Journal of Medical Imaging and Radiation Sciences 56 (2025) 101799

Journal of Medical Imaging and Radiation Sciences
Journal de l'imagerie médicale et des sciences de la radiation

www.elsevier.com/locate/jmir

Research Article

Time constraints and workload in the computed tomography department

Nisanthi Yoganathan[a,*], Cláudia Sá dos Reis[b] and Florentino Serranheira[c,d]

[a] Department of Radiology, Hospital of Yverdon-les-Bains (eHnv), 1400 Yverdon-les-Bains, Switzerland
[b] School of Health Sciences (HESAV), University of Applied Sciences and Arts Western Switzerland (HES-SO), Lausanne 1011, Switzerland
[c] NOVA National School of Public Health, Universidade NOVA de Lisboa, Lisbon, Portugal
[d] Comprehensive Health Research Center (CHRC), Lisbon, Portugal

ABSTRACT

Introduction: The escalating use of Computed Tomography (CT) has promoted higher radiographer workload, which can contribute to an increase of risks such as stress, job dissatisfaction, and potential health and safety issues. This study aimed to assess the impact of organizational, spatial, and temporal factors on procedures and workload in a CT unit, emphasizing patient safety and radiographer well-being. Addressing time pressure and optimizing workplace ergonomics are crucial in maintaining a balance between efficiency and quality, ensuring safe practices in modern medical imaging units.

Methods: The study was conducted in a Swiss university hospital CT unit and employed the Systems Engineering Initiative for Patient Safety (SEIPS) model to analyse the radiographers' workflow and time constrains. Observations and tasks' analysis were used to collect data, including timing and location of tasks performed by radiographers.

Results: The radiographers' workflow in the CT department is complex, involving multiple tasks. The entire process spans from 26 to 41 min but the Machine-Time (time spent inside the CT room) ranged from 10 to 16 min. The study identified inefficiencies in the workflow, namely in time spent on patient preparation and unsuited machine-time rate. The layout of the department, including limited space in the preparation area, contributing to ergonomic challenges for radiographers. Organizational factors, such as scheduling practices, also impacted workflow. The examination durations varied by type of scan and patient, leading to time pressure and potential safety concerns.

Conclusions: The study highlighted the need for more realistic time allocation in CT examinations to improve patient and radiographer safety. Recommendations include extending machine-time rate, adapting examination durations based on the type of CT, and assigning a dedicated radiographer for order review. It is also crucial improving the working environment to accommodate ergonomic needs. Addressing these issues can enhance the efficiency and safety of CT departments, benefiting both patients and radiographers.

Implications for Practice: Healthcare organizations should consider these study recommendations to improve the efficiency and safety of CT departments. By implementing the recommended changes, such as adjusting CT-time rate and optimizing working environments, radiographer satisfaction and patient safety can be increased, ultimately leading to safer and more effective CT services.

RÉSUMÉ

Introduction: L'utilisation croissante de la tomodensitométrie (TDM) a entraîné une augmentation de la charge de travail des radiographes, ce qui peut contribuer à accroître les risques comme le stress, l'insatisfaction au travail et les problèmes potentiels de santé et de sécurité. Cette étude visait à évaluer l'incidence des facteurs organisationnels, spatiaux et temporels sur les procédures et la charge de travail dans une unité de TDM, en mettant l'accent sur la sécurité des patients et le bien-être des radiographes. La gestion de la pression temporelle et l'optimisation de l'ergonomie du lieu de travail sont essentielles pour maintenir un équilibre entre l'efficacité et la qualité, et garantir des pratiques sûres dans les unités d'imagerie médicale modernes.

Méthodologie: L'étude a été menée dans un service de TDM d'un hôpital universitaire suisse et a utilisé le modèle SEIPS (Systems Engineering Initiative for Patient Safety) pour analyser le flux de travail et les contraintes de temps des radiographes. Les observations et l'analyse

Contributors: All authors contributed to the conception or design of the work, the acquisition, analysis, or interpretation of the data. All authors were involved in drafting and commenting on the paper and have approved the final version.

Funding: This study did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Competing interests: All authors declare no conflict of interest.

Ethical approval: The ethics committee (CER-VD) approved this study (Req-2021–01,188).

* Corresponding author.
E-mail addresses: nisanthi.yoganathan@outlook.com (N. Yoganathan), claudia.sadosreis@hesav.ch (C. Sá dos Reis), serranheira@ensp.unl.pt (F. Serranheira).

1939-8654/$ - see front matter
https://doi.org/10.1016/j.jmir.2024.101799

des tâches ont été utilisées pour recueillir des données, notamment sur le moment et l'emplacement des tâches effectuées par les radiographes.

Résultats: Le flux de travail des radiographes dans le service de TDM est complexe et comporte de multiples tâches. L'ensemble du processus dure de 26 à 41 minutes, mais le temps machine (temps passé à l'intérieur de la salle de TDM) varie de 10 à 16 minutes. L'étude a identifié des inefficacités dans le flux de travail, notamment le temps consacré à la préparation du patient et le taux de temps machine inadapté. L'agencement du service, y compris l'espace limité dans la zone de préparation, contribue aux problèmes d'ergonomie pour les radiographes. Des facteurs organisationnels, tels que les pratiques de programmation, ont également eu une incidence sur le flux de travail. Les durées d'examen variaient en fonction du type de scanner et du patient, ce qui a entraîné des contraintes de temps et des problèmes de sécurité potentiels.

Conclusions: L'étude a mis en évidence la nécessité d'une répartition plus réaliste du temps lors des examens de TDM afin d'améliorer la sécurité des patients et des radiographes. Les recommandations comprennent l'extension du taux de temps machine, l'adaptation des durées d'examen en fonction du type de TDM et l'affectation d'un radiographe dédié à la révision des ordonnances. Il est également essentiel d'améliorer l'environnement de travail pour répondre aux besoins ergonomiques. La résolution de ces problèmes peut améliorer l'efficacité et la sécurité des services de TDM, au bénéfice des patients et des radiographes.

Implications pour la pratique: Les établissements de santé devraient tenir compte des recommandations de cette étude pour améliorer l'efficacité et la sécurité des services de TDM. En mettant en œuvre les changements recommandés, tels que l'ajustement du taux de temps de TDM et l'optimisation des environnements de travail, la satisfaction des radiographes et la sécurité des patients, conduisant en fin de compte à des services de TDM plus sûrs et plus efficaces.

