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Technologists' Competency in Computed Tomography (CT) Practice in Salmaniya Medical Complex: A Self-Based Assessment

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Abstract

Background: Competency in computed tomography (CT) practice is essential to ensure high-quality imaging and minimize radiation dose. In Salmaniya Medical Complex (SMC), differences in educational and training backgrounds among its CT technologists have raised concerns about the standardization of CT practice.

Aim: To assess the competency level of CT technologists in SMC and identify factors influencing their performance.

Methods: A cross-sectional study was conducted among 33 CT technologists at SMC using a self-assessment questionnaire. The study examined competency levels across three domains: patient care and communication, radiation safety and protection, and image production and optimization. Statistical analysis was performed using descriptive and non-parametric tests, including Wilcoxon Signed-Rank, Mann-Whitney U, and Kruskal-Wallis tests.

Result: Competency scores across all domains were significantly below the satisfactory threshold ($p < 0.05$). Radiation safety scored the lowest, while patient care and communication scored the highest. Demographic factors, including education and years of experience, showed no significant influence on competency. Interest in continuous professional development was positively associated with competency levels.

Conclusion: The findings highlight a critical need for targeted training programs to address competency gaps in CT practice. In addition, a national postgraduate program and mandatory licensing could ensure consistent competency levels among technologists in Bahrain.

Key words: Competency, CT technologist, self-assessment, patient care, communication, radiation safety, radiation protection, image production, optimization.

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Definition of Terms and Abbreviations

American Registry of Radiologic Technologists (ARRT): It is an organization that grants credentials to professionals in the fields of radiation therapy and medical imaging to advance their practice and careers. Offering credentials in radiation therapy, radiography, sonography, computed tomography, and nuclear medicine technology.

Competency: It is having the skills, knowledge and attitude to do something well enough to meet a basic standard.

Computed Tomography (CT): Is a diagnostic imaging technique that creates cross-sectional images of the inside of the body by combining computer technology and X-rays. It visualizes various aspects of the body, including the bones, muscles, fat, organs, and blood arteries, in great detail.

Optimization: The process of improving image quality while minimizing radiation exposure to the patients. It involves adjusting technical parameters and using advanced imaging techniques to achieve the desired diagnostic outcomes with the lowest risks possible.

Patient Care: It is the comprehensive support provided to patients undergoing imaging procedures to ensure safety and comfort. This includes effective communication, patient management and safe practice throughout the imaging procedures.

Radiation Safety: A set of practices and protocols designed to protect patients, healthcare workers, and the public from ionizing radiation during medical imaging or treatment procedures. It can be achieved by proper shielding, monitoring radiation doses, and adhering to established safety standards.

Salmaniya Medical Complex (SMC): It is Bahrain's largest public healthcare facilities, offering a variety of medical services where medical imaging services, including CT scans, are performed.

Self-Assessment: A reflective process where individuals evaluate their own skills, knowledge, or competencies to identify areas of strength and improvement. It is an important aspect in reviewing performance, receiving feedback, and professional development.

Chapter one (1); Introduction and Background

1.1 Introduction and background:

Computed Tomography (CT) was invented by Godfrey Hounsfield and Allan Cormack in the early 1970s, leading to their 1979 Nobel Prize in Physiology or Medicine. CT revolutionized the field of diagnostic imaging by enhancing the limited capabilities of traditional X-ray examinations. X-rays provide two-dimensional radiographers of internal structures by passing radiation through the body part of interest. However, CT utilizes a rotating X-ray source and sensitive detectors to create a three-dimensional view of the organs by producing multiple detailed cross-sectional images. This process provides a greater depth perception and eliminates the overlapping of structures to improve the complications often encountered in X-ray interpretation, (The Noble Prize, 1979). Therefore, CT has become an indispensable tool in the diagnosis, treatment planning, and monitoring of various medical conditions. It replaced many outdated procedures such as Intravenous Urography (IVU) and gastrointestinal fluoroscopic examinations, (Dervishi et al., 2022). The demand for CT imaging is growing because it provides detailed images in seconds and has different applications. For example, it is commonly used in the diagnosis of bone abnormalities such as trauma, fractures, tumors, and infections. CT holds an important advantage in monitoring the progress and treatment of cancer, heart diseases, lung nodules, and liver masses. Furthermore, it can guide procedures such as surgeries, biopsies, and radiation therapy. CT scans can help with treatment planning and organ system evaluation for the presence or absence of abnormalities, making them a vital tool in modern medicine (Mayo Clinic, 2022). However, CT delivers a significant radiation dose despite its importance. It uses a higher dose of radiation compared to traditional X-ray. The effective dosage of traditional X-rays is about 0.1 mSv to 10 mSv depending on the type of X-ray examination. For example, a chest X-ray provides about 0.1 mSv, but a dental X-ray exposes patients to about 0.005 mSv. CT scans tend to have larger doses because their imaging requires more detail. The effective dose for a CT scan is between 2 mSv to 20 mSv or even higher depending on the type of scan and the area of the body studied, (American College of Radiology, 2022). In general, producing an optimized image quality with the least achievable dose is the primary role of CT technologists, (Inoue, 2023). The American Registry of Radiologic Technologists (ARRT), A leading credentialing organization that offers certification in a wide range of radiologic disciplines, performed a thorough analysis to determine the key roles of the CT technologist.

According to the results, CT technologists must be competent in safety, patient care, image production, and procedures to ensure optimal CT practice. These competencies are built on knowledge and skills acquired from educational programs and practical training. Therefore, the continuous education and evaluation of technologists practicing CT is important worldwide. In Bahrain, Radiological Technologists complete a comprehensive four-year undergraduate program encompassing different imaging modalities. The previous program used to be a two-year diploma program that qualified graduates as radiographers. Both graduates can practice CT in Bahrain and will be referred to as technologists in this study. However, undergraduate educational programs may not prepare technologists for their role in practicing CT competently. The rationale for this study lies in the lack of standardization in CT practice in Bahrain, largely due to variations in CT technologists' educational programs and the absence of specialized postgraduate education in CT imaging. This research examines self-reported competency among technologists practicing computed tomography (CT) at Salmaniya Medical Complex. It will identify the gaps and limitations of the current CT practice based on technologists' perception to encourage and guide future educational programs in Bahrain.

1.2 Problem Statement:

There is a potential gap in the competency levels of technologists performing CT examinations in Bahrain. This gap may arise from inconsistent standardization of the requirements to practice CT. For example, different educational backgrounds with or without CT training experiences are practicing currently in SMC. This can cause a risk of suboptimal image quality, diagnostic inaccuracies, and compromised patient care. Therefore, assessing the competency levels of technologists performing CT examinations is needed. This study will utilize the self- assessment approach to get a comprehensive understanding of this issue using technologists' preceptive.

1.3 Significance of Problem:

CT is a vital diagnostic tool utilized by different clinical facilities in Bahrain. However, its effectiveness depends on the technologist's competency. Therefore, measuring technologists' self-perceived competency in SMC, Bahrain's largest medical facility, is crucial to identify potential gaps in practice. Addressing these deficiencies can aid with the development of targeted training programs and continuing education initiatives to ultimately improve the CT practice in Bahrain.

1.4 Research Objectives:

General objectives:

This study aims to evaluate the self-reported competency of CT technologists in SMC to identify areas for improvement and enhance CT practice.

Specific Objectives:

1. To evaluate the overall self-reported competency levels of CT technologists in SMC.
2. To categorize the strengths and weaknesses in CT practice as identified by CT technologists in SMC.
3. To identify demographic factors affecting self-assessed competency of CT technologists in SMC.
4. To assess the impact of CPD, training and satisfaction on the overall self-reported competency of CT technologists in SMC.
5. To explore the barriers to competency development of CT practice in SMC.

1.5 Research Question:

1. What is the current self-reported competency in patient care and communication among CT technologists in SMC?
2. What is the current self-reported competency in safety and radiation protection among CT technologists in SMC?
3. What is the current self-reported competency in Image production and optimization among CT technologists in SMC?
4. What is the current level of the overall self-assessed competency among CT technologists in SMC?
5. What are the common areas of strength and weakness identified by SMC CT technologists in their practice?
6. What demographic factors influence the overall self-assessed competency of SMC CT technologists?

7. How does continuous professional development (CPD), training and satisfaction impact self-assessed competency levels?

1.6 Hypothesis:

Null Hypothesis: Technologists practicing CT in SMC are not significantly lacking competency based on self-assessment.

Alternate Hypothesis: Technologists practicing CT in SMC are significantly lacking competency based on self-assessment.

1.7 Organization of the Study:

Chapter one (1); Introduction and Background

This chapter will introduce the essential role of computed tomography (CT) in modern medical diagnostics. It will focus on the advantages of CT scans and the associated radiation risks. It will also discuss the factors influencing radiation dose and the importance of optimizing image quality while minimizing exposure.

It will highlight the need for competent radiologic technologists to master various exposure parameters for individual cases. Moreover, it will cover the research aim, question, problem, hypothesis, and objectives.

Chapter two (2); Literature Review

This chapter will discuss the importance and growth of CT in healthcare. It will emphasize the role of CT technologists by highlighting the fundamental competencies required to practice CT. In addition, this chapter will identify the gaps and limitations in the published literature to lay the foundation for this study.

Chapter three (3); Research Methodology and Data Collection

This section explains the structured process employed by the researchers to collect, analyze, and interpret data. It addresses the study's design, sampling procedure, data collection, and analysis.

