, (D) Encounter type.

Variations in the TATs of CT scans between the ISH, IAH, and SAH.

Even though the studied hospitals used the same protocols and admission system, the order to accept TAT, the order to result TAT, and the accept to result TAT of the CT scan were significantly different between the three studied hospitals (p-value <0.001). The order to accept TAT of the CT scan was significantly higher at the IAH compared with ISH and SAH; however, no significant difference was observed in the order to accept TAT of CT scans between ISH and SAH. The order to result TAT of the CT scan was significantly lower at the ISH compared with IAH and SAH, and no significant difference was observed in the order to result TAT of CT scans between IAH and SAH.

Regarding the accept to result TAT of the CT scan, it was significantly variable between the three studied hospitals. The lowest value of the accept to result TAT of the CT scans was observed in CT scans from the ISH, followed by CT scans from the SAH, and then by those from the IAH (ISH< SAH< IAH). Results are shown in Table 4.5.

Table 4.5.Variations in the TATs of CT scans between the ISH, IAH, and SAH.

TAT	Hospital	n	Mean rank	p-value
Order to accept TAT (min)	ISH	2479	3854[a]	**<0.001**
	IAH	3420	4426.5[b]	
	SAH	2321	3918.9[a]	
Order to result TAT (min)	ISH	2479	3758.2[b]	**<0.001**
	IAH	3420	4218.6[a]	
	SAH	2321	4327.5[a]	
Accept to result TAT (min)	ISH	2479	3717.4[a]	**<0.001**
	IAH	3420	4397.2[b]	
	SAH	2321	4107.9[c]	

Superscripts (a, b, and c) correspond to the results of Dunn’s post hoc test.

Chapter Five: Discussion

The purpose of this study is to determine the average TAT for a CT scan from the order to the final report, the average time from a CT scan order to accept, and the average time from CT scan acceptance to the final report. Additionally, the study evaluated whether the type of CT scan, the ordering department, and the day and time of the order influence the above-mentioned average TATs.

The results of the study indicate that the averageaverage TAT for a CT scan from the order to the final report is 837 minutes (13.95 hours), the average time from a CT scan order to accept is 78 minutes (1.3 hours), and the average time from CT scan accept to the final report is 462 minutes (7.7 hours).

Also, the order to accept TAT is associated with the working shift, the ordering department, and the type of CT scan. The lower order to accept TAT was found in the B shift, followed by the A shift, while it was longest in the C shift. Based on the ordering department, the order to accept TAT from low to high values were CT scans from the outpatient, emergency, and inpatient departments, respectively. Furthermore, using contrast media was found to be associated with increased order to accept TAT.

Similarly, the accept to result TAT is associated with the working shift, the ordering department, the type of CT scan, and the working day. The accept to result TAT from shift B was higher than that of CT scans from shift A; however, no significant difference was observed in CT scans from shift C compared with CT scans from the other shifts. Outpatient CT scans had a significantly higher accept to result TAT compared to inpatient and emergency CT scans, but there was no significant difference between inpatient and emergency CT scans. Using contrast media in CT scans was associated with higher accept to result TAT. A higher accept to result TAT was observed in the weekend CT scans compared with weekday CT scans.

Finally, the order to result TAT is associated with the working shift, the ordering department, the type of CT scan, and the working day. A higher order to result TAT was found in the C shift compared with the other shifts; no significant difference was observed between the A and B shifts. A lower order to result TAT was found for emergency CT scans compared with outpatient CT scans; no significant differences were observed between inpatient CT scans and the other encounter sources. Using contrast media was associated with a higher order to result TAT. Higher order to result TAT were observed in the weekend CT scans compared with weekly day CT scans.

5.1 Effect of Working Shift on TAT

The study revealed that CT scans from the C shift had the longest order to result TAT and order to accept TAT, while the B shift exhibited a longer accept to result TAT. These disparities can be attributed to variations in staffing levels across shifts. Palestinian hospitals generally employ fewer radiographers during the B and C shifts compared to the A shift (Obaid, 2019).