Keywords: Radiologic technologist; Medical imaging; Diagnostic radiographer, computed tomography; Workforce; Work shadowing; Staff wellbeing; Ergonomics and Human Factors

Introduction

The use of Computed Tomography (CT) has risen lately due to its capacity of enhancing diagnostic information to improve patient health outcomes by directing the potential personalized pathways for each patient regarding possible treatments and follow up [1]. In 2019, Swiss hospitals were equipped with 219 scanners (+9 % in five years). Almost 1.18 million scanner examinations were carried out in Switzerland in 2019. Hospital scanners are increasingly in demand, the CT examinations average carried out each day, per scanner has risen from 11 in 2014 to 13 in 2019, according to the Federal Statistical Office (FSO) [2]. This escalation of CT examinations has an impact on the radiographers' workload since the radiographers must perform more examinations but in the same period of time. Increasing the radiographer's workload, seems to be a potential to increase risks, namely those associated to high levels of stress, which can cause job unsatisfaction, lack of concentration, errors, and absenteeism [3]. That can affect the department's ability to provide a safe and effective care to the patients [4], being important for the healthcare organizations prioritizing the well-being and safety of radiographers, as this can lead to significant improvements in patient outcomes [5]. By providing radiographers with the necessary resources and support, healthcare organizations can create a culture of safety and promote patient-centered care.

One of the predispositions to error in healthcare systems is time constrains, as pressure and rush. Healthcare professionals often work in challenging environments and are under high expectations of great performance [6]. Being rushed in their work, radiographers can have additional stress, which can conduct to errors and patient/ worker safety issues [3]. To address this problem, it is essential to focus on the timeline analysis, workflow, and work environment to understand the context and the needs to perform adequately a certain task. By doing so, radiographers can prioritize approaches that can improve safety and perform their CT work with quality and accuracy.

The workflow of radiographers in medical imaging departments (MIDs) can be described as a complex process where radiographers are constantly stressed to repeat systematically several steps with every patient [7]. Nevertheless, some steps depend on the type of examination (e.g. anatomical region, with or without contrast, type of patient/mobility/disabilities). The analysis of the CT workflow is a way to describe the performance of the system, of each employee, and the time necessary to complete a CT examination. As the workflows usually present time variations, this needs to be integrated as well, to build up an integrative workflow diagram, that allows understand all the examination process [7]. Patients characteristics, as the patient's profile, whether they are an out or inpatient, elderly, young, or having physical or cognitive impairments [8], need also to be integrated in the CT workflow analysis, increasing its reliability.

Nevertheless, the advancement of medical imaging technology led to a constant demand for speed and efficiency, which, if this is not carefully managed, it can compromise the quality of care. As demonstrated in some studies [7,9], time pressure negatively impacts decision-making as well [9], being essential to strike a balance between efficiency and quality to ensure the best possible care for patients [7].

Besides these aspects, the work environment and organization also play a crucial role in the workflow and safety. A "healthy" workplace should take into account both the physical and the psychosocial work environment, and it should include appropriate equipment designed and compatible with the local designed architecture [10,11]. Indeed, neglecting ergonomics in healthcare not only reduces efficiency and productivity but can also lead to issues such as work-related musculoskeletal disorders [12–14]. Therefore, optimizing workplace ergonomics should be a priority in any MID that prioritizes safe practices [14,15].

The negative correlation between speed and accuracy has been highlighted [7,9] over the years, especially in image interpretation and decision-making [7,16]. It has been noted that an optimal level of stress (eustress) is essential for enhancing work performance, preventing the detrimental impact of time pressure on decision-making, but it should never be overtaken [9,17]. The literature has further revealed that time pressure constitutes one of the obstacles to the adoption of evidence-based practice in healthcare, impacting the decision-making [18].

The objective of this study was to examine how organizational, spatial, and temporal factors affect both the duration of procedures and the workload in a CT unit, with a focus on safeguarding the health and safety of patients and radiographers. In addressing this objective, the study contributes to fulfil a gap in the literature. Specifically, the novelty of this research lies on its exploration of the work of radiographers and its detailed analysis of the workflow. While numerous studies have investigated the role of radiologists in similar settings, the specific challenges faced by radiographers have received limited attention in the literature. Therefore, this study offers a unique perspective on the dynamics within CT units, shedding light on critical aspects that have previously been overlooked.

Methods

Settings

This study was performed in one of the Swiss university hospitals. The CT unit team was composed by 30 radiographers, 44 radiologists, and was producing around 33.000 CT scans annually, including in and outpatients at the time of this study. The CT unit has two identical CT scanners that operate on weekdays from 7:30AM to 5:30PM. The time allocated currently to perform a CT-scan in this institution is 15 min (*Machine-Time*) regardless examination or patient type.

The ethics committee (CER-VD) and the ethics from the hospital as well as the administrative board approved this study [19] (Req-2021–01,188).

Research design

An ergonomic approach, Systems Engineering Initiative for Patient Safety (SEIPS) model of work system and patient safety, was used to analyze the radiographer's workflow in the CT unit and to provide recommendations for managing workload efficiently [20]. This model SEIPS was one of the 18 patient's safety developmental centers originally funded by the Agency for Healthcare Research and Quality (AHRQ) and analyses system interactions, describing how system design can influence the care processes [20,21]. Additionally, SEIPS model goes further by specifying the system components (Organization, Environment, Tasks, Persons, and Technology and Tools) that can contribute to causes of medical errors and its control. The model also focuses incidents and adverse events, showing the nature of the interactions between all the components presented above. The design of the components and their interactions are also analysed with this model since they can contribute to accept or reject the processes under evaluation [20]. In order to identify these interactions, an ergonomics task analysis was conducted through observation of these components (Organization, Environment, Tasks, Persons, and Technology and Tools). The method of observation was chosen, due to the rapidity associated to this technique as well as the fact of being non-invasive [22].

Data collection

Different methods were used to collect data about radiographers' prescribed work,[1] real work, and safety. A questionnaire was sent to all 30 radiographers performing CT examinations to collect information on their perceived work, as well as their workflow, workplace, and work conditions. The survey was written in French, and it was sent via a web link to the chief-radiographer of CT department, who distributed it to all radiographers working in it. The survey was available from the 8th of September 2022 to 8th of October 2022, and to reinforce the participation rate, a reminder mail was sent [23]. The survey consisted of 55 questions organized into six parts: A. Consent, B. Environment, C. Task, D. Technical means, E. Organization, F. Security, G. Commentary. The survey was previously tested by a group of radiographers performing CT in another hospital to determine the required time to complete and to assess the understanding of the questions [24]. No personal data of the participants were required, and the survey was anonymous [25]. It consisted of closed-ended questions using a 4 points Likert-scale to prevent neutral responses: "strongly disagree," "disagree," "agree," and "strongly agree." An open-ended question was also included at the end to allow participants to provide additional comments [26].

In order to understand the work systems, care process, and various outcomes, observations were conducted to assess the real work in the CT department, with a grid adapted from the previous work by James Spradley's [27], which was previously tested. The grid provided a structured way of recording data consistently across multiple observations, ensuring comparability and reducing the risk of missing key elements of the workflow. This method was chosen to offer a clear framework that could help identify patterns and correlations between the work environment, timing, and workload. The grid was complemented by field notes to capture additional qualitative observations such as non-verbal cues, interruptions, and environmental

[1] **Prescribed Work**: Refers to the tasks and responsibilities as envisioned by management, outlining what is expected from radiographers.
Real Work: The actual tasks performed by radiographers, reflecting the practical realities and challenges encountered in the field.