Chapter four (4); Result and discussion

In this chapter, the final result will be explained, and the result of the disturbed survey will be discussed. Moreover, it will explain the outcomes reached and show knowledge and skills gaps among CT technologists in Bahrain. Also, it will clarify if the hypothesis is accepted or rejected. The goal is to provide previews into the current state of CT technologists' practice in Bahrain.

Chapter five (5); Conclusion and Recommendations, Limitations

This chapter will summarize the whole study, discuss the limitations, and propose tailored recommendations to improve CT programs in SMC. These recommendations will include suggestions for curriculum improvements and implementing competency assessment tools. The final goal is to reach these findings and recommendations to relevant stakeholders to improve the field of radiologic technology in SMC.

1.8 Chapter Summary:

Computed Tomography (CT) is a vital medical imaging technique that assists physicians in diagnosing illnesses, injuries, and abnormalities. It plays a crucial role in planning and guiding therapeutic procedures and monitoring the effectiveness of medical treatments. As CT technology becomes increasingly used in healthcare, the competency of CT technologists is essential, as they significantly impact patient outcomes. Moreover, when there are gaps in knowledge and skills, various issues can arise, including compromised safety for both patients and technologists, as well as problems with protocols and image quality. However, these issues may be resolved, and CT practice can be improved by funding advanced training programs.

Chapter (2); Literature Review

2.1 Background:

CT is a crucial imaging tool due to its effectiveness in diagnosing critical conditions. However, the CT technologist responsible for operating these machines must possess sufficient Competency to optimize image quality and ensure the safety of both patients and technologists. These competencies will impact the diagnosis and treatment process significantly. The ARRT conducted a comprehensive analysis to identify the responsibilities of CT technologists. The findings indicate that CT technologists must be competent in safety, patient care, communication, image production, and optimization. This ensures the delivery of high-quality imaging while prioritizing patient well-being, minimizing risks, and adhering to professional standards, (American Registry of Radiologic Technologists, 2022). While technologists often demonstrate proficiency in many areas, previous studies usually focus on specific areas of CT practice, potentially leading to gaps in accuracy and comprehensiveness. This literature review discusses the role of CT technologists by highlighting the fundamental competencies required to practice CT. It will identify the gaps and limitations in the published articles to lay the foundation for this study.

2.2 The Role of CT in Modern Healthcare:

Computed Tomography (CT) is a sophisticated diagnostic imaging technique that generates X-rays to create detailed cross-sectional images of an object, enabling accurate representation of internal structures. The principle of CT is based on rotating an X-ray source around an object to capture multiple projections from multiple angles. Algorithms are used to reconstruct these projections into 3D images to visualize features often obscured in traditional X-ray imaging.

There are five main types of CT systems: conventional CT, multi-slice CT, dual-energy CT, spectral CT, and photon-counting CT. The fundamental difference between these types is their slice acquisition capabilities, energy range, and detection method. Conventional CT generates one slice at a time, while other systems can produce multiple slices simultaneously. Moreover, spectral and dual-energy CT use a wide range of energy levels to enhance material differentiation, while photon-counting CT counts individual X-ray photons to improve spatial resolution. The constant development in CT technology requires continuous education to maximize the benefits of its capabilities (Hsieh & Flohr, 2021).

CT is an important technology with many applications in different fields. CT is a non-destructive testing tool used in materials science, biology, geology, and archaeology to examine and analyze complex structures. In the medical field, CT scans have become an indispensable examination in pre-surgical planning, diagnosing, and monitoring different medical conditions (Withers et al., 2021). The United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) periodically conducts a global survey to summarize information on radiation exposure across different populations and regions. The estimated annual total count of CT scans in 2021 is approximately 400 million, an increase of 82 percent compared to the previous survey. The average frequency increased from 34 to 55 CT scans per 1,000 population per year. The importance of CT scans is evident from the significant increase in the number of annual examinations.

However, CT is the largest contributor to the overall collective dose (61.6 percent), while accounting for 9.6 percent of all imaging procedures (United Nations Publications, 2022). In a higher-quality CT scan, the image detail is enhanced but associated with a higher patient dose. As a result, potential radiation damage can manifest as localized heating, structural changes, discoloration, and DNA damage in biological tissues. For an average human, high doses of radiation, above 200 mSv, can slightly increase the risk of cancer. Medical CT scans usually involve lower doses of up to 20 mSv approximately. While higher doses of X-rays potentially cause more damage, the energy of radiation affects its interaction with materials. High-energy X-rays can be less damaging because they penetrate materials without causing as much harmful interaction with cells (Withers et al., 2021).

2.3 Core Competencies for CT Technologists:

The origin of competency can be historically delineated to approximately 3,000 years ago when the Chinese civil service recruited personnel through skill and knowledge assessments, diverging from reliance on supervisors' recommendations (Ayoo, Wilcox, LaVelle, Podems, & Barrington, 2020). In this study, the term competency refers to having the skills and knowledge to achieve optimization in CT practice. In 2021, the ARRT conducted a comprehensive practice analysis to identify the primary responsibilities of CT technologists. According to the results, CT technologists should be competent in in-patient care, communication, safety, image production, and optimization (ARRT, 2022).

2.3.1 Patient Care and Communication:

CT technologists are responsible for operating advanced imaging equipment and playing a crucial role in patient care through effective communication skills. They need to possess effective communication with both patients and colleagues and must be able to communicate complex medical information clearly and empathetically and work within teams to coordinate and optimize all aspects of patient care. They often serve as the first point of contact for imaging studies, (Rockall, Justich, Helbich, & Vilgrain, 2022).

Technologists should use effective communication techniques like plain language, visual aids, and analogies, and seek patient feedback for better understanding. Active listening and support can also help reduce patient anxiety, which often worsens due to uncertainties related to CT procedures (Rockall, et al., 2022). In most instances, technologists often administer contrast agents, requiring great expertise to avoid complications. Improper administration or patient inability to monitor adverse reactions can lead to serious issues. When an adverse event, such as a contrast response or other problem occurs, more caution should be used. An early and open discussion will comfort patients, gain their trust, and encourage them to work as a team to address any issues that arise. These techniques help bridge the gap between complex medical terminologies and patient's health literacy, building trust and cooperation (Rockall et al., 2022).

Comprehensive training programs are crucial for technologists to ensure patient safety and comfort during CT imaging procedures. These programs focus on technical aspects, patient relations, and emotional support. Better-trained technologists can manage different patient demographics with reduced risks, making the experience smoother and less stressful for patients. These competencies directly influence the quality of care provided (Rockall et al., 2022).

2.3.2 Radiation Safety and Protection:

Radiation protection refers to the protection of people and the environment from the harmful effects of ionizing radiation exposure. The use of ionizing radiation in diagnostic radiography offers both benefits and potential risks for patients (Fiagbedzi, Gorleku, Nyarko, Asare, & Ackah Ndede, 2022).

The main principles of radiation protection include justification, optimization (known as ALARA, or "as low as reasonably achievable"), and dose limitation. Radiation protection guidelines are centered on three main strategies: maintaining distance, minimizing exposure time, and using shielding for external irradiation (Khamtuikrua & Suksompong, 2020). Several specific factors impact radiation dose, such as procedure complexity, equipment settings, and technologist techniques. Additionally, the design features of CT scanners, including slice collimation and advanced technologies like iterative reconstruction, have significantly enhanced dose reduction while preserving essential image quality and anatomical detail. Modern automatic exposure control (AEC) systems, such as real-time 3D dose modulation, are crucial in ensuring consistent image quality by dynamically adjusting exposure parameters during imaging procedures. Furthermore, dynamic Z-axis tracking minimizes unnecessary radiation during helical scanning by automatically adjusting the X-ray beam position, thereby reducing unused radiation at the start and end of a scan.

Establishing quality assurance (QA) programs within radiology is essential for maintaining the reliability, safety, and effectiveness of diagnostic imaging procedures. These QA programs encompass various aspects of imaging, including equipment checks, pre-procedural preparations, and routine quality control assessments. Their primary objective is to provide adequate clinical diagnostic information while minimizing patient exposure to radiation, in line with the ALARA principle (Dudhe, Mishra, Parihar, Nimodia, & Kumari, 2024). Research has revealed significant differences in radiation dose across different sites and countries, even for similarly sized patients. These variations may arise from differences in equipment and scanning protocols used for modalities involving ionizing radiation (Smith-Bindman et al., 2019). Such discrepancies in radiation dose may indicate a lack of knowledge or skills in adjusting imaging protocols, highlighting the importance of technologists possessing comprehensive knowledge of dose optimization during examinations (Fiagbedzi et al., 2022).

Repeated radiation exposure increases the risk of genetic mutations and chromosomal aberrations in males, females, and fetuses if thresholds are surpassed. Several studies have estimated the risk of hematological malignancies associated with CT scan radiation exposure in children and young adults, conducted through large-scale national cohort and case-control studies.

While many individual studies and a recent meta-analysis suggest an increased risk of leukemia linked to repeated CT scans (Bosch et al., 2023), the absence of optimization criteria for radiology staff has exacerbated the incidence of ionizing radiation exposure, potentially impacting both patients and radiology personnel. This rising incidence of adverse effects from ionizing radiation may stem from insufficient knowledge among radiology staff about protective measures and practices.