In the three healthcare facilities that were chosen for this study, the A shift had four to five radiographers, the B shift had two to three, and the C shift had only one. This means that the B and C shifts have fewer employees, which can result in delays in registration, patient preparation, and imaging procedures. The absence of essential personnel like the radiology department secretary, nurse, and head technician during these shifts further exacerbates these delays. Having multiple radiologists on duty during the A shift as opposed to a single radiologist on other shifts allows for more efficient report completion, which contributes to shorter TAT.

TATs may be impacted if there is no on-call radiologist available during the night shift, which could impede prompt communication about CT procedures or patient preparation. These findings align with a previous study that explored factors contributing to CT trauma scan TAT variation and evaluated the effects of an automated intervention on-time metrics, which found that imaging technologist variability, time of day, and day of the week of trauma scans played a significant role in CT trauma TAT variability (Wood et al., 2023).

These findings suggest the need for adequate staffing and resources during all shifts to improve TAT and patient care (Lamb et al., 2015). The current results are in line with a systematic review that summarized the research on how holidays, weekends, and nights affect employee outcomes and quality in healthcare settings.

Studies on employee outcomes have shown a statistically significant link between night shift work and adverse effects, such as increased fatigue, reduced mental well-being, and job dissatisfaction. Furthermore, patient outcomes were observed to be inferior during weekends and nights compared to daytime shifts. Future research should explore the underlying causes of these differences in care quality between off-shift and weekday day-shift work (De Cordova et al., 2012).

5.2 Effect of Ordering Departments on TAT

Regarding the departmental influence on the TAT, the study indicated that the order to accept TAT for outpatient CT scans was shorter than that from emergency or inpatient departments, and this could be attributed to the outpatients' direct access to the radiology department and the swift handling of registration and financial procedures. In contrast, inpatients and emergency patients frequently face delays due to waiting for insurance financial clearance, which extends the TAT. Additionally, coordinating imaging with the radiology department for these patients is more time-consuming compared to the more straightforward process for outpatients.

Efficient registration and financial procedures help minimize patient processing delays, leading to faster imaging appointments and report generation (Boland et al., 2010). Regarding scheduling, ED patients may be given priority for CT imaging over inpatients, as delays in imaging generally have a lesser impact on inpatients, except in urgent cases.

However, it is essential to expedite the transfer of emergency patients from the emergency unit to prevent overcrowding and reduce the LOS. Consequently, imaging for inpatients may be deferred, unlike for emergency patients, explaining the shorter order to accept TAT for emergency CT scans compared to inpatient scans. Furthermore, numerous emergency cases and inpatients, including those from the intensive care unit (ICU) and cardiac care unit (CCU), might experience movement restrictions or necessitate anesthesia and continuous monitoring, hence complicating the transfer procedure to the CT table.

The study revealed that the accept to result TAT for outpatient CT scans was significantly greater than that for inpatient and ED scans. This can be attributed to the generally stable condition of outpatients compared to emergency patients and inpatients, which facilitates the CT processes (Schuur et al., 2011). Hospitals generally prioritize the prompt issuance of reports for inpatients and ED patients. For instance, at ISH, reports should be released and documented within one day for inpatients, within six hours for ER patients, and within three days for outpatients.

5.3 Effect of Contrast Media on TAT

Compared to CT scans without contrast media, the order to result TAT is longer for scans involving contrast media administration, whether IV or oral. This is partially due to the lower financial cost of scans without contrast, which can expedite the financial authorization process. Additionally, scheduling scans without contrast is often quicker than that with contrast due to the time required for oral contrast administration and potential kidney function tests. Moreover, scans with contrast require several pre-scan instructions to ensure the safety and effectiveness of the outcomes, thus the overall process is extended.