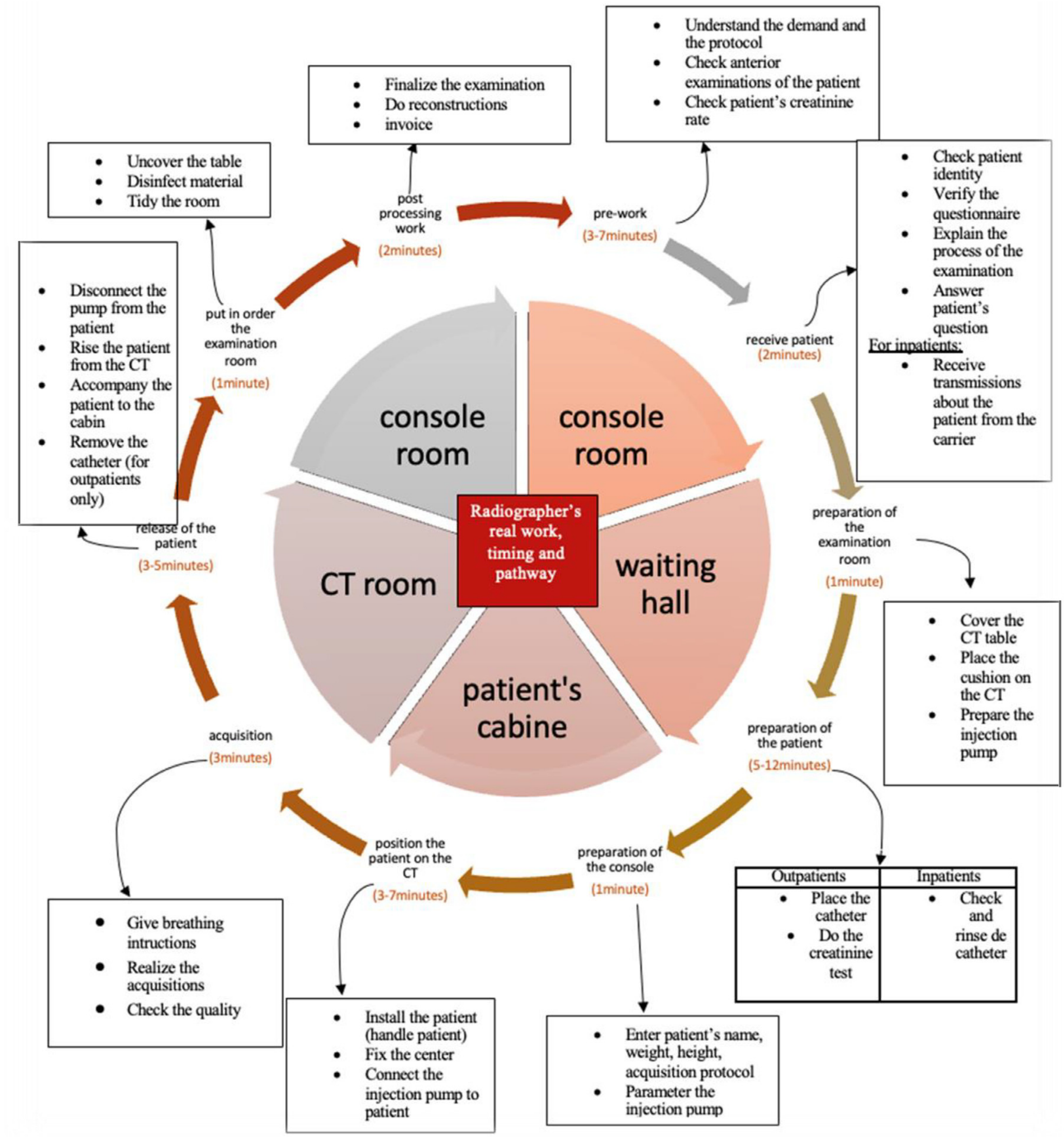

Fig. 1. Radiographer's real work with timing spent in each activity/task and location in the Computed Tomography unit.

factors that could not be easily quantified in the grid. The use of the grid in this study offered several advantages. First, it ensured consistency in data collection across different sessions and observers, allowing for uniformity and reliability in capturing workflow data. Additionally, the grid provided a systematic approach by breaking down complex workflows into manageable categories, facilitating an easier analysis. It also helped produce objective data by focusing on measurable aspects of the radiographers' workflow, thus reducing subjectivity.

The time spent by the radiographers on each CT examination task was measured from the patient's arrival in the CT unit until the end of the examination. The data collected included all types of patients (e.g. out and inpatients, age, sex, mobility) included the location (Environment) where the task was performed, the path taken by the radiographers, the task itself, the duration of the task, and the objective of the task.

The observation was carried out for 15 days, as the researchers had limited time in the CT Department, and during different days to consider the possible variations that can happen every day. 17 of 33 radiographers were observed during this period. It was a non-participatory observation, notes were taken and registered in the observation grid. No questions were asked to the radiographers or to the patients during the examination procedures. Observations were also realised during lunch break to identify if there were any differences in the radiographers' behaviours to keep up with the time allocated.

To ensure that the presence of the researcher did not influence workflow and examination times, several measures were adopted.

Firstly, with a familiarization period, which was during the pre-test of the grid, the researcher spent an initial period in the CT unit prior to data collection, allowing the radiographers to become accustomed to their presence. This reduced the likelihood of changes in behavior due to observation (Hawthorne effect).

Secondly, the researcher maintained a passive, non-intrusive stance during data collection, avoiding direct interactions with the radiographers or interference in their tasks.

Finally, the observation period was extended, which means data were collected over an extended period to capture typical variations in workload and workflow, ensuring that any potential short-term adjustments by radiographers due to the researcher's presence would not significantly affect the overall findings.

In this observational study, the potential biases were addressed through reflexivity. Reflexivity involves the conscious reflection on the researchers' own influence on the study, from data collection to analysis. To manage these biases, the researchers maintained reflexive journals throughout the study, where they documented their thoughts, emotions, and potential preconceptions. This practice helped them recognize and mitigate any personal biases that could affect the observation or interpretation of the data.

Data analysis

Descriptive statistics were initially used to identify the duration of each task, with Excel being employed to calculate measures such as mean, median, and standard deviation, as well as to create visual representations of the data [28]. Qualitative data analysis was then conducted to understand the context in which the observed behaviors occurred. This involved reviewing field notes and observations taken during the workflow monitoring process, capturing details such as non-verbal interactions, environmental factors, and specific challenges faced by radiographers. A thematic analysis approach was used, where recurring patterns and themes related to workflow disruptions, and safety practices were identified. This allowed for a deeper understanding of the observed workflow and the factors that may affect it. [29,30].