2.3.3 Image Production and Optimization:

Producing an optimal image for an accurate diagnosis is the goal of any imaging modality. According to the (ARRT) image production depends on several factors such as image parameters, post-proccing, and artifact recognition. Technologists must possess the necessary skills and knowledge to achieve this goal. Precise patient centering is critical in CT because misalignment could adversely impact image quality and dosage. According to research, educational training reduced the mean misalignment for patient centering from −1.96 to 1.14 cm (DeWeese, Griglock, Moody, Mehlberg, & Winters, 2022). A study evaluated technological interns' competency in patient positioning, image acquisition, and processing. In patient positioning the score is (2.4/5) and it is indicated low competency and a need for improvement (Florentino et al., 2018). Moreover, AI-based positioning demonstrated superior positioning accuracy with reduced off-center distance, resulting in a 12 percent reduction in radiation dosage and enhanced image quality for CT imaging compared to manual (Kundu, Nayak, Kadavigere, Pendem, & Priyanka, 2024). Image acquisition and processing is an important step in CT scans. Interns' competency in image acquisition/processing is (2.3/5), The score showed low competence (Florentino et al., 2018). In general, CT technologists have a moderate understanding of dose and protocol parameters. However, there is a significant lack of factors affecting noise, spatial, and contrast resolution knowledge and skills (Alhorani et al., 2024). Improvements in technologist's scan parameters manipulation are necessary to optimize image quality and dose (Kazemi, Hajimiri, Saghatchi, Molazadeh, & Rezaeejam, 2023). Therefore, competency in image production techniques is a fundamental block in the optimization process.

The most requested CT procedures are brain, abdominal, and chest scans (Abdulkadir et al., 2021,). Each specific procedure mandates unique parameters and protocols depending on the body part of interest and the reason for the examination.

Generally, technologists need a comprehensive understanding of patient factors such as human anatomy, physiology, pathology, and contrast media, to perform any CT procedure competently (ARRT, 2022). As a result, the ICRP established Diagnostic Reference Levels (DRLs). It is a benchmark established to guide the optimization of radiation exposure with detailed information for each CT procedure customized for different body habits. DRLs are essential for identifying abnormal radiation doses and optimizing CT scans. Balancing image quality and patient exposure requires a combination of technical expertise and knowledge of DRLs. All in all, it is the responsibility of the technologist to customize these factors for each unique case in a CT procedure and ensure optimization.

2.3.4 Factors Influencing CT Technologist Competency

Several factors influence the competency of CT technologists. Understanding these factors is crucial in developing strategies for optimizing practice in CT technology. These factors can be categorized as follows:

A. Demographic Characteristics

Demographic factors such as gender and age have been examined in research on CT technologist competency. According to (Abuzaid, Elshami, Noorajan, Khayal, & Sulieman, 2020), no significant gender-based differences were found in knowledge scores among CT technologists, suggesting that both male and female technologists can achieve similar competency levels with the right training and experience. Therefore, gender does not appear to limit the acquisition of professional skills or advanced knowledge in the CT field. Age, on the other hand, may not always directly correlate with competency, though it often intersects with work experience. A study by (Alhorani et al. ,2024) found that older technologists, particularly those aged 36-45 and above, demonstrated higher knowledge scores. This suggests that experience may enhance older technologists' ability to handle complex tasks, while younger technologists are often more adaptable to mastering new technologies.

B. Education and training

Education level and training programs are critical in shaping CT technologists' skills. Technologists with advanced degrees or specialized CT training typically demonstrate a higher level of competency in areas such as image production, radiation safety, and patient care (Alhorani et al., 2024). Similarly, (Chaka, Adamson, Foster, & Snaith, 2022) found that postgraduate education significantly enhances radiographers' abilities in technology and image interpretation. Prior to these studies, radiographers often displayed limited knowledge of CT technology; however, postgraduate training enabled them to achieve substantial expertise. These findings underscore the importance of continuous education and retraining, ensuring that technologists remain current with advancements in technology, regulatory standards, and patient care practices.

C. Professional Experience

Experience is a critical factor in the competency of CT technologists. As technologists gain more years of practice, they build expertise, confidence, and improved capabilities for handling complex cases. Research consistently shows that experienced technologists perform better in knowledge assessments; for instance, (Mallinson, Hardy, & Scally. ,2024) found that those with over 15 years of experience scored higher than their less experienced peers. This evidence suggests that years of practice help technologists refine their skills, foster professional confidence, and efficiently manage complex procedures.

D. Institutional and Regional Variations

Institutional policies and regional factors significantly impact the competency of CT technologists. Access to advanced technology, training resources, and institutional support can vary widely between regions, with disparities in regulatory standards, radiation safety protocols, and continuing education opportunities often leading to differing competency levels. A study by (Alhorani et al., 2024) comparing technologists in Jordan, UAE, Ireland, and Malaysia revealed varying levels of understanding of dose parameters and image quality, underscoring the influence of institutional and regional factors. Standardizing educational programs and regulatory practices could help mitigate these disparities and promote consistent competency across regions.

2.4 Limitations of Existing Research:

In examining the existing literature on CT technologists' competency, several studies present limitations that impact the generalizability and comprehensiveness of their findings. For instance, the study by (Abuzaid et al., 2020) was geographically restricted to the UAE, making it difficult to generalize the findings to other Gulf regions, such as Bahrain, due to differences in healthcare systems and training environments. Future research should address this limitation to develop a more holistic understanding of CT technologists' competency, especially in diverse regions like Bahrain.

Furthermore, the study by (Rockall et al.,2022) analyzed patient feedback data but did not account for potential biases, such as arbitrary feedback and non-communication-related factors like wait times or individual health outcomes, which may reduce the accuracy of the data. In addition, (Smith-Bindman et al., 2019) study faced challenges in its scope due to the limited number of participating institutions outside the U.S.; thus, its findings may not truly represent other countries. Also, technical factors related to dose such as the use of iterative reconstruction software were overlooked, though their impact is considered modest. The convenience sampling of institutions using radiometric dose monitoring software may not capture the broader picture, highlighting a need for further diversity in CT registry sampling.

The study by (Alhorani et al., 2024) used a questionnaire that focused solely on knowledge relating to MIP (Maximum Intensity Projection), excluding important areas like radiobiology and radiation protection, which impacts the validity of the results. The voluntary nature of the questionnaire limited the sample's representativeness and possibly introduced bias. Additionally, environmental factors at the time of questionnaire completion could have affected responses, introducing some uncertainty into the data.

Moreover, the study by (Mallinson et al., 2024) acknowledged limitations, including a small expert panel size and a regional focus that restricted generalizability. Another limitation was the lack of consideration for technical aspects, such as iterative reconstruction software, which might impact the study's completeness.

Finally, in the studies by (Fiagbedzi et al., 2022) and (Abuzaid, Elshami, Noorajan, Khayal, & Sulieman, 2020), the small sample sizes limited the statistical power of the findings, making it challenging to confidently extend the results to a broader population. Such limitations underscore the need for broader, more inclusive research to better understand CT and radiologic technologists' competencies across different regions and contexts. By addressing these limitations and implementing best practices, the field can improve radiation safety protocols, advocate for standardized recommendations, and ultimately enhance patient-centered care through optimized CT imaging.

2.5 Conclusion:

This literature review emphasizes the critical role of competency among CT technologists in delivering high-quality patient care and ensuring diagnostic accuracy. Competency involves essential aspects such as patient care, communication, radiation safety, image production, and various factors influencing competency. The findings reveal that CT technologists play an integral role in achieving optimal patient outcomes while adhering to the ALARA principle, which aims to minimize radiation exposure. Moreover, Comprehensive training programs that focus on communication skills, technical expertise, and emotional support are crucial for enhancing patient safety and comfort, eventually leading to improved quality of care (Rockall et al., 2022). The literature also highlights the importance of radiation safety, indicating significant variations in radiation doses administered across different institutions and regions. As the use of CT technology continues to grow, technologists need to have a solid understanding of dose optimization protocols to protect both patients and healthcare providers from the risks associated with ionizing radiation (Fiagbedzi et al., 2022). Furthermore, the review points out that proficiency in image production is fundamental to CT practice. Technologists must demonstrate skills in patient positioning, understanding image parameters, and utilizing advanced imaging technologies effectively. Evidence of low competency in these areas underscores the need for targeted training programs that improve the skills necessary for optimal image acquisition and processing (Alhorani et al., 2024) and (Kundu et al., 2024). Finally, the review identifies demographic factors, education, professional experience, and institutional and regional variations as significant influences on CT technologist competency. Understanding these factors is vital for developing strategies to elevate practice standards in CT technology (Abuzaid et al., 2020; Mallinson et al., 2024).

In summary, the competency of CT technologists is a complex construct that integrates knowledge, technical skills, and effective patient communication. Addressing gaps through specialized education and ongoing professional development is essential to uphold best practices and ensure optimal patient outcomes.