For instance, CT scans with IV contrast require more time for patient preparation, including a more detailed medical history of the patient including inquiries about previous allergic reactions against contrast media or any other allergies. Patients are also provided with specific instructions to familiarize them with the sensations associated with IV contrast administration so that their normal body response can be recognized beforehand. In addition to the above-mentioned instruction, the contrast media administration process extends the CT scan due to the need to establish an IV line, fill and clear the injector of air, and perform multiple scan phases (e.g., arterial, venous, delayed) (Bae, 2010).

The transfer time of the CT scan with contrast media to the PACS is also longer since image files are generally larger than CT scans without contrast. Finally, the interpretation of results by radiologists requires a longer duration due to the complexity of IV contrast scans compared with other scans (Reiner et al., 2001).

Similar findings were also identified by previous studies in which the factors associated with delayed CT in the ED were identified. The IV line issues, such as infiltration, difficult access, inadequate size, contrast allergies, and the need for contrast administration were revealed as common contributors to delays in CT scans (Dhanik et al., 2024).

Additionally, an earlier study demonstrated an average reduction in ED LOS of approximately two hours among patients undergoing abdominal and pelvic CT examinations with IV contrast alone compared to those receiving both IV and oral contrast (Hopkins et al., 2012). Inline previous outcomes also revealed that patients who did not receive any contrast during CT examinations had an estimated four-hour shorter LOS in the ED compared to those who underwent CT with oral contrast (Huynh et al., 2004).

5.4 Effect of Working Day on TAT

The quality of healthcare in hospitals could be variable according to the day of the week; weekdays and weekends. Compared to weekdays, the recent study revealed that the time required for order to accept, accept to result, and order to result processes of CT scans was significantly longer on weekends. This is primarily attributed to a reduced workforce on weekends; typically consisting of only one radiographer and one radiologist in addition to the absence of a radiology nurse and secretary on weekends. Comparable findings were previously reported in studies concerned with the quality of care provided on weekdays versus weekends. The lower quality of healthcare and higher rates of preventable complications were associated with insufficient hospital staffing on weekends (Becker, 2007).

An earlier study demonstrated that the delays in services could also be attributed to the longer registration process at the accounting department, caused by fewer employees and the lack of an internal accountant on weekends (Abushab et al., 2018).

Moreover, insurance companies' approvals generally tend to take longer periods on weekends compared with weekdays (Smolderen et al., 2010). Secretaries play a crucial role in streamlining administrative processes, such as report transcription and distribution, however, administrative employee numbers are generally shortened on weekends. Implementing total quality management techniques can enhance efficiency in hospitals, leading to faster report turnarounds (Seltzer et al., 1997).

Consequently, increased staffing and incentives for performing weekend procedures might be necessary to sustain the quality of healthcare services in hospitals. Sufficient staffing in the hospital departments should be part of the hospital’s strategies to ensure the highest quality of healthcare service.

A previous study conducted by De Cordova et al. (2012) illustrated qualitative and quantitative evidence on the impact of night shifts, weekends, and holidays on quality and employee outcomes in hospitals. It was found that patient outcomes on weekends and employee outcomes at night are generally worse than during the day (De Cordova et al., 2012).

It is obvious from the current findings and previous reports that patients admitted to hospitals on weekends often experience what is called the weekend effect of healthcare, which leads to prolonged waiting times and potentially compromised patient care. The contributing factors could be summarized as reduced staffing levels, longer waiting times, delays in care, limited availability of specialists such as radiologists, and reduced availability or longer TATs for certain diagnostic tests or procedures on weekends (Piras et al., 2024).

Furthermore, an earlier work conducted by Krupinski et al. (2010) revealed that radiologists exhibited diminished attention to displayed images and elevated symptoms of fatigue and oculomotor strain leading to decreased diagnostic accuracy following a day of clinical reading. These findings highlight the significant impact of fatigue on radiologists' performance. Therefore, radiologists should be aware of the potential effects of fatigue and implement strategies to mitigate its influence to ensure optimal diagnostic accuracy (Krupinski et al., 2010).