A comparison between the prescribed work (as defined by management, based on interviews with the chief radiographer) and the real work performed by the radiographers helped to identify the factors contributing to the discrepancies between the two. To conduct this analysis, a structured observational approach was used where the tasks and procedures outlined by management were directly compared with the actual practices observed during the study. This involved reviewing workflow documents and task protocols provided by the management, which detailed the expected duties, timings, and sequences of activities for radiographers. These were then compared against the field notes and observational data collected during the study, which documented the real-time actions and interactions of radiographers in the CT unit.

Results

Workflow

Real workflow for a radiographer in the CT department involved several tasks, each one with a specific duration (Figs. 1 and 2). Results showed the entire process spans from 26 to 41 min but the Machine-Time (time spent in the CT room) ranges from 10 to 16 min.

During the 15-minute Machine-Time, as mandated by the CT unit's hierarchy (work as imagined and prescribed), the radiographer was responsible for patient positioning on the CT table, checking the patient information and injecting contrast for enhanced CT scans, performing the images acquisition (including providing instructions for breath-holding), quality checking before the patient leaves the CT table, disconnecting the patient from the injector, assisting the patient to stand up from the CT table, and preparing the CT room for the next patient.

According to the survey (Table 1), all participants ($n = 18$) stated that examination scheduling is inefficient. 13/18 participants feel that protocols are not provided with enough time in advance. Additionally, 17 out of 18 participants responded that they do not have sufficient time to provide quality service, with 16/18 of them feeling that this time constraint compromises both patient and radiographer safety. Fifteen radiographers mentioned that they do not have enough time to perform post-processing tasks immediately after the examination. Moreover, all participants stated that it is difficult to manage unforeseen events such as allergic reactions and complicated patients. Of all, 15 participants reported frequent schedule delays, and 14/18 participants affirmed that adding new examinations to the schedule is common.

Environment

The layout of the CT department (Fig. 3) includes a mirrored unit configuration, cabin placement, and the radiographers' pathway from the waiting hall to the CT area.

The pathway of radiographers working in the CT department is limited to the console room, preparation room, waiting hall, and CT examination room. The radiographer is mostly stationed in the preparation room and console room during the work process. The arrangement of the different areas minimizes the need for the radiographer to walk to other locations outside the CT unit.

During patient preparation, specifically catheterization procedure, it was observed that the preparation cabin has a limited workspace. The radiographer uses a trolley to prepare catheterization materials in the cabin to perform the procedure. However, if multiple patients are being prepared simultaneously, there is insufficient space to maintain patient privacy and close the cabin door, since the cabins face each other. Furthermore,

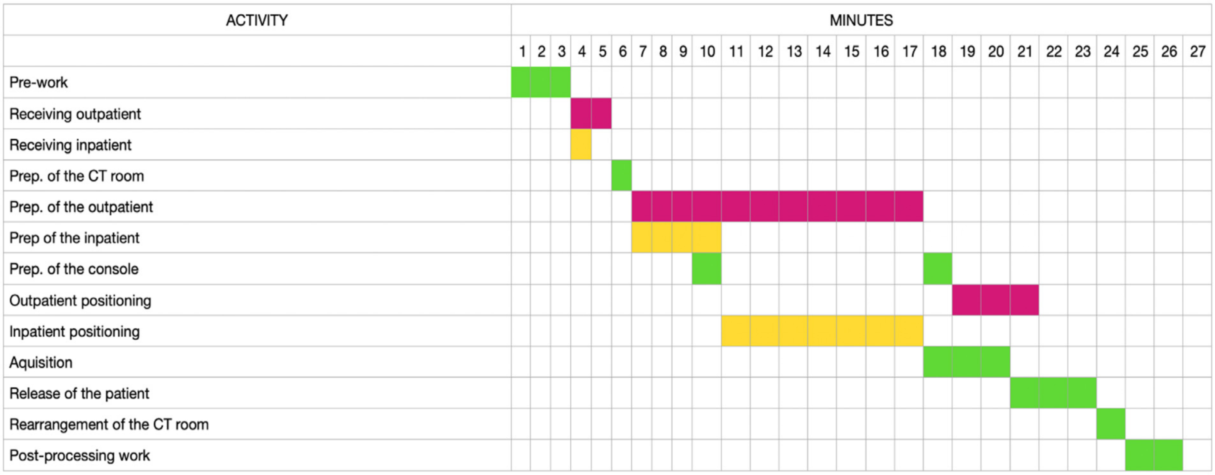

Fig. 2. Gantt Chart of radiographer's activity per examination.

Table 1
Responses obtained from radiographers about the work un a Computed Tomography Department.

	Totally disagree	Disagree	Agree	Totally agree
Organization				
Optimal Timing	12	3	2	
The protocols are given in advance	6	7	5	
The Machin-Time of 15minutes is sufficient	11	7		
The 15-minute "machine time" duration is wise to ensure the safety of the patient and the Radiographer	10	6	2	
I have enough time to perform post-processing tasks and billing immediately after the exam is performed	2	13	2	1
it is easy to manage unforeseen events such as allergic reactions and complicated patients	15	3		
It is not frequent that you schedule delays	12	3	2	1
It is common to add new examination to the schedule	13	1	3	1
Environment				
The CT department's layout is suitable for Radiographer's needs	3	12	3	
The working environment allows you to provide quality work	12	1	5	
The space for patient preparation is adequate	3	8	6	1

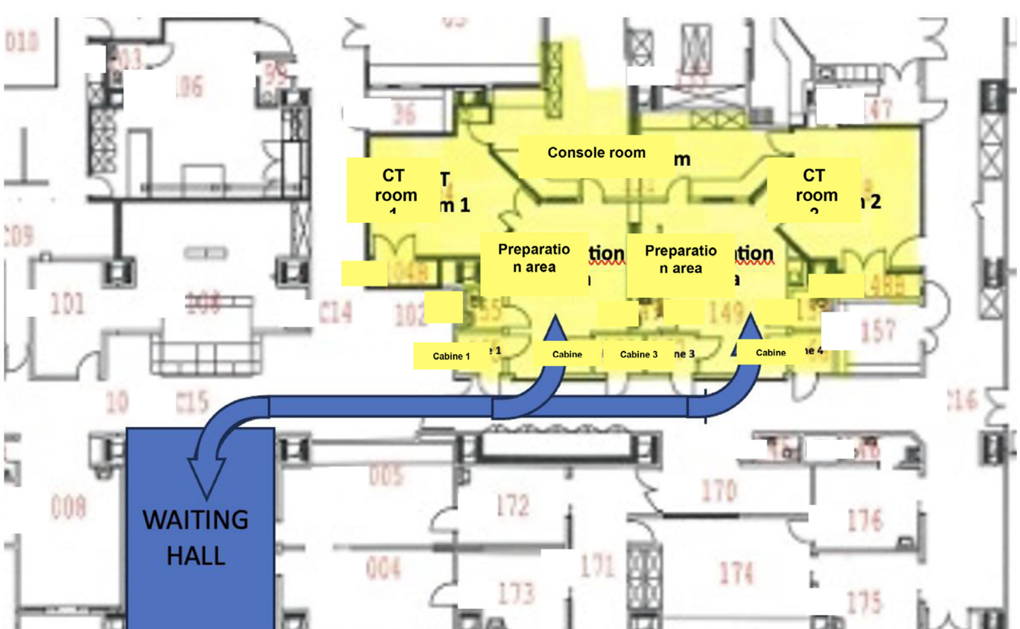

Fig. 3. Computed Tomography unit's layout and radiographer's pathway for a typical examination.