2.6 Chapter summary:

This literature review chapter provides a detailed analysis of the essential aspects of clinical competency in radiologic technology, focusing specifically on CT practice. Crucial themes identified in the reviewed research include effective communication strategies with patients, the importance of safety protocols for managing radiation exposure, advancements in imaging technology, and the role of postgraduate education and continuous professional development (CPD) in upholding high standards of practice. Effective communication between CT technologists and patients fosters cooperation and enhances diagnostic accuracy, while technological advancements significantly impact radiation safety, emphasizing the need for technologists to stay informed about emerging techniques and protocols. Additionally, postgraduate education and continuous professional development (CPD) are crucial for deepening CT-specific expertise and sustaining best practices. The chapter explores the interconnected aspects of clinical competency, illustrating how expertise in patient care, adherence to safety standards, and technical proficiency collectively enhance CT practice. Research suggests that experience and specialized training affect self-reported competency, identifying areas that require targeted improvement. These insights align with the study's objectives to evaluate the competency levels of CT technologists, categorize their strengths and weaknesses, examine demographic impacts, and assess the roles of continuous professional development (CPD) and job satisfaction in enhancing competency. Furthermore, the review identifies barriers to competency growth, promoting a culture of ongoing learning and professional development. Ultimately, it underscores the importance of a competency-based approach in CT practice and lays a strong foundation for investigating the competency development of CT technologists at SMC.

Chapter (3); Research Methodology

3.1 Introduction:

This study aims to evaluate the self-reported competency of CT technologists in Salmaniya Medical Complex (SMC) to identify areas for improvement and enhance CT practice. A systematic approach will be employed, including outlining the study design, sampling method, data collection, and analysis techniques. The study design section will highlight the comprehensive framework of this study. Following that, the sampling procedure section will cover the target population, sample size, and sampling process applied in this study, including the selection of inclusion and exclusion criteria. Moreover, the data collection section will provide a detailed description of the questionnaire design, validation process, and scoring system. It will also discuss the techniques used for data collection in this study. Furthermore, the statistical analysis strategy for answering these research questions will be thoroughly explained. The research limitations and ethical considerations will be addressed to ensure the integrity of the study.

3.2 Study Design:

This study investigates the competency of SMC technologists in CT practice using an observational cross-sectional approach. This design allows for data collection at a single point in time, making it efficient for assessing current competency levels among technologists. The strength of the cross-sectional approach lies in providing snapshots of current competency, capturing a wide range of relevant data without requiring the extended time commitment of longitudinal designs, thus facilitating a comprehensive assessment aligned with the study evaluation goals. The population will include all technologists practicing CT in SMC, utilizing a census or complete enumeration of the entire target population. Data will be collected using an online self-assessment questionnaire. Data analysis will be conducted using Microsoft Excel and R programming languages to perform descriptive and inferential analysis. Ethical considerations such as informed consent, privacy, and confidentiality will be prioritized. Potential limitations include biases associated with self-reported data. The project timeline is set for three months with no budget requirements. These results will provide significant insights into the current state of CT practice at SMC. It will identify the gaps of CT practice and inform the development of future CT training programs.

3.3 Population and Sampling Design:

3.3.1 Sampling Design:

The sampling for this study focuses on assessing the competency of CT technologists at the SMC facility. The target population is 33 technologists currently capable of practicing CT at the radiology department. This study will utilize census or complete enumeration due to the miniscule population size. Census is the process of collecting data from every member of the target population. To ensure a focused assessment, the study includes only certified technologists actively employed in the department, excluding any CT trainees. A census method is used to get comprehensive coverage of all technologists within this setting without sampling. In other words, this study will encompass the full population of CT technologists at SMC, which is 33 personnel. Data collection will be conducted through a secure, online self-assessment questionnaire, enabling participants to confidentially evaluate their competency levels. Given the relatively small population size, conducting a census is a feasible and practical approach to data collection. This method collects data from every individual in the population, the study eliminates potential sampling biases. By including all members, the study can achieve a higher level of accuracy and credibility of the findings.

3.3.2 Inclusion Criteria:

This study targets SMC technologists practicing CT because they are responsible for their practice and the management of trainees or students' practices. Therefore, only employed technologists practicing CT at SMC are eligible to participate in the study including:

- Different levels of education, from diploma certificates to the highest degrees available will be included.
- All job titles (e.g., radiologic technician, radiologic technologist, senior radiologic technologist).
- Radiology staff who occasionally perform CT, such as during staff shortages.

In addition, the pilot study participants will be included in the study because the same questionnaire will be implemented.

3.3.3 Exclusion Criteria:

- Technologists who do not practice CT as part of their job responsibilities at SMC.

3.4 Data collection instrument (tools):

3.4.1 Questionnaire Content and Structure:

The questionnaire is designed to align with the research objectives and research questions. It is inspired by the "Task Inventory for Computed Tomography" by the American Registry of Radiologic Technologists (ARRT). In 2021, the ARRT surveyed a large national sample of CT technologists to identify their responsibilities. According to the results, all CT technologists should be competent in-patient care, safety and image production applied in any CT procedures (ARRT, 2022). In this study, the questionnaire aims to measure the level of self-reported competency of SMC technologist practicing CT. It highlights the effect of demographic, occupational and development variation on competency. This questionnaire consists of four sections:

1. Informed Consent: The informed consent will be obtained at the beginning of the questionnaire. It will outline the purpose of the research, what participation entails, and any potential risks. Ensuring the participants anonymous, confidentiality and free will.

2. Demographic and Occupational Data: This section will collect background information on participants, including gender, educational qualifications, years of experience and participation in relevant training programs. This section provides a foundational understanding of the participants' context within the field of CT technology.

3. Sefl-Assessed Competency: It consists of 10 questions where participants will rate their competency in different aspects of CT practice on a Likert scale ranging from strongly disagree, disagree, neutral, agree, strongly agree. The questions focus on three main areas: patient care and communication, radiation safety and production, and image production and optimization.

In the First question, the participants will evaluate their overall competency in CT practice. From questions two up to four, the participants will evaluate their competency in different areas of patient care and communication. For example, patient assessment, preparation, management, effective communication, contrast agent administration and adverse reactions control. In questions five to seven, the participants will report their competency in various aspects of radiation safety and production. Focusing on radiation protection, DRLs, infection control techniques, adjustment of image parameters, and the ALARA principle. In the last three questions, the participants will assess their competency in the process of image production and optimization. Including patient positioning, centering techniques, knowledge of CT physics, image acquisition, processing and interpretation.

4. Competency Development Assessment: It includes questions from 11 to 13. The participants will be asked about different competency growth factors using yes or no questions. The questions focus on training adequacy, interest in professional development, and satisfaction with current practice.

3.4.2 Scoring System:

Questions regarding self-assessed competency from two to ten will be weighed equally with each choice on the Likert scale corresponding to a specific score. Strongly disagree or no competency equals zero points, disagree or poor competency equals one point, neutral or intermediate competent equals two points, agree or modest competency equals three points and strongly agree or Absolute competent equals four points. The points from questions two to four indicate the participant's competency score in patient care and communication, while points from questions four to six reflect competency score in safety and radiation protection. Also, the points of questions seven to nine reflected the participant competency score in image production and optimization. Additionally, the overall competency score will be determined by combining the sum of points from questions two to 10. All the scores will be calculated out of four to ease comparison.

3.5 Data collection procedure:

The data for this study will be collected through an online self-assessment questionnaire. A rigorous process is employed to establish the questionnaire's validity and reliability. This involves an expert review by radiologic technology program lecturers from the College of Health Science to refine the questionnaire and ensure clarity and relevance.

It is also followed by pilot testing with two technologists representing five percent of the target population. In addition, the questionnaire was tested using Cronbach's alpha psychometric analysis to verify its internal reliability. Cronbach's alpha analysis yielded a coefficient of 0.9, indicating excellent internal consistency among the questionnaire items. This result suggests that the questionnaire is highly reliable. A Cronbach's alpha test value generally above 0.7 is considered acceptable, with higher values indicating greater reliability. The pilot study participants responded positively to the questionnaire's content and clarity. Therefore, no changes will be made to the survey questions. All eligible CT technologists at SMC will be invited to participate, and informed consent will be obtained. Consent will be obtained electronically, ensuring participants understand the study's purpose, procedures, potential risks, and benefits. To maintain confidentiality, participant responses will be anonymized, and data will be securely stored on a password-protected server. Anonymization is achieved by removing any personally identifiable information, such as names or employee IDs. Participants will receive a unique link to access the secure Microsoft Forms platform where they can complete the questionnaire. The collected data will be thoroughly cleaned, validated, and analyzed to identify areas of strength and weakness in the current CT practice in SMC.

3.6 Statistical analysis:

The data collected will be analyzed using Microsoft Excel software and the R statistical programming language. This statistical analysis will address the research questions through a range of descriptive and inferential statistical tests with a significance level of 95% and a p-value threshold of <0.05. Frequency tables will be used to summarize demographic and occupational data. To assess current self-reported competency in specific areas—such as patient care and communication, safety and radiation protection, or image production and optimization —we will calculate the means and standard deviations of scores from the relevant questions. Then, one sample Wilcoxon signed-rank test will be conducted to determine if the medians significantly differ from the predetermined competency threshold (a score of four). The scores of questions one and overall competency score— derived from the sum of scores for questions two to 10—will also be analyzed using means, standard deviations, and one sample Wilcoxon signed-rank test to compare the results with the predetermined competency threshold. To identify common strengths and weaknesses, frequency distributions and percentages of responses for each competency question will be analyzed. In addition, to explore differences in overall self-assessed competency scores based on demographic and occupational factors—such as gender, education level, and years of experience—the Mann-Whitney U test and Kruskal-Wallis statistical tests will be used depending on the data. In addition, Mann-Whitney U test will be used to explore relationships between continuous professional development, training adequacy, satisfaction levels, and overall competency. Data visualization techniques such as boxplots, density plot, and bar charts will be used to present the data in a clear and comprehensible manner. All in all, we aim to provide a comprehensive understanding of self-reported competencies among CT technologists at SMC. Exploring the influence of demographic and professional development factors on competency levels will highlight strengths and weaknesses and enhance CT practice.