5.5 Variation in TAT Across Hospitals

Hospitals are generally variable in their workload which consequently affects the number of ordered diagnostic tests including CT scans, so TAT differs by hospital. In the current study, the IAH recorded a significantly higher number of CT scans than ISH and SAH during the six-month study period.

Even though the three studied hospitals have standardized protocols and admission systems, significant disparities persisted in the order to accept TAT, order to result TAT, and accept to result TAT across the three Palestinian hospitals. IAH exhibited longer order to accept and accept to result TATs compared to the other hospitals. These variations in TAT between hospitals could be explained by several factors, such as workload, staffing levels, protocol differences, equipment efficiency, departmental organization, patient characteristics, and external factors (Boateng-Antwi, 2019).

Supporting findings were previously documented regarding the factors associated with longer TAT. The factors could be associated with human beings; either patients or staffing, machines-associated factors, management-related factors, and external affecting factors. Higher patient load and potentially lower staffing levels contributed to longer wait times (Schull et al., 2007).

The age and maintenance frequency of CT scanners can influence scan times and image processing efficiency since older or less efficient equipment could be associated with obvious delays in processing (Rydberg et al., 2000; Townsend et al., 2004). In addition, variations in departmental organization, coordination between different departments, and communication efficiency could influence the TAT (Zeithaml et al., 1988).

The TAT is not only affected by the patients' load, however, the complexity of medical conditions and the time required for preparation can also influence the TAT. Patients with more severe conditions or requiring special preparations experienced longer scan durations and reporting times (Rathnayake et al., 2017).

External factors, including the financial process, such as insurance verification and payment method, can also contribute to TAT variations. More efficient insurance procedures can facilitate the process from order to acceptance of the CT scan. Additionally, regulatory requirements and accreditation standards variability between hospitals and insurance companies are potentially affecting their processes and TAT (Teglasi, 2010).

In general, hospitals are more concerned with the accept to result TAT, and it is used as an indicator of work effectiveness. The three selected hospitals in the current study established a 72-hour timeline for outpatient scans, a 24-hour timeline for inpatients, and a 6-hour timeline for CT scans from the ED. According to the study outcomes, the result to accept TAT was significantly lower in CT scans from ISH compared with the other studied hospitals, and IAH had the same values. Therefore, ISH demonstrated the most effective workflow in CT scans compared to the other hospitals.

Although the World Health Organization does not specify the exact TAT for CT scans, it emphasizes the critical importance of timely diagnostics in emergency care to enhance patient outcomes(World Health Organization, 2024).

A study conducted at King Saud University, focusing on poly-trauma patients, reported a median time of 102 minutes to complete a CT scan. This duration is comparable to international figures, such as 93 minutes in Australia and 105 minutes in the United States (Bamalan et al., 2024).

The National Health Service in England provides clear benchmarks for imaging TATs: reports should be available within 12 hours for urgent inpatients, 24 hours for non-urgent inpatients, and 4 hours post-acquisition for ED patients, while outpatient reports should be completed within 7 days (NHS England, 2023).

5.6 The Multifaceted Role of TAT in Healthcare Evaluation

The TAT is not used only to evaluate the efficiency of work in the radiology department, but it is important to be evaluated in all departments of the hospital to help assess their performance. As it is considered one of the most important quality indicators in medical laboratories for reporting results.Because different types of tests have different acceptable limits for reporting results. In the previous study, TAT is estimated to be 5-5.5 hours for non-stat or routine tests.

The NCBI states that "A 90% completion time (sample registration to result reporting) of <60 minutes for common laboratory tests is suggested as an initial goal for acceptable TAT." (Chawla et al., 2010; Hawkins, 2007). TAT in medical laboratories can be influenced by various factors, including sample volume, staff expertise, and resource availability, which is similar to the factors in the radiology department in the current study (Dawande et al., 2022).

