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AWARENESS OF EMPLOYEES AT THE FACULTY OF HEALTH SCIENCES
ABOUT THE NATIONAL BREAST SCREENING PROGRAM

RADIOGRAPHERS AND WORKPLACE VIOLENCE – A SYSTEMATIC REVIEW

COMPARISON OF DIGITAL AND ANALOGUE PET/CT:
A SYSTEMATIC REVIEW AND META-ANALYSIS

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5

Erna Alukic, Zala Blazun, Katja Gartner, Nejc Mekis

**AWARENESS OF EMPLOYEES AT THE FACULTY OF HEALTH SCIENCES ABOUT
THE NATIONAL BREAST SCREENING PROGRAM**

10

Laura Dolenc, Pia Fenko, Karmen Veis, Tina Starc

RADIOGRAPHERS AND WORKPLACE VIOLENCE – A SYSTEMATIC REVIEW

18

Nina Leskovar, Sebastijan Rep

**COMPARISON OF DIGITAL AND ANALOGUE PET/CT:
A SYSTEMATIC REVIEW AND META-ANALYSIS**

Spoštovani kolegi,

z veseljem vam predstavljam najnovejšo številko revije Medical Imaging and Radiotherapy Journal (MIRTJ), letnik 41 (2024). Skupaj z uredniškim odborom z veseljem nadaljujem poslanstvo revije pri spodbujanju kakovostnih raziskav ter razvoju novih idej na področju radiološke tehnologije.

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Dear colleagues,

It is my great pleasure to present the latest issue of the Medical Imaging and Radiotherapy Journal (MIRTJ), Volume 41 (2024). Together with the Editorial Board, I am delighted to continue the journal's mission of encouraging high-quality research and fostering new ideas in the field of radiological technology.

We highly value your ongoing support and invite you to keep spreading the word about our journal and encouraging your colleagues to submit their research contributions. For Slovene authors, we continue to provide free translations into English to make the path toward international recognition and publishing easier. MIRTJ remains freely accessible to all readers through our website and indexed databases. We warmly invite you to browse the latest issue and review the submission guidelines on our website: <http://mirtjournal.net/index.php/home>.

Thank you for your ongoing support.

Sincerely,
Alenka Matjašič

Editor-in-Chief
Medical Imaging and Radiotherapy Journal (MIRTJ)

Original article

AWARENESS OF EMPLOYEES AT THE FACULTY OF HEALTH SCIENCES ABOUT THE NATIONAL BREAST SCREENING PROGRAM

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ABSTRACT

Purpose: The aim of the study was to determine the level of awareness of the DORA screening programme (mammography) among female employees of the Faculty of Health Sciences in Ljubljana.

Methods: In the first part of the study, a descriptive method with a literature review was used. In the second part of the study, a quantitative method was used with the help of a pilot questionnaire. The Chi-square test and Fisher's exact test were used to statistically analyse the samples obtained, depending on the sample size.

Results and discussion: A total of 94% of the women surveyed, between whom there were no statistically significant differences in terms of age, educational level and workplace, had already participated in the DORA screening programme. All women surveyed were aware of the DORA screening programme and its purpose. The level of awareness of the risk factors for breast cancer was moderate. However, only 58% of women reported performing self-examinations, while 20% had never performed one. Our results suggest that the women in this study have a greater awareness of breast cancer screening than the women studied in other countries, and this awareness has increased over time. Although the level of awareness among members of Faculty of Health Sciences is moderate (the average of correct responses was 78%), many of the women surveyed are still not sufficiently aware of the importance of early detection of breast cancer. We believe that knowledge could be improved through the organisation of individual lectures and the increased promotion of screening programmes.

Conclusion: We found that women are well informed about the purpose and methods of the screening programme, but less so about risk factors. Knowledge about the screening programme may lead to earlier detection, and faster and more successful treatment.

Keywords: screening programme, DORA, awareness, breast cancer, mammography

IZVLEČEK

Namen: Namen raziskave je bil ugotoviti, kakšna je ozaveščenost zaposlenih žensk na Zdravstveni fakulteti v Ljubljani o presejalnem programu DORA.

Metode: V prvem delu raziskave je bila uporabljena deskriptivna metoda s pregledom internetne in knjižnične literature. V drugem delu raziskave je bila uporabljena kvantitativna metoda s pomočjo pilotnega anketnega vprašalnika. Za statistično analizo pridobljenih vzorcev smo uporabili Hi kvadrat test in Fisherjev Exact Test, odvisno od velikosti vzorca.

Rezultati in razprava: 94 % anketiranih žensk, med katerimi ni bilo statistično značilnih razlik v starosti, stopnji izobrazbe in delovnem mestu, je že sodelovalo v presejalnem programu DORA. Vse anketirane ženske so vedele, kaj je presejalni program DORA in čemu je namenjen. Stopnja ozaveščenosti o dejavnih tveganja za raka dojke je bila zmerna. Vendar pa je le 58 % žensk poročalo, da so opravljale samopregledovanje, medtem ko jih 20 % ni nikoli opravilo samopregledovanja. Naši rezultati kažejo, da se ženske v tej študiji bolj zavedajo presejalnih testov za raka dojke v primerjavi z ženskami, ki so bile vključene v raziskavah v drugih državah, prav tako je opažen porast ozaveščenosti skozi leta. Čeprav je stopnja ozaveščenosti zaposlenih na Zdravstveni fakulteti zmerna (povprečje pravih odgovorov je 78 %), se mnoge anketirane ženske še vedno premalo zavedajo pomena zgodnjega odkrivanja raka dojke. Menimo, da bi lahko znanje izboljšali z organizacijo individualnih predavanj in večjo promocijo presejalnih programov.