Table 3.1: The following table summarizes each research question with the corresponding statistical tests that will be used to deduce the results and findings:

Research Question	Statistical Tests
What is the current self-reported competency in patient care and communication among CT technologists in SMC?	**Mean, standard deviation and one sample Wilcoxon signed-rank test of scores from questions two to four.**
What is the current self-reported competency in safety and radiation protection among CT technologists in SMC?	**Mean, standard deviation and one sample Wilcoxon signed-rank test of scores from questions five to seven.**
What is the current self-reported competency in Image production and optimization among CT technologists in SMC?	**Mean, standard deviation and one sample Wilcoxon signed-rank test of scores from questions eight to 10.**
What is the current level of the overall self-assessed competency among CT technologists in SMC?	**Mean, standard deviation and one sample Wilcoxon signed-rank test of scores from questions two to 10.**

Do the participants' general perception scores differ from the overall self-assessed competency scores?	**One sample Wilcoxon signed-rank test of scores from question one and Wilcoxon signed-rank test (tow-tailed) between scores from question one and Total competency scores from questions two to 10.**
What are the common areas of strength and weakness identified by SMC CT technologists in their practice?	**Frequency distributions and percentages for each question.**
What demographic factors influence the overall self-assessed competency of SMC CT technologists?	**Mann-Whitney U or Kruskal-Wallis statistical test depending on the data.**
How does continuous professional development (CPD), training and satisfaction impact self-assessed competency levels?	**Mean of ranks, sum of ranks and Mann-Whitney U statistical test**

3.7 Ethical considerations:

Over the course of this study, specific ethical guidelines will be followed to protect the participants' rights and well-being. During the survey, the first part of the digital questionnaire will provide a concise synopsis of the study and the informed consent. The synopsis will provide the participants with a brief description of the study's purpose, procedures, potential risks and benefits. Furthermore, the consent form will ensure the participant's confidentiality, anonymity, privacy and voluntarily participation. All data collected from participants will be kept confidential and stored securely. Participant identity and personal information will be anonymized and accessed only by authorized personnel. Voluntary consent will be obtained before participating. Moreover, the participants' concerns and questions will be addressed immediately. They have the right to withdraw from this study at any time without facing any consequences. Also, this study does not involve any vulnerable populations, individuals with limited decision-making capacity, or hazardous risks. In addition, it received approval from the Scientific Research and Publication Committee (SRPC) at the College of Health and Sport Sciences, University of Bahrain. This is crucial for ensuring that the research adheres to ethical guidelines and protects the rights and welfare of the participants.

3.8 Chapter Summary:

This study will employ an observational cross-sectional design to measure the self-reported competency levels of CT technologists at the SMC. A census approach will be conducted to include all 33 eligible technologists, ensuring comprehensive data collection. This complete enumeration method minimizes sampling bias and allows for a thorough understanding of the competency among all technologists. Data collection will be achieved using an online self-assessment questionnaire designed to evaluate competencies in patient care, communication, radiation safety, protection, image production, and optimization. In addition, the questionnaire will be rigorously developed and validated to ensure reliability and validity. Statistical analysis will be performed using Microsoft Excel and the R programming language. The strengths of this methodology lie in its inclusive approach, encompassing all eligible CT technologists, and its capacity to provide a real-time snapshot of competency levels, effectively pinpointing areas for targeted training program enhancements.

Chapter (4); Result and Discussion

4.1 Introduction

This chapter offers a detailed analysis of data collected on the competency of technologists in CT at SMC. The questionnaire evaluates the participants' self-reported proficiency in the core CT competencies. Utilizing Microsoft Excel 2016 and the R programming language, the data was organized and analyzed using descriptive and inferential statistics. This study uses participant self-assessment of competency—in patient care and communication, radiation safety and protection, and image production and optimization—to gain a comprehensive understanding of the overall competency in CT practice. In addition, the study examines demographic and occupational variables, such as gender, educational background, years of work experience, and training, to understand their influence on the competency levels of CT technologists. Furthermore, it investigates the effect of different competency development factors such as continuous professional development, satisfaction, and training on competency level.

4.2 Demographic and Occupational Data

Table 4.1: Summary of the Participants' Demographic and Occupational Data

Demographic and Occupational Data	Total n (%)
Gender	
Male	12 (36)
Female	21 (64)
Education levels	
Diploma or equivalent degree	17 (52)
Bachelor's degree	14 (42)
Master's degree	2 (6)
Doctorate	0 (0)
Education Background	
Bahraini educational institutions	24 (73)
Foreign educational institutions	9 (27)

Experience, years	
Less than 1	0 (0)
1-5	10 (30)
5-10	7 (21)
More than 10	16 (48)
CT training course	
None	16 (48)
One	8 (24)
Two	3 (9)
Three	2 (6)
More than three	4 (12)

This study included 33 technologists. Complete responses were received, and none were rejected for any reason, demonstrating a full response rate. Among the respondents, the majority were female compared to 36 percent of males (Table 4.1). The educational landscape indicates that the staff is educated in Bahrain predominantly, with 52 percent holding diplomas or equivalent degrees and 42 percent possessing bachelor's degrees. Only two participants have advanced degrees, suggesting a potential gap in higher academic qualifications within the field. Furthermore, the data shows that 48 percent of participants exceed ten years in CT practice, with no participant with less than a year of experience. Although 52 percent of technologists participated in CT training courses, 48 percent of the staff did not. This implies that approximately half of the technologists at the SMC do not possess post-graduation CT training. This research performed a census to provide an overview of the CT workforce at the SMC, it enabled the analysis of their demographic, educational, and training characteristics.

4.3 Normality testing

Table 4.2: Normality Testing

Scores	**Shapiro-Wilk Test**	
	W	**p-value**
Patient Care and Communication	0.88	0.002
Radiation Safety and Protection	0.9	0.006
Image Production and Optimization	0.93	0.04
Participants’ General Perception	0.73	1.805e-06
Total Competency	0.93	0.04

Data distribution testing is a crucial initial step in data analysis because it governs the choice of statistical tests. As demonstrated in (Table 4.2), the Shapiro-Wilk test is used to evaluate the normality of the different scores. The null hypothesis (H_0) states that the data is normally distributed, while the alternative hypothesis (H_1) states that the data is not normally distributed. The results show that p-values for all variables are less than 0.05, leading to the rejection of the null hypothesis for each variable. This indicates that the data is not normally distributed.

Therefore, non-parametric statistical tests, which do not require the assumption of normality, are used to analyze the dataset. For example, the Wilcoxon Signed-Rank, Mann-Whitney U, and Kruskal-Wallis H test were utilized. These tests provide more reliable insights into the characteristics and relationships within the data, ultimately enhancing the precision of findings.

4.4 The Self-Reported Competency Levels

Table 4.3: Comparison Between Participants' Different Scores and the Threshold of 3.9

Scores	One Sample Wilcoxon Signed-Rank Test		
	Mean ± SD	**Median**	**p-value**
Patient Care and Communication	3.45 ± 0.49	3.7	5.71e-06
Radiation Safety and Protection	3.17 ± 0.7	3	3.093e-06
Image Production and Optimization	3.22 ± 0.55	3.3	6.307e-07
Participants' General Perception	3.24 ± 0.56	3	1.56e-05
Total Competency	3.28 ± 0.49	3.4	1.079e-06

The self-assessment questionnaire assesses competency in patient care and communication, radiation safety and protection, and image production and optimization. Each category is represented by three questions to evaluate the technologist's competency level in the specific area. All scores are combined to yield the total competency score representing the overall competency level across all assessed areas.

As illustrated in (Table 4.3), the one-sample Wilcoxon signed-rank test is used to evaluate the self-reported competency of CT technologists at SMC. This is a directional test, where the H_1 specifies that the observed medians are significantly less than the threshold.

The p-values for all categories are below 0.05, rejecting the H_0. This indicates that all the observed medians are below the threshold of 3.9, as supported by (Figure 4.1). Radiation Safety and Protection have the lowest scores median of 3, with a mean of 3.17 ± 0.7. In contrast, patient care and communication showed the highest median (3.7) and a mean of 3.45 ± 0.49. Moreover, the image production and optimization score median is 3.3, with a mean of 3.22 ± 0.55. This result aligns with findings from (Florentino et al. 2018), which also identified low competency levels in patient positioning and image acquisition, scoring 2.4/5, highlighting a consistent need for improvement in these areas. Furthermore, the total competency score median is significantly less than the threshold score with a p-value <0.05. It demonstrates a median of 3.4, with a mean of 3.28 ± 0.49. According to (Figure 4.1) and (Table 4.3), the results support a statistically significant deficiency in competency across all domains.