The TAT is also used as an indicator when assessing its role as a new factor in vascular smooth muscle cell proliferation. The research established a screening method to identify inhibitors or promoters of smooth muscle cell growth involving TAT. This suggests that TAT may serve as a biomarker or therapeutic target in conditions related to vascular smooth muscle cell behavior, particularly in studies focused on vascular health and disease management (Nakano, 2010).

The TAT is also used in the inpatient department to evaluate the quality of work and improve the efficiency of the discharge process because a delay in the discharge process causes stagnation of patients, ultimately affecting new admissions (Chaudhari et al., 2021).

The TAT also monitors medication dispensing speed, especially for urgent orders (e.g., antibiotics, thrombolytics). Medication dispensing time significantly impacts patient safety, and efficient medication dispensing minimizes the potential for errors, thereby enhancing patient safety. A study demonstrated that employing pharmacy technicians in a geriatric ward reduced medication dispensing time by an average of 1.4 hours daily. This change correlated with a tendency towards fewer reported medication errors, indicating improved patient safety (Kjeldsen et al., 2023).

5.7 Limitations

This study has several limitations that should be considered when interpreting the results. The study was conducted in private, non-governmental hospitals within Palestine. The findings may not be generalizable to other healthcare systems, particularly those in different countries or regions with distinct hospital structures (e.g., public vs. private). Moreover, the study design did not control for all external factors that could potentially influence CT scan TAT. These factors may include variability in patient inflow (e.g., higher emergency case volume during specific shifts) and other operational emergencies within the radiology department.

Furthermore, variability in technology could influence the outcomes for other hospitals since the effectiveness of workflow optimization strategies may be impacted by the level of technological infrastructure at different healthcare facilities. The study findings are based on information regarding the implementation timeframe of the electronic recording system within the participating radiology departments. Facilities with more advanced technology may experience different results.

Lastly, some potentially confounding variables that could affect the CT workflow have not been included in the study design such as personal factors (e.g., staff skill levels) and contextual factors (e.g., workload distribution) and this could be explained by the absence of such hospital records and difficulty is the standardization of some factors to make their comparison applicable.

5.8 Conclusion and Recommendations

Workflow and the time required to perform CT scans in hospitals are vital indicators for the quality of services in hospitals and consequently patient satisfaction. Hospitals are continuously concerned with improving their medical services including CT scans via decreasing the duration of CT scans beginning from ordering to receiving results while at the same time sustaining the highest level of CT scan quality. The TAT is considered an important measurement for the evaluation of the CT scan workflow in hospitals and could be used as a quantitative indicator of working efficiency.

The TAT in CT scan could be influenced by several factors including the working shift, the working day, the CT scan request source, and the use of contrast media in the scan. Determining the effect of the above-mentioned factors could be of great importance to implement strategies that would decrease the TAT and achieve the highest possible level of CT department productivity while maintaining the proper quality of patient care and satisfaction.

In general, the order to accept TAT was longer for CT scans requiring contrast media administration compared with those without contrast media, CT scans ordered at the C shift relative to the other shifts, and those ordered from the inpatient department compared with those ordered as an emergency and those ordered for outpatients.

The order to result TAT for CT scan was also longer for CT scans with contrast media, longer for CT scans performed during the weekend compared with those performed during the weekdays, and longer for CT scans ordered during the C shift compared with the other shifts.

The accept to result TAT for CT scans, which is the most frequently used indicator in quality control, was also higher for CT scans with contrast media, higher for CT scans performed during weekends compared with those performed during the weekdays, longer for CT scans ordered for outpatients relative to those ordered from inpatients or for an emergency case. However, the pattern of variation based on the studied parameters was variable between the three studied hospitals. Moreover, significant variations in the TATs between the studied hospitals were observed.

According to the current study findings from three Palestinian hospitals adopting proper documentation systems, it is recommended to develop and implement standardized protocols for CT scan orders, acceptance, as well as CT scan conductance until results are released and interpreted in hospitals. Taking all these procedures into consideration can streamline processes and reduce variability in TAT.