due to workspace restrictions, radiographers assume extreme postures, while performing catheterization. As the radiographer has no space in the cabin to place the trolley, they must rotate outside the cabin each time to handle or store equipment on the trolley. Nevertheless, the layout of the service seems allowing for an optimal patient pathway. It starts with the outpatients announcing themselves at the department reception. After that, they move to the waiting area located near by the reception, from where they are taken to the CT preparation area. The following step is the entrance in the CT room and come out once finished. Similarly, hospitalized patients come with a transporter who leave them in the preparation area, transferring their information over to the radiographer. They are prepared, if necessary, in the CT room located a few meters away, and come out of the CT room once the examination is finished. Finally, they wait in the preparation area for the transporter that will pick them up to go back to the ward.

For this section, 15/18 of the radiographers conveyed that they feel the CT unit's layout is not suitable for their needs, and 13/18 find that the working environment does not allow them to provide quality work, with 11/18 feeling that the space for patient preparation is inadequate (Table 1).

In the commentary, participants expressed that the CT room is too narrow making it difficult to move easily around between the injector and the tables containing the examination equipment. And another radiographer wrote: "Lack of ergonomics and space in all rooms."

Organization

A total of 7 radiographers are scheduled to operate the two CT scanners. While 2 radiographers handle the image acquisitions, 4 others prepare the next patients in the 4 available preparation rooms and cabins. The remaining radiographer covers for colleagues during break times. Each radiographer is responsible for the patient throughout the entire process—from reception to discharge—ensuring continuity of care and avoiding an assembly-line approach.

Each radiographer performed CT examinations to 13 to 15 patients per day, at intervals of 15 min. Typically, the image acquisition took less time than 15 min, but since patients usually arrived earlier, once the radiographers had finished the procedures with one patient, they concentrated their attention to the following patient. Most of the time, the radiographers had the individualized CT protocol in advance to apply to each patient, allowing them to streamline their workflow. However, observations highlighted on three occasions that the radiographer needed more time to perform the full procedure, since the protocol was not available. When there were no protocols available at the beginning of the examination, radiographers needed to consult the radiologists to discuss the protocol (procedure typical in Swiss context), search for patient information and look at previous examinations. The absence of previous protocols put the radiographers in stressful situations that disrupted their workflow. These aspects were also mentioned by the radiographers in the survey. In fact, in one commentary, it was mentioned: "we are always faced with a form that is not completed in advance [with the protocol], having to collect information via the PACS, soarian or other…"

It was also noted that when patients were added to the schedule during the day of the examination, it required an additional work from the radiographer because they had to fit them in between the patients who were already scheduled and find the best time for them to perform the examination. In the survey, one of the radiographers wrote: "There is too much patient flow, and the 15-minute time slot is too short, which causes stress for radiographers and sloppy patient management. As soon as an element in the management process changes from the 'standard' patient, both in terms of preparation and acquisition, we take longer times than the time slot normally allocated. The delay typically was accumulated in the time slots of subsequent patients. Finally, several patients are ready to move for image acquisition, but we are limited by the number of machines."

During the observation, it was noted that the patients who were added to the schedule, were typically hospitalized (inpatients) (and therefore with mobility issues), who arrived with a transporter in advance that had to be previously requested/validated. It was also observed that radiographers agreed to carry out examinations on inpatients between free time slots or between 2 outpatients. However, transport procedures were not aligned with patient slots, and most of the times this was not performed in a way that was disrupting to the radiographer's and CT patient's workflow.

Timing

The management allocates 15 min (machine-time) for the acquisition process. Observations demonstrated that the average time taken for an outpatient CT examination was 24 min, and for an inpatient, it was 25 min (from the patient reception to their release). This time was calculated from all observed types of examination (head CT, chest- abdomen-pelvis CT, upper/lower limb CT, and abdomen CT). Figs. 4 and 5 illustrate the breakdown of time spent at each stage of the workflow process.

The real time CT examination (Figs. 2, 4 and 5) includes the preparation of the outpatient (21 % of the total time) and only 12 % for the preparation of an inpatient. This difference is due to the need of outpatients for catheterization while inpatients arrive with the catheter already in place. For inpatients, positioning is the most time-consuming step (20 % of the total time) since they were often with mobility issues.

Considering machine-time, the average time required was 6 min for an outpatient and 13 min for an inpatient. In addition to image acquisition, machine-time includes patient transfer to the room and CT table, positioning and centering, patient connection to the injection pump, as well as disconnection after the injection, transfer from the CT room to the booth/preparation room, and time to re-organize the room for the following patient.

Even with the standardization of the examination time by the hierarchy, it was observed variations depending on the type

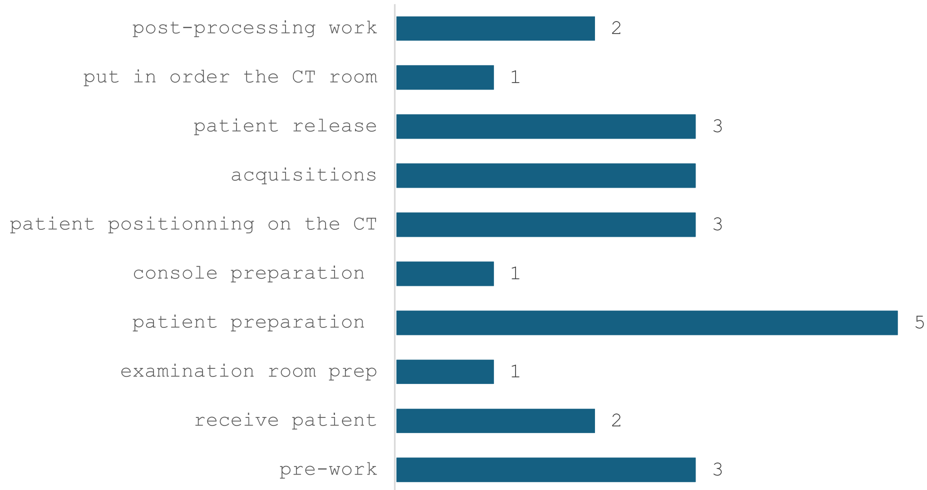

Fig. 4. Observed timing (minutes) and distribution of radiographer's activities for outpatients considering 24 min of activity.