Figure 4.1: The Comparison Between Participants' Different Scores

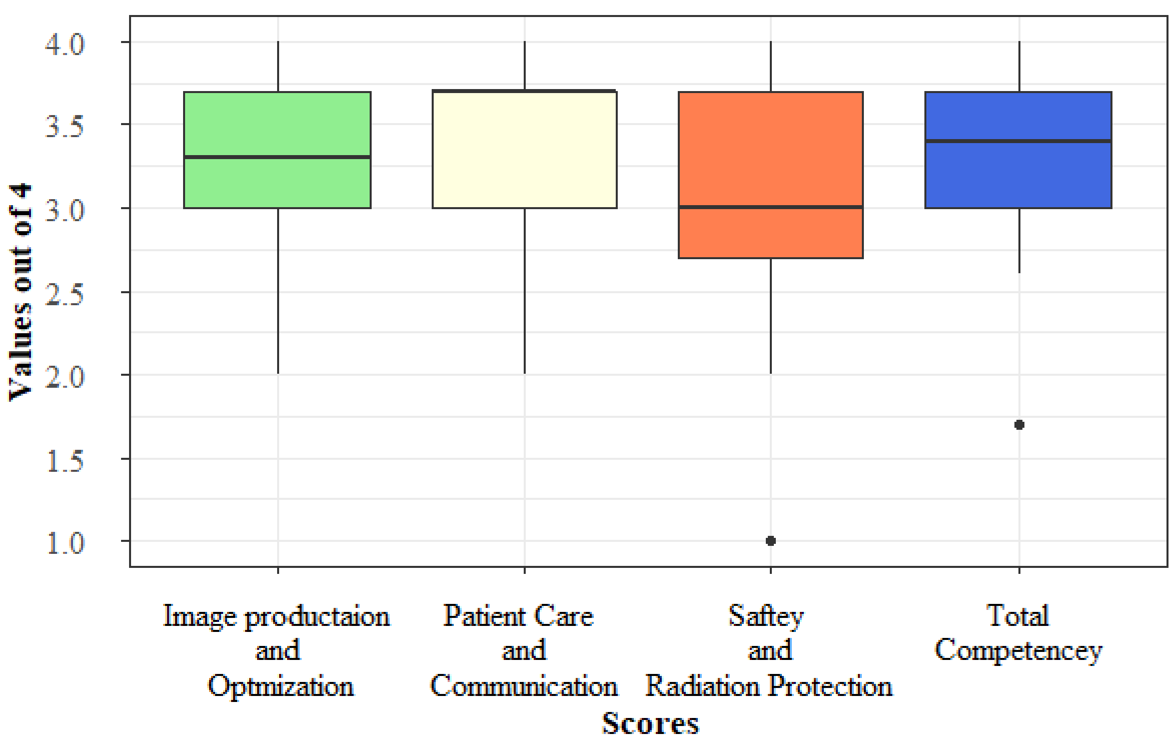
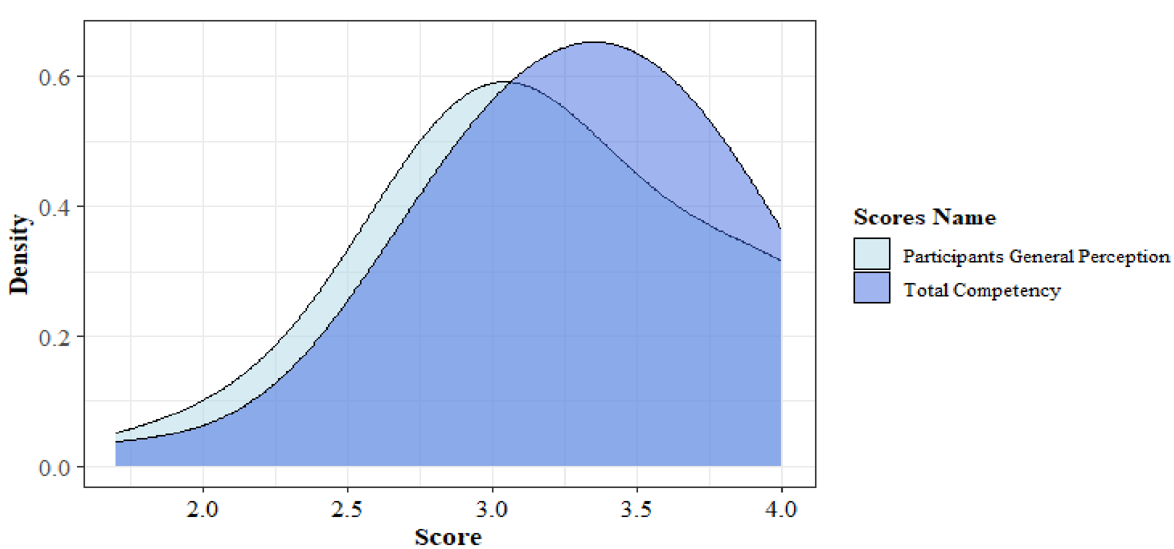


Table 4.4: Comparison Between Participants' General Perception Scores and Total Competency Scores

Scores	Wilcoxon Signed-Rank Test (two-tailed)	
	W statistic	P-value
Participants' General Perception -Total Competency	505.5	0.62

Moreover, the participants' general perception of competency is deduced from the first question score. It is compared to the threshold using the one-sample Wilcoxon signed-rank test. The p-value below 0.05 indicates a rejection of the H_0. Therefore, the observed median score of 3 is less than the threshold with a mean of 3.24 ± 0.6. (Table 4.4) compares the technologists' general perception of their competency level and self-reported total competency scores. According to (Table 4.4), there is no statistically significant difference because the p-value is greater than 0.05. The data suggests an alignment between the technologists' self-perceptions of their competency and their actual competency score. The findings here indicate that the technologists in this study have a reasonably correct self-perception of their competency level which is an unsatisfactory competency level as demonstrated in (Figure 4.2).

Figure 4.2: Comparison Between Participants' General Perception Scores and Total Competency Scores



4.5 Strengths and Weaknesses of Participants

Table 4.5: Frequency and Percentage Summary of Self-Assessed Competency

Question	**Unsatisfactory levels of competency**			**Satisfactory level of competency**	
	Total n (%)				
	Strongly disagree	Disagree	Neutral	Agree	Strongly Agree
Patient Care and Communication					
I am skilled in-patient assessment, preparation and management.	0 (0)	0 (0)	0 (0)	13(39.4)	20 (60.6)
I am confident in communicating effectively with patients and colleagues.	1 (3)	0 (0)	0 (0)	13 (39.4)	19 (57.6)
I am capable of contrast agent administration and adverse reactions control.	0 (0)	0 (0)	4 (12.1)	17 (51.5)	12 (36.4)
Radiation Safety and Protection					
I utilize radiation protection techniques and DRLs in my practice.	1(3)	0 (0)	6 (18.2)	14 (42.4)	12 (36.4)
I perform infection prevention and control techniques correctly.	0	0	4 (12.1)	15 (45.5)	14 (42.4)
I always apply the ALARA principle in my practice.	1 (3)	2 (6.1)	2 (6.1)	16 (48.5)	12 (36.4)
Image Production and Optimization					
I am confident in my patient positioning and centering techniques.	1 (3)	0 (0)	0 (0)	6 (18.2)	26 (78.8)
I am knowledgeable about CT physics, image acquisition, processing and interpretation.	0	1 (3)	10 (30.3)	14 (42.4)	8 (24.2)
I adjust image parameters to fit each patient and achieve optimization.	0 (0)	0 (0)	9 (27.3)	12 (36.4)	12 (36.4)

In this study, scores above the threshold of 3.9 are considered absolute competency indicating optimal and satisfactory competency required for CT practice. Therefore, any other term—strongly disagree, disagree, neutral, agree, strongly agree competency—is an unsatisfactory level. The study analyzes competency in three areas: patient care and communication, radiation safety and protection, and image optimization. Differentiating between satisfactory and unsatisfactory competency can help pinpoint the exact gap in CT practice at the SMC.

4.5.1 Patient Care and Communication

As shown in (Table 4.5), The p-value is < 0.05 indicating that the level of competency in patient care and communication is significantly less than the threshold. Results of the response frequency and percentages reveal mixed performance. A notable 60.6 percent of respondents reported high satisfactory competency in patient preparation and management. Similarly, 57.6 percent expressed confidence in their ability to communicate effectively with patients and colleagues. Conversely, a lower percentage of only 36.4 percent indicated proficiency in contrast agent administration and adverse reaction control. Therefore, CT technologists in SMC excel in patient management but may lack contrast-related knowledge and skills. In general, patient care and communication have the highest score of satisfactory competencies, as illustrated in (Figure 4.3). These findings align with the prior study by (Florentino et al., 2018) found that the overall mean score for patient care and management is low.

4.5.2 Radiation safety and protection

Technologists practicing CT in SMC are significantly lacking in radiation safety and protection competency, as shown in (Table 4.5). According to the data gathered, radiation protection techniques, adherence to DRLs, and application of the ALARA principle were scored the lowest with only 36.4 percent of responses exhibiting satisfactory competency. While most participants fall below the required standard, 42.4 percent demonstrate a satisfactory level of infection prevention and control techniques. As demonstrated in (Figure 4.3), radiation safety and protection have the lowest score of satisfactory competencies. The same problem was also found in several studies regarding radiation protection among CT technologists, as many ignore radiation safety (Fiagbedzi, et al., 2022).