Proper matching between the orders of CT scans on different days and shifts with the number of healthcare workers at the radiology department including the availability of nurses, the number of radiotechnologists, and radiologists and with the number of CT machines in the department is crucial to decrease the TAT of CT scans. In addition, investing in training programs focused on the efficient use of contrast media and patient preparation can help minimize delays associated with these practices.

Exploring the integration of technology solutions, such as automated scheduling systems or real-time tracking of orders, could enhance communication and improve TAT. Implementing a framework for continuous quality improvement within radiology departments can help monitor TAT and identify areas for ongoing enhancement.

Finally, future research should delve deeper into the long-term implications of these delays to fully understand the impact of TAT on patient outcomes. Longitudinal studies examining the connection between TAT and clinical outcomes could provide valuable information for improving imaging processes. Comparative analyses of different healthcare facilities can help identify best practices and innovative approaches that have successfully reduced TAT. Moreover, exploring the influence of external factors, such as healthcare policy changes and technological advancements, on TAT is crucial for understanding the dynamic nature of radiology services.

Future research should take into consideration multicenter studies involving more public and private hospitals in various regions of Palestine, improving the generalizability of the results and enabling more national comparisons of CT scan TAT and related factors.

In addition, qualitative assessments, such as interviews or focus groups with radiographers, radiologists, physicians, patients, and radiographers, may provide more specifics on operational inefficiencies, workflow difficulties, and communication barriers than would be obtained from quantitative analysis only.

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Appendices

Appendix 1: IRB Approval Letter

Arab American University
Institutional Review Board - Ramallah

الجامعـــة العربيـــة الأمريكيـــة
مجلس اخلاقيات البحث العلمي – رام الله

IRB Approval Letter

Study Title: "Enhancing CT-scan Turnaround Time (TAT) through Workflow Optimization: A Comprehensive Analysis".

Submitted by: Sondos Khaled Fayez Rabay'a

Date received: 8th March 2024

Date reviewed: 18th April 2024

Date approved: 18th April 2024

Your Study titled **"Enhancing CT-scan Turnaround Time (TAT) through Workflow Optimization: A Comprehensive Analysis"** with the code number **"R-2024/A/48/N"** was reviewed by the Arab American University Institutional Review Board - Ramallah and it was approved on the 18th of April 2024.

Sajed Ghawadra, PhD
IRB-R Chairman
Arab American University of Palestine

الجامعة العربية الأمريكية . فلسطين
مجلس اخلاقيات البحث العلمي . رام الله
IRB-R
ARAB AMERICAN UNIVERSITY-PALESTINE
INSTITUTIONAL REVIEW BOARD - RAMALLAH

General Conditions:

1. Valid for 6 months from the date of approval.
2. It is important to inform the IRB-R with any modification of the approved study protocol.
3. The Bord appreciates a copy of the research when accomplished.

رام الله – فلسطين

Tel: 02-294-1999 **E-Email:** IRB-R@aaup.edu **Website:** www.aaup.edu

Appendix 2: Permission Letter from Ar

Arab American University — الجامعــــة العربيـــــة الأمريكيـــة

Faculty of Graduate Studies — كلية الدراسات العليا

2024/5/2

الى من يهمه الأمر

<u>**تسهيل مهمة بحثية**</u>

تحية طيبة وبعد،

تُهديكم كلية الدراسات العُليا في الجامعة العربية الأمريكية أطيب التحيات، وبالإشارة الى الموضوع أعلاه، تشهد كلية الدراسات العُليا في الجامعة أن الطالبة **سندس خالد فايز ربايعه** والتي تحمل الرقم الجامعي 202113060هي طالبة ماجستير في برنامج علوم التصوير الطبقي والرنين المغناطيسي وتعمل على رسالة الماجستير الخاصة بها بعنوان:

" تحسين وقت الاستجابة للتصوير المقطعي المحوسب من خلال تحسين سير العمل: تحليل شامل"، تحت إشراف الدكتور أحمد أبو عرة. نأمل من حضرتكم الإيعاز لمن يلزم لمساعدتها للحصول على المعلومات اللازمة للدراسة، علماً أن المعلومات ستستخدم لغاية البحث فقط وسيتم التعامل معها بغاية السرية، وقد أُعطيت هذه الرسالة بناءً على طلبها.