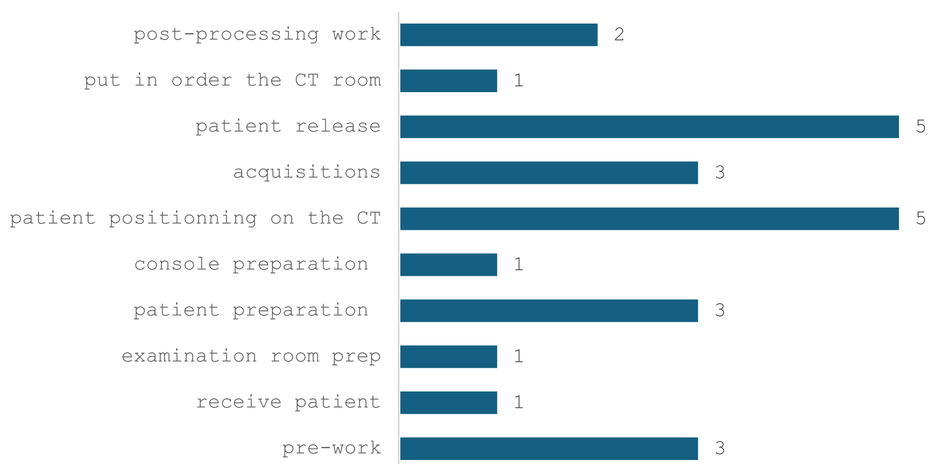

Fig. 5. Observed timing (minutes) and distribution of radiographer's activities for inpatients considering 25 min of activity.

Table 2
Timing per type of examination and type of patient.

Type of CT examination	Inpatient	Outpatient	Acquisition time
Chest-abdomen-pelvis	*25 min*	*20 min*	*1* min *46 s*
Abdominal	*24 min*	*20 min*	*1* min *20 s*
Head	*5 min*	*4 min*	*31 s*
Upper/lower limb	*5 min*	*5 min*	*45 s*

of examination and the type of patient (Table 2). The average acquisition time for a CT scan of the head was 31 s, while for a chest-abdomen-pelvis CT lasted 1 min and 46 s. However, when considering the total examination time (from the patient's arrival until they leave the CT room), it was 25 min for an inpatient and 20 min for an outpatient considering chest-abdomen-pelvis CT examinations. CT scans of the limbs were faster, with an average acquisition time of 45 s and a total examination time of 5 min for both types of patients.

Nevertheless, the survey showed that radiographers find this time too short. In fact, in the comments collected it is written: "the change to 15 min increases the risk of error because we have to work even faster to keep up with the pace and the hazards of the day (delays, examinations longer than expected, added examinations, etc. ….)".

Safety

To ensure patient safety, the radiographer needs to check information and procedures before, during, and after the acquisition process. These checks begin with patient identification and the verification of patient's safety questionnaire, while during the acquisition, the focus is on the exposure parameters selection considering the application of radiation protection principals.

In terms of radiographer's safety, it has been observed that there is a risk associated with needle manipulation during catheter's placement when preparing the patient for the contrast media injection. As the space for patient preparation was limited, the radiographer's movements also posed a risk of contamination and/or needlestick injuries during catheter insertion. Due to the limited space in the preparation booths, radiographers adopt inappropriate postures, which can increase the risk of work-related musculoskeletal disorders (WRMDs).

Before the acquisition, when positioning the patient over the CT table, it was also observed a potential risk of mishandling bedridden patients. Although radiographers often take precautionary measures when handling patients, like seeking assistance from other colleagues, they were sometimes alone with the patient, mainly due to the busy schedules of their colleagues, necessitating to handle solo patient transfers.

This is also reflected in the survey since 16/18 radiographers mentioned experiencing back pain. Regarding workload, 15/18 participants indicated that the number of patients they handle is not optimal, 16 feel that their workload is not appropriate. One of the radiographers mentioned in the comments that "during the night, the workload is high for a single radiographer, and patient transfers are difficult and unsafe because there are no available colleagues to help".

Moreover, a significant gap in disinfection practices was observed. Although hospital protocols mandate thorough disinfection after each patient encounter, consistent non-compliance was noted, particularly in the preparation cabins within the CT department. Armrests used during catheterization were often not sanitized regularly, increasing the risk of transmitting healthcare-associated pathogens. This issue was also evident in radiographers' workflow: while they consistently organized and cleaned the CT room between patients, the preparation cabins were rarely given the same level of attention.

Discussion

The aim of this study was to identify the organizational, spatial, and temporal elements that can affect workload, and contribute to patient and radiographer safety during CT examinations.

The results of this study, are supported by previous research [22] as well as the SEIPS model, emphasizing the critical need for providing ergonomic spaces to ensure the safety and well-being of radiographers, since their safety can impact on patient's safety as well. The observations conducted during the study revealed that the patient and examination preparation were the activities requiring more time from radiographers, due to the lack of an ergonomics design. As a result, radiographers adopt awkward positions during the catheterization on the patient. The awkward postures present potential to increase the risk of work-related musculoskeletal disorders (WRMSDs) [14]. Consequently absenteeism can occur, impacting even more the workload of the other members of the team since they need to perform their normal work plus the work attributed to the absent colleague [31–33].

Regarding organizational components, a thorough exploration of the radiographer's workflow is essential to identify any obstacles that may obstruct their work and develop strategies to mitigate these obstacles [33]. Effective scheduling practices also play a vital role in implementing a safe workflow, as time pressure has been shown to negatively impact both patients and radiographers [19]. Therefore, the implementation of efficient scheduling systems is crucial to mitigate the detrimental effects of time pressure and ensure the well-being of both patients and radiographers. Otherwise, there is a risk of rushing through the examination, potentially compromising safety by increasing the risk of musculoskeletal disorders, if the scheduling is not adequate [14].

Improving these components will positively impact the radiographer's workflow by streamlining it. Studies have shown that radiographers in CT units have a multitude of tasks to perform during an examination. Being able to carry out these tasks without interruptions will significantly reduce the turnover time [34–36].

This study reports a total time duration of 24 min for outpatients and 25 min for inpatients (average duration of all observed types of examinations), from pre-work to patient release. Similarly, other studies [34,37] found that radiographers need between 22 and 27 min to successfully complete all the tasks before moving on to the next patient.

In all components assessed, time is the constraining factor. In fact, time influences the organization of the service, which tends to create a workflow allowing to perform as many examinations as possible. Although this system allows for a large number of examinations to be performed, it has the drawback of increased potential of causing harm to patients and staff safety. As mentioned earlier, in CT, these harms frequently occur due to the time pressure experienced by radiographers. As a result, the radiographers' physical and psychosocial health can also be affected, which may impact on patient and radiographer safety [38].