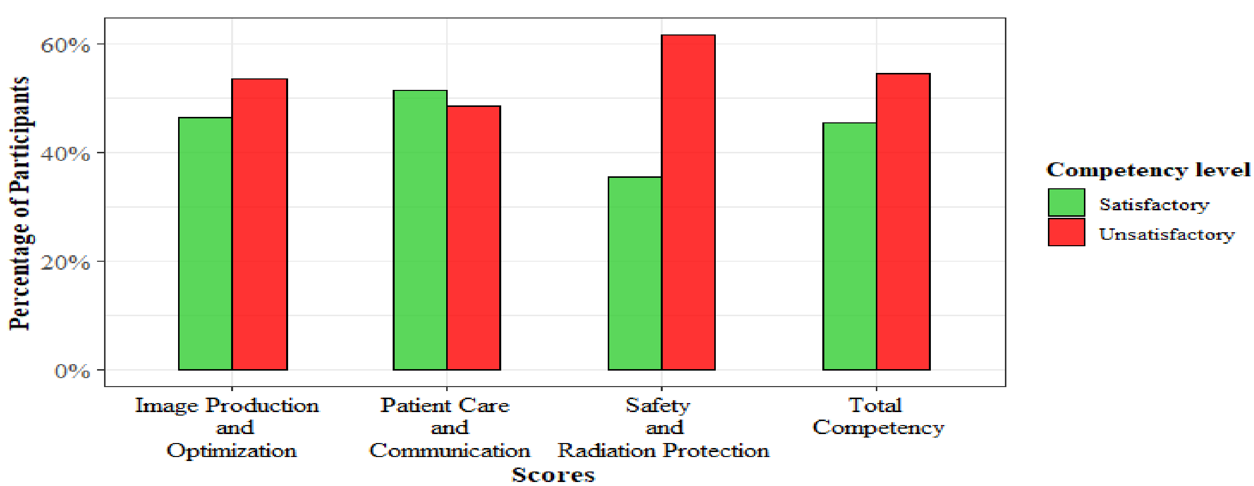
Consequently, the findings of this research underscore the need for collaboration between the radiology department and academic institutions to design targeted training programs and courses that enhance awareness and knowledge of radiation safety among technologists.

4.5.3 Image Production and Optimization

The level of competency in image production and optimization is inadequate. In physics and image acquisition, the results from (Table 4.5) showed that only 24.2 percent of responses demonstrate satisfactory competency. Similarly, only 36.4 percent of responses exhibit satisfactory competency in adjusting image parameters and optimization. This indicates that most participants lack competency in physics, image acquisition, and parameter optimization. However, 78.8 percent of responses reported satisfactory competency in patient positioning and centering techniques. Most of the image production and optimization scores are unsatisfactory, as demonstrated in (Figure 4.3).

All in all, the participants' highest score is in patient care and communication while the lowest is in radiation safety and protection. All the scores have unsatisfactory percentages that are considerably high, as illustrated in (Figure 4.3). This is aligned with the statistical test results where all the scores were not up to the satisfactory level.

Figure 4.3: Satisfactory versus Unsatisfactory Competency in Different Categories.



4.6 Impact of Demographic and Occupational Variables on Competency

Table 4.6: Demographic and Occupational Variables Influence on the Total Competency Scores

Variable	Statistic	p-value
Gender	120[a]	0.84*
Education level	1.08[b]	0.58**
Education Country	101.5[a]	0.81*
Years of Experience	3.5[b]	0.17**
Training Courses	3.84[b]	0.43**

[a]W static
[b]Kruskal-Wallis H (chi-squared)
*p-value calculated using the Mann-Whitney U test
**p-value calculated using the Kruskal-Wallis test

As illustrated in (Table 4.6), the influence of demographic and occupational factors on total competency is tested using Kruskal-Wallis H and Mann-Whitney U tests. The Kruskal-Wallis H test was used for variables with more than two categories, while the Mann-Whitney U test was used for binary variables. All variables possessed a p-value greater than 0.05 which is not considered statistically significant. This indicates that gender, education level, country of education, and participation in training courses do not significantly impact competency levels. While a slight trend suggests that those with more years of experience may have slightly higher competency scores, this difference is also not statistically significant (p-value equals 0.17). Therefore, it appears that there is a need for targeted CT training for all participants despite their demographic and occupational differences. The findings align with (Abuzaid et al. 2020), confirming that demographic variables, such as gender, do not impact knowledge scores among CT technologists. However, the results for occupational factors, including years of experience, did not align with the findings from (Mallinson et al. 2024), who reported that years of experience significantly influenced knowledge levels. The differences observed could be due to the study's small targeted population and homogeneity; if the population is small or lacks significant variability in years of experience, education level, or gender, it may have limited the statistical power to detect differences.

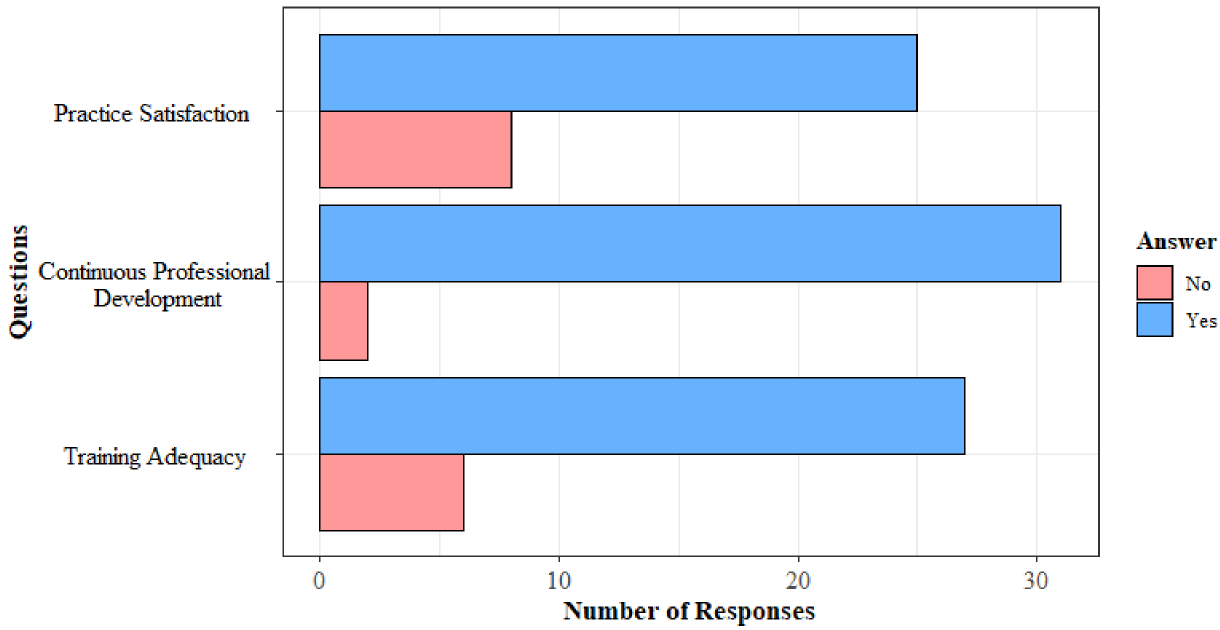
4.7 Factors Influencing Competency Development

Table 4.7: Factors Influencing Competency Development

Questions	**Mann-Whitney U test**		
	Mean Rank	**Sum of Ranks**	**p-value**
I have adequate training and experience in CT technology.			0.76
No	15.8	95	
Yes	17.3	466	
I am interested in continuing my education and professional development.			0.03
No	2.75	5.5	
Yes	17.9	556	
I am satisfied with my current CT practice.			0.98
No	16.9	135	
Yes	17	426	

As shown in (Table 4.7), the results of the Mann-Whitney U test for three different questions related to competency development. In the first and third questions, both p-values are greater than 0.05, this means that the ranks between different responses are not statistically significant. Similarity in the mean ranks for each answer category support the p-value. However, the results for the second question, “I am interested in continuing my education and professional development”, revealed a statistically significant difference. The p-value of 0.03 suggests a significant difference between groups with different answers. Also, the mean rank of the answer “Yes” is higher, indicating that there is a strong association between interest in continuing education and a higher competency level among technologists. This highlights the positive impact of creating a learning culture.

Figure 4.4: Responses to Competency Development Factors Questions



4.8 Summary of Findings

1. The competency scores for CT technologists showed that all three assessed areas fell below the satisfactory threshold. Notably, Radiation Safety and Protection received the lowest score, while Patient Care and Communication received the highest score.

2. The alignment between self-perceived and self-reported competency indicates that CT technologists are aware of their competency levels.

3. Different occupational factors such as educational level, years of experience, and training courses did not affect the total competency score. Despite the diverse occupational backgrounds in SMC, most technologists demonstrate an unsatisfactory level of competence.

4. Demographic factors such as gender and educational country did not influence the competency level of technologists practicing CT in SMC.

5. Competency development factors—such as practice satisfaction and training adequacy—did not influence the competency scores of technologists in SMC. However, participants who were interested in continuous professional development possessed higher levels of competency.

4.9 Chapter Summary

This chapter presents a comprehensive analysis of the study findings, including competency levels of CT technologists at (SMC) in three key areas: patient care and communication, radiation safety and protection, and image production and optimization. The data was gathered through self-assessment questionnaires, revealing a significant competency gap across all evaluated areas. Patient care and communication showed the highest competency scores, while radiation safety and protection were the lowest. Additionally, demographic and occupational variables such as gender, education, and experience were analyzed, showing no impact on competency levels. The findings highlight the need for targeted specialized study in CT imaging in SMC, continuous professional development, and strategic enhancements in education to address these gaps and improve CT practices at SMC.