وتفضلوا بقبول فائق الاحترام

عميد كلية الدراسات العليا

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تقييم وقت الاستجابة للتصوير المقطعي المحوسب والعوامل المرتبطة به في المستشفيات الفلسطينية: تحليل شامل

سندس خالد فايز ربايعه

أسماء لجنة الاشراف:

د. احمد أبو عرة

د. عبد الناصر عاصي

د. حسين المصري

ملخص

مقدمة: أدى الطلب المتزايد على فحوصات التصوير المقطعي المحوسب إلى الضغط على أقسام الأشعة لتحسين سير العمل وتقليل أوقات الاستجابة. تشمل أوقات الاستجابة العملية بأكملها بدءًا من طلب الفحص، وحتى إنهاء التقرير. يعد تحسين وقت الاستجابة عاملاً مهماً في تحسين رضا المرضى وتسهيل سير العمل في المستشفيات. تفحص هذه الدراسة متوسط الوقت المستغرق من طلب التصوير المقطعي المحوسب إلى القبول، ومن الطلب إلى النتيجة، ومن القبول إلى النتيجة في المستشفيات الفلسطينية، وتحدد العوامل المؤثرة في هذه الأوقات.

المنهجية: أُجريت دراسة مقطعية بأثر رجعي، تمت الموافقة عليها من قبل مجلس الهجرة واللاجئين، باستخدام بيانات من 8220 طلب تصوير مقطعي محوسب من ثلاثة مستشفيات فلسطينية. اُسْتُخْدِمت التحليلات الإحصائية الوصفية وغير والبارومترية لاستكشاف العلاقة بين أوقات الاستجابة ومتغيرات مثل نوع الفحص، ويوم الفحص والمناوبة، واستخدام وسائط التباين.

النتائج: كان متوسط الوقت المستغرق من الطلب إلى القبول، ومن الطلب إلى النتيجة، ومن القبول إلى النتيجة 78 و837 و462 دقيقة على التوالي. كشفت الدراسة عن وجود اختلافات كبيرة في الوقت المستغرق في جميع المستشفيات التي خضعت للدراسة. كان الوقت المستغرق في مستشفى ابن سينا التخصصي أقصر بوجهٍ عام مقارنةً بالمستشفى الاستشاري العربي والمستشفى العربي التخصصي. كانت أوقات الاستجابة متفاوتة إلى حد بعيد بناءً على نوبات العمل ويوم العمل ونوع المقابلة واستخدام وسائط التباين. كان لفحوصات التصوير المقطعي المحوسب للمرضى الخارجيين أوقات تحول أقصر من فحوصات المرضى الداخليين أو فحوصات الطوارئ، وأدى استخدام وسائط التباين إلى زيادة أوقات الاستجابة، وأظهرت الفحوصات التي أجريت خلال عطلة نهاية الأسبوع زيادة في أوقات التحول.

الاستنتاج: تُعد الأوقات المستغرقة في إجراء فحوصات التصوير المقطعي المحوسب من المؤشرات المهمة لإنتاجية قسم الأشعة في المستشفى. وتتأثر أوقات التحول إلى حد بعيد بعدة عوامل بما في ذلك يوم الطلب، ونوبة العمل، ومصدر الطلب، واستخدام وسائط التباين. ولتحسين كفاءة التصوير المقطعي المحوسب ونتائج المرضى، يجب أن تركز الإستراتيجيات على تحسين التوظيف، وتبسيط عمليات القسم، ومعالجة العوامل المتعلقة بالمريض.

الكلمات المفتاحية: التصوير المقطعي المحوسب، وقت الاستجابة، نوبة العمل، وسائط التباين، سير عمل الأشعة.