To meet time constraints, radiographers often modify their workflow, compromising certain tasks, leading to disparities between prescribed and actual work. This adaptation is evident during patient reception, particularly in the anamnesis process where verifying patient identity takes precedence over obtaining clinical history—despite the latter being emphasized by the hierarchy [39]. Similarly, during the explanation of the examination process, radiographers neglect communicating with patients undergoing CT scans, disregarding the importance of effective communication highlighted by Newell and Jordan [39] for patient-centered care and safety.

A noticeable gap is also evident in disinfection practices. While hospital hygiene protocols recommend thorough disinfection after each patient encounter, our study identified consistent non-compliance, particularly in the inconsistent disinfection of the patient preparation cabin. This lapse, including the irregular sanitization of patient-used armrests during catheterization, poses a potential risk for the transmission of healthcare-associated pathogens, aligning with other findings identifying MIDs as potential reservoirs for such infections [40,41].

Furthermore, discrepancies between prescribed and real work arise in patient handling. Despite the availability of supportive equipment to assist and training for the professionals, observations reveal that some radiographers still choose for less time-consuming, manual handling methods on multiple occasions. This practice, not only threatens the radiographers' wellbeing by putting their backs at risk but also increases the likelihood of work-related illness, injury, and absenteeism [14]. Prioritizing safe patient handling practices and ensuring that prescribed time is enough for utilizing available assistive devices are essential to ensure patient safety and maintain the quality of care provided by radiographers.

Considering the observed context, recommendations can be provided, namely to improve the time allocation and efficiency of CT room management. Firstly, it is recommended to address the issue of time pressure by increasing the machine time allocated for each patient to 16.5 min. This can be achieved by extending the working day by 1 hour (7AM to 6PM instead of 7.30AM to 5.30PM). Allowing more time for each examination, radiographers will be able to perform their duties without rushing, ultimately leading to improved patient care and safety [7]. Secondly, it is crucial to consider the divergence in examination durations for different types of scans. To accommodate these variations, it is recommended to adapt the schedule accordingly. For outpatient appointments, the following time-machine durations are suggested: allocate 5 min for a head CT, 20 min for a chest-abdomen-pelvis CT, and 10 min for upper and lower limb CT scans. These adjusted durations reflect the necessary time required to conduct the examinations by specificity, ensuring safety [37].

Furthermore, for inpatient examinations, it is important to account for factors such as mobility and potential complexities. Thus, it is recommended to increase the examination duration by 5 min compared to the outpatient appointments. Specifically, for inpatient CT scans, allocate 10 min time-machine for a head CT, 25 min for a chest-abdomen-pelvis CT, and 15 min for upper and lower limb CT scans. These adjusted durations can allow for a comprehensive and safe examinations tailored to the needs of inpatients.

Additionally, to avoid potential difficulties or complications with patients who deviate from the standard protocols, it is recommended to assign a dedicated radiographer for each working day. This radiographer would be responsible for reviewing the examination requests/clinical question 5 to 7 days in advance and rechecking them 24–48 h before the scheduled examination. This proactive approach ensures that any special requirements or deviations from the standard protocols can be identified and addressed in a timely manner. By having a designated radiographer responsible for this task, potential issues can be anticipated and solved, leading to a smoother and more efficient workflow, improved patient experiences, and reduced risks of errors or misunderstandings [42].

Providing an ergonomic working space for radiographers, in this specific setting, to perform their tasks adequately and safely, involves having a sufficient and spacious preparation area that allows for proper positioning. It is also vital to maintain a working environment free from obstacles such as cables on the floor, which pose a risk of falling [43].

The implementation of this recommendations should contribute to a more realistic and efficient time allocation within this CT department. By reducing time pressure, improvements on patient care and better CT outcomes will be easier to achieve respecting the safety of patients and healthcare workers.

Limitations

The study provides valuable insights into the workflow in a CT department, but few limitations should be acknowledged. Firstly, this exploratory research was conducted in only one CT department, which limits the generalizability of the findings to other departments or settings.

Additionally, the study focused exclusively on the perspective of the radiographers and did not consider the patients' perspectives, other healthcare providers, or hospital managers. As a result, the study may have overlooked other important factors that contribute to the discrepancies between prescribed and real work in a CT department, such as organizational or system-level issues, patient preferences and specific needs (e.g. autistic persons, cognitive impaired-persons) [14,44–46], or financial constraints.

Despite these limitations, the study provides a valuable insight into the challenges faced by radiographers in meeting the demands of increasing CT examination volumes and highlights the importance of understanding the gap between prescribed work and real work to contribute to improve patient safety and patient care quality. Further studies are recommended to analyse other CT department layouts and contexts to be possible a data generalization, as well as the identification of the most suitable work strategies to eliminate hazards and reduce risks, contributing to improve work safety.

Conclusions

This study has identified the key organizational and spatial components that are crucial for ensuring the quality of a CT department including the improvement of safety for both patients and radiographers. An efficient schedule that considers the type of examination, patient characteristics (age and mobility), and unexpected incidents (e.g., protocol of examination missing) is essential.

The findings of this study highlight the inadequacy of the standard 15-minute machine time to conduct quality and safe work, emphasizing the need for a more realistic and efficient time allocation. Increasing the machine time or planning examination durations based on the type of scan are solutions proposed for a better time rate management.

Acknowledgements

The authors would like to acknowledge the support and help obtained from all radiographers working in the CT department included in this study.