Chapter (5); Conclusion, Limitations and Recommendations

5.1 Conclusion

In conclusion, this study aimed to assess the self-reported competencies of CT technologists across three primary domains: patient care and communication, radiation safety and protection, and image production and optimization. The data were analyzed using Microsoft Excel and R programming tools. This study examined whether the self-assessed competencies met the threshold of 3.9 across the three domains. The findings indicate significant competency gaps across all evaluated domains. According to the statistical analysis, all the results were below the threshold. Moreover, the demographic and occupational variables such as education, years of experience, and training showed no statistically significant impact on competency. Furthermore, interest in continuous professional development influenced competency scores positively.

5.2 Limitations

This study is susceptible to several limitations that should be considered throughout the research process. For example, a limitation of this study is the reliance on self-reported data. This can inherently introduce subjectivity and limited insight into the assessment process. Participants may overestimate or underestimate their abilities due to personal biases or a lack of accurate self-awareness. Also, participants may intentionally provide inaccurate responses due to social acceptance or desirability. Additionally, the online survey approach can create some challenges. The nature of digital data collection heightens the risk of technical issues and privacy concerns. To conclude, awareness of these limitations is essential for an understanding of the study's outcomes. To mitigate these limitations, several strategies were employed. Firstly, the questionnaire is concise and clear to minimize misinterpretation by the participant. Secondly, a pilot study was conducted to identify potential concerns with the survey.

Moreover, robust data security measures, including encryption and secure data storage, are utilized to protect the participant's privacy. By considering the limitations and implementing the mitigation strategies, the study's reliability and validity can be enhanced.

5.3 Recommendation

This set of recommendations is built on the findings of evaluating the competency of SMC technologist practicing CT. It will highlight applications that are beneficial on both local and national scales.

1. Further research can address the research problem through different approaches. For example, a knowledge and skill-based assessment of CT technologists in SMC can endorse and expand on this study's findings.

2. The findings suggest a potential competency gap in SMC. Therefore, research targeting all CT technologists in SMC can identify potential deficiencies on a national scale.

3. The radiology department of SMC would benefit from creating a targeted CT course to address the observed competency gaps.

4. The National Health Regulatory Authority (NHRA) can develop a mandatory license to control the CT practice in SMC. This will ensure that all technologists practicing CT align with the desired level of competency.

5. A national post-graduate program specialized in CT is highly recommended.

Reference

Abdulkadir, M. K., Piersson, A. D., Musa, G. M., Audu, S. A., Abubakar, A., Muftaudeen, B., & Umana, J. E. (2021). Assessment of diagnostic reference levels awareness and knowledge amongst CT radiographers. *Egyptian Journal of Radiology and Nuclear Medicine*, *52*(1). doi:10.1186/s43055-021-00444-x

Abuzaid, M. M., Elshami, W., Noorajan, Z., Khayal, S., & Sulieman, A. (2020). Assessment of the professional practice knowledge of computed tomography preceptors. *European Journal of Radiology Open*, *7*, 100216. doi:10.1016/j.ejro.2020.01.005

Alhorani, Q., Al-Ibraheem, A., Rawashdeh, M., Alkhybari, E., Sabarudin, A., A. Latiff, R., & Mohamad, M. (2024). Investigating knowledge of DRLs, image quality and radiation dose in PET/CT and CT imaging among medical imaging professionals. *Heliyon*, *10*(9), e30030. doi:10.1016/j.heliyon.2024.e30030

American College of Radiology. (2022, May). Radiation dose to adults from common imaging examinations. Retrieved from https://www.acr.org/-/media/ACR/Files/Radiology-Safety/Radiation-Safety/Dose-Reference-Card.pdf

American Registry of Radiologic Technologists. (2022). Computed tomography. Retrieved from https://www.arrt.org/pages/earn-arrt-credentials/credential-options/computed-tomography

Ayoo, S., Wilcox, Y., LaVelle, J. M., Podems, D., & Barrington, G. V. (2020). Grounding the 2018 AEA evaluator competencies in the broader context of professionalization. *New Directions for Evaluation*, *2020*(168), 13-30. doi:10.1002/ev.20440

Bosch de Basea Gomez, M., Thierry-Chef, I., Harbron, R., Hauptmann, M., Byrnes, G., Bernier, M., … Cardis, E. (2023). Risk of hematological malignancies from CT radiation exposure in children, adolescents and young adults. *Nature Medicine*, *29*, 3111–3119. Retrieved from https://doi.org/10.1038/s41591-023-02620-0

Chaka, B., Adamson, H., Foster, B., & Snaith, B. (2022). Radiographers' self-perceived competencies after attending postgraduate courses in CT and MRI. *Radiography*, *28*(3), 817-822. doi:10.1016/j.radi.2022.01.008

Dervishi, B., Hyseni, F., Musa, J., Saliaj, K., Vokshi, V., Rakovica, L., & Gafurri, Z. (2022). The importance of CT urography in early diagnosis of anatomical variations in urogenital tract: Case presentation. Radiology Case Reports, 17(10), 4025-4029. https://doi.org/10.1016/j.radcr.2022.07.074

DeWeese, L., Griglock, T., Moody, A., Mehlberg, A., & Winters, C. (2022). The improvement of patient centering in computed tomography through a technologist-focused education initiative. *Journal of Digital Imaging*, *35*(2), 327-334. doi:10.1007/s10278-021-00580-w

Dudhe, S. S., Mishra, G., Parihar, P., Nimodia, D., & Kumari, A. (2024). Radiation Dose Optimization in Radiology: A Comprehensive Review of Safeguarding Patients and Preserving

Image Fidelity. *Cureus*, *16*(5). https://doi.org/10.7759/cureus.60846

Fiagbedzi, E., Gorleku, P. N., Nyarko, S., Asare, A., & Ackah Ndede, G. (2022). Assessment of radiation protection knowledge and practices among radiographers in the central region of Ghana. *Radiation Medicine and Protection*. https://doi.org/10.1016/j.radmp.2022.06.001

Florentino, C. B., Gustilo, R. L., Jailani, H. U., Maceren, M. R., Periabras, N. O., & Alipio, M. (2018). The clinical competencies of radiologic technology interns of Batch 2018-2019 on radiological science modalities: Basis for proposed enhancement program. *Journal of Radiological Science and Practice*, doi:10.13140/RG.2.2.30168.14085

Hsieh, J., & Flohr, T. (2021). Computed tomography recent history and future perspectives. *Journal of Medical Imaging*, *8*(05). doi:10.1117/1.jmi.8.5.052109
https://www.nobelprize.org/prizes/medicine/1979/press-release/

Inoue, Y. (2023). Radiation dose management in computed tomography: Introduction to the practice at a single facility. *Tomography,* *9*(3), 955-966. https://doi.org/10.3390/tomography9030078

Kazemi, Z., Hajimiri, K., Saghatchi, F., Molazadeh, M., & Rezaeejam, H. (2023). Assessment of the knowledge level of radiographers and CT technologists regarding computed tomography parameters in Iran. *Radiation Medicine and Protection*, *4*(1), 60-64. doi:10.1016/j.radmp.2023.01.002

Khamtuikrua, C., & Suksompong, S. (2020). Awareness about radiation hazards and knowledge about radiation protection among healthcare personnel: A quaternary care academic center–based study. *SAGE Open Medicine*, *8*, 205031212090173. https://doi.org/10.1177/2050312120901733

Kundu, S., Nayak, K., Kadavigere, R., Pendem, S., & Priyanka. (2024). Evaluation of positioning accuracy, radiation dose and image quality: Artificial intelligence based automatic versus manual positioning for CT KUB. *F1000Research*, *13*, 683. doi:10.12688/f1000research.150779.1

Mallinson, M., Hardy, M., & Scally, A. (2024). Developing CT workforce competencies: What knowledge and skills should we expect of an early career radiographer? *Radiography*, *30*(5), 1355-1362. https://doi.org/10.1016/j.radi.2024.07.010

Mayo Clinic. (2024, May 7). CT scan - Mayo Clinic. Retrieved from https://www.mayoclinic.org/tests-procedures/ct-scan/about/pac-20393675

Rockall, A. G., Justich, C., Helbich, T., & Vilgrain, V. (2022). Patient communication in radiology: Moving up the agenda. *European Journal of Radiology*, *155*, 110464. doi:10.1016/j.ejrad.2022.110464

Smith-Bindman, R., Wang, Y., Chu, P., Chung, R., Einstein, A. J., Balcombe, J., … Miglioretti, D. L. (2019). International variation dose for computed tomography examinations: prospective cohort study. *BMJ*, *364*, k4931. https://doi.org/10.1136/bmj.k4931

The Nobel prize. (1979). *The Nobel prize in physiology or medicine 1979*. https://www.nobelprize.org/prizes/medicine/1979/press-release/

United Nations Publications. (2022). *Sources, effects and risks of ionizing radiation, United Nations scientific committee on the effects of atomic radiation (UNSCEAR) 2020/2021 report: Report to the General Assembly, with scientific annex a evaluation of medical exposure to ionizing radiation*. Retrieved from https://www.unscear.org/unscear/publications/2020_2021_1.html

Withers, P. J., Bouman, C., Carmignato, S., Cnudde, V., Grimaldi, D., Hagen, C. K., … Stock, S. R. (2021). X-ray computed tomography. *Nature Reviews Methods Primers*, *1*(1). doi:10.1038/s43586-021-00015-4