References

[1] Itri JN, Bakow E, Woods J. Creating an outpatient center of excellence in CT. *J Am Coll Radiol*. 2014;11(12):1137–1143. doi:10.1016/j.jacr.2014.08.032.
[2] Office fédéral de la statistique. Équipement médico-technique des hôpitaux et des cabinets médicaux en 2019. Bundesamt für Statistik (BFS): 2021.
[3] Ugwu A. Psychosocial stress and its predictors among radiographers in south-eastern. *Nigeria*. 2011;49(2).
[4] Hutton D, Eddy A. How was it for you? What factors influence job satisfaction for band 5 and 6 therapeutic radiographers. *Radiography*. 2013;19(2):97–103. doi:10.1016/j.radi.2012.10.002.
[5] Hutton et Eddy 2013 How was it for you what factors influence job sat.pdf n.d.
[6] Saparniene et al. 2023 Working environment of health care professionals –.pdf n.d.
[7] Reiner B.I., Siegel E.L. Reengineering workflow: a focus on personnel and process. In: Dreyer KJ, Thrall JH, Hirschorn DS, and Mehta A, editors. *PACS*, New York: Springer-Verlag; 2006, p. 73–95.
[8] Anzai Y, Heilbrun ME, Haas D, Boi L, Moshre K, Minoshima S, et al. Dissecting costs of CT study: application of TDABC (Time-driven activity-based costing) in a tertiary academic center. *Acad Radiol*. 2017;24(2):200–208. doi:10.1016/j.acra.2016.11.001.
[9] Whitaker S, Cox WAS. An investigation to ascertain whether or not time pressure influences the accuracy of final year student radiographers in abnormality detection when interpreting conventional appendicular trauma radiographs: a pilot study. *Radiography*. 2020;26(3):e140–e145. doi:10.1016/j.radi.2019.12.010.
[10] Siewert B, Brook OR, Mullins MM, Eisenberg RL, Kruskal JB. Practice policy and quality initiatives: strategies for optimizing staff safety in a radiology department. *RadioGraphics*. 2013;33(1):245–261. doi:10.1148/rg.331125174.
[11] Carter JB, Banister EW. Musculoskeletal problems in VDT work: a review. *Ergonomics*. 1994;37(10):1623–1648. doi:10.1080/00140139408964941.
[12] Cernean N, Serranheira F, Gonçalves P. Sá Dos Reis C. Ergonomic strategies to improve radiographers' posture during mammography activities. *Insights Imaging*. 2017;8(4):429–438. doi:10.1007/s13244-017-0560-7.
[13] Costa S, Oliveira E, Reis C, Viegas S, Serranheira F. Mammography equipment design: impact on radiographers' practice. *Insights Imaging*. 2014;5(6):723–730. doi:10.1007/s13244-014-0360-2.
[14] Fernandes K, Sá Dos, Reis C, Serranheira F. Radiographers' musculoskeletal health in Western Switzerland: wRMSDs symptoms prevalence and risk factors. *Work*. 2023;74(4):1527–1537. doi:10.3233/WOR-211379.
[15] Ofori-Manteaw B.B., Antwi W.K., Arthur L. Ergonomics and occupational health issues in diagnostic imaging: a survey of the situation at the korle-bu teaching hospital 2015.
[16] Whitaker et Cox 2020 - An investigation to ascertain whether or not time pdf n.d.
[17] Hu Y, Wang D, Pang K, Xu G, Guo J. The effect of emotion and time pressure on risk decision-making. *J Risk Res*. 2015;18(5):637–650. doi:10.1080/13669877.2014.910688.
[18] The influence of time pressure on adherence to guidelines in primary care: an experimental study. 2013.
[19] Tsiga et al. 2013 The influence of time pressure on adherence to gui.pdf n.d.
[20] Carayon et al. 2006 Work system design for patient safety the SEIPS m.pdf n.d.
[21] Carayon et al. 2013 Macroergonomics in health care quality and patient.pdf n.d.
[22] Hignett S, Lu J. Review of current ergonomic methods for assessing exposure to whole-body vibration and proposed guidelines for assessment of motion sickness in ride comfort testing. *Int J Ind Ergon*. 2003;31(5):283–297 n.d.. doi:10.1016/S0169-8141(02)00144-6.
[23] Gustavson et al. 2012 Attrition and generalizability in longitudinal stu.pdf n.d.
[24] Pollien et al. 2020 Preparation of survey data.pdf n.d.
[25] REGULATION (EU) 2016 679 of the European P.pdf. 2016.
[26] Hyman - open- versus close-ended survey Questions.pdf. 2016.
[27] Spradley 2011 - The ethnographic interview.pdf n.d.
[28] Spriestersbach et al. 2009 Descriptive Statistics.pdf n.d.
[29] Raskind et al. 2019 A review of qualitative data analysis practices in.pdf n.d.
[30] Vankipuram et al. 2018 A method for the analysis and visualization of cli.pdf n.d.
[31] Pallotta OJ, Roberts A. Musculoskeletal pain and injury in sonographers, causes and solutions. *Sonography*. 2017;4(1):5–12. doi:10.1002/sono.12093.
[32] Krishnan KS, Raju G, Shawkataly O. Prevalence of work-related musculoskeletal disorders: psychological and physical risk factors. *Int J Environ Res Public Health*. 2021;18(17):9361. doi:10.3390/ijerph18179361.
[33] Goyal N, Jain N, Rachapalli V. Ergonomics in radiology. *Clin Radiol*. 2009;64(2):119–126. doi:10.1016/j.crad.2008.08.003.
[34] Boland et al. 2008 Maximizing outpatient computed tomography producti.pdf n.d.
[35] The role of the radiographer in computed tomography imaging.pdf. 2017.
[36] Impact of Preprocedure Time-Out Checklist for Computed Tomography-Guided Procedures on Workflow and Patient Safety. 2019.
[37] Rachh P, Pendley AM, Duong PAT, Hanna TN, Heilbrun ME. Decreasing ct acquisition time in the emergency department through lean management principles. *Radiographics*. 2021;41(3):E81–E89. doi:10.1148/rg.2021200107.
[38] Carayon et al. 2014 Human factors and ergonomics as a patient safety p.pdf n.d.
[39] Newell et Jordan 2015 The patient experience of patient-centered communi.pdf n.d.
[40] Ilyas F, Burbridge B, Babyn P. Health care–associated infections and the radiology department. *J Med Imaging Radiat Sci*. 2019;50(4):596–606 e1. doi:10.1016/j.jmir.2019.07.011.
[41] Kramer A, Schwebke I, Kampf G. How long do nosocomial pathogens persist on inanimate surfaces? A systematic review. *BMC Infect Dis*. 2006;6(1):130. doi:10.1186/1471-2334-6-130.
[42] Sheth S, Mudge B, Fishman EK. The pre-CT checklist: a simple tool to improve workflow and patient safety in an outpatient CT setting. *Clin Imaging*. 2020;66:101–105. doi:10.1016/j.clinimag.2020.05.014.
[43] World health organization healthy workplaces: a model for action: for employers, workers, policy-makers and practitioners. *Ambient Trab Saludab Un Modelo Para Acción Para Empleadores Trab Autoridades Norm Prof*. World Health Organization; 2010.
[44] Stogiannos N, Harvey-Lloyd JM, Brammer A, Cleaver K, McNulty JP, Dos Reis CS, et al. Toward autism-friendly magnetic resonance imaging: exploring autistic individuals' experiences of magnetic resonance imaging scans in the United Kingdom, a cross-sectional survey. *Autism Adulthood*. 2023;5(3):248–262. doi:10.1089/aut.2022.0051.
[45] Stogiannos N, Pavlopoulou G, Papadopoulos C, Walsh G, Potts B, Moqbel S, et al. Strategies to improve the magnetic resonance imaging experience for autistic individuals: a cross-sectional study exploring parents and carers' experiences. *BMC Health Serv Res*. 2023;23(1):1375. doi:10.1186/s12913-023-10333-w.
[46] Carlier S, Vorlet P, Sá Dos Reis C, Malamateniou C. Strategies, challenges and enabling factors when imaging autistic individuals in Swiss medical imaging departments. *J Med Imaging Radiat Sci*. 2023;54(4):S53–S63. doi:10.1016/j.jmir.2022.11.002.