Zaključek: Ugotovili smo, da so ženske dobro ozaveščene o namenu in metodah presejalnega programa, slabše pa o dejavnih tveganja. Znanje o presejalnem programu lahko pripomore k bolj zgodnjem odkrivanju, hitrejši obravnavi in uspešnejšemu zdravljenju.

Glavne besede: presejalni program, DORA, ozaveščenost, rak dojke, mamografija

INTRODUCTION

Cancer screening programmes are a public health measure in which people without clinical problems are examined. These women may have a pre-invasive or early invasive form of cancer or simply be exposed to some risk factor. None of the screening programmes make a definitive diagnosis. Screening detects abnormalities, while additional diagnostic tests allow us to make a diagnosis (1,2).

Screening tests are performed at the initiative of the individual or their doctor. They can also be organised at the level of the population. In the case of organised screening tests, the at-risk population is invited to be screened through personal invitations or promotional materials in the form of public information (1).

The main objective of the national cancer control programmes in Slovenia is to detect precancerous changes in the cancer spectrum at an early stage of development. Slovenia has several programmes: ZORA (National Screening Programme for the Detection of Precancerous Changes in the Cervix), SVIT (National Programme for the Prevention and Early Detection of Precancerous Changes and Cancer of the Colon and Rectum) and DORA (National Screening Programme for Breast Cancer) (3).

The DORA national breast cancer screening programme has been active in Slovenia since 2008 and functions in accordance with European guidelines for ensuring the quality of breast cancer screening and diagnostics. For a screening programme to be effective, at least 70% of the target population must participate, as stipulated by European guidelines. In 2023, participation in the DORA screening programme was 77% (4,5). Breast cancer screening is the examination of apparently healthy women without clinical problems (1). Screening mammography is the most commonly used method of breast cancer screening worldwide. Other methods include breast self-examination, ultrasound, digital tomosynthesis, magnetic resonance imaging, the identification of certain genetic oncogenes and clinical examinations (6). Screening mammography reduces breast cancer mortality by 20% to 35% in women aged 50 to 69 years (7). The main benefits of breast cancer screening programmes are early the detection of changes, and the classification and prevention of risk factors, resulting in less extensive treatment, faster recovery, better survival, lower mortality and timely treatment of the disease (6). In Slovenia, the DORA (DORA = Dojka (breast) + Rak (cancer)) screening programme was launched for the early detection of breast cancer. The aim of the programme is to detect breast cancer as early as possible in the screened population and reduce mortality from this type of cancer (8). In 2023, the DORA programme was implemented using 22 digital mammograms at locations throughout Slovenia, including 13 stationary, 3 dislocated and 3 mobile units (4).

The DORA programme is aimed at women between the ages of 50 and 69, as they are most likely to develop breast cancer during this period. In 2019, the DORA programme detected breast cancer in 625 women in Slovenia who had accepted the invitation even though they were convinced they were healthy. A total of 107,887 mammograms were performed in 2019 (9).

The aim of our study was to determine the level of awareness of the breast cancer and the screening mammography programme among female employees (academic and non-academic) at the Faculty of Health Sciences at the University of Ljubljana, Slovenia.

METHODS

A quantitative method of data collection was carried out in the form of a survey. We surveyed female employees at the Faculty of Health Sciences. The survey was sent to 95 working women at the Faculty of Health Sciences via the Dean's Office. The period for data collection and the survey was one month. The questionnaire was sent out at the beginning of January 2021 and a reminder was sent out a week later. A total of 53 women responded. Of all completed questionnaires, 50 were valid, which corresponds to a response rate of 52.6%.

The questionnaire was created using the Google Forms platform. It contained demographic and DORA questions. The questionnaire was tested and customised. The questionnaire was completely anonymous and the results were used exclusively for the preparation of this paper.

After reviewing the literature, we found certain levels of knowledge in an article on the awareness of female health workers in Saudi Arabia (13). We adapted these to our circumstances and established the following levels:

- Up to 50% correct answers = poor level of awareness
- 50% - 70% correct answers = moderate level of awareness
- 70% - 90% correct answers = good level of awareness
- Over 90% correct answers = excellent level of awareness

To determine the level of awareness, the answers to the following questions were used:

- What is the main purpose of the DORA screening programme?
- What is the DORA programme for?
- What is the method used for the early detection of precancerous lesions in the DORA programme?
- What are the risk factors for cancer?
- How often do you perform breast self-examinations?

To conduct the questionnaire, we first obtained permission from the Dean of the Faculty of Health Sciences. The data obtained was statistically analysed using Microsoft Excel (Microsoft, USA) and IBM SPSS Statistics V. 25 (IBM, USA) and compared to the research questions. The Chi-square test was used for the statistical analysis. In cases where fewer than five people belonged to a group, Fisher's exact test was used.

RESULTS

Below are the results of the survey, which are divided into different chapters: Demographic data analysis, mammography awareness, and screening programme surveys by age, education and work position.

Analysis of demographic data

The survey contained the demographic questions. Respondents were asked about their age, education and work position.

As the figure below shows, most women between the ages of 50 and 59 participated in the survey, i.e. 20 people, which corresponds to 40% of all women who participants. The smallest percentage was women between the ages of 60 and 69 (8%), while the other age groups were women between the ages of 40 and 49 (28%), those between the ages of 30 and 39 (14%), and women under 30 (10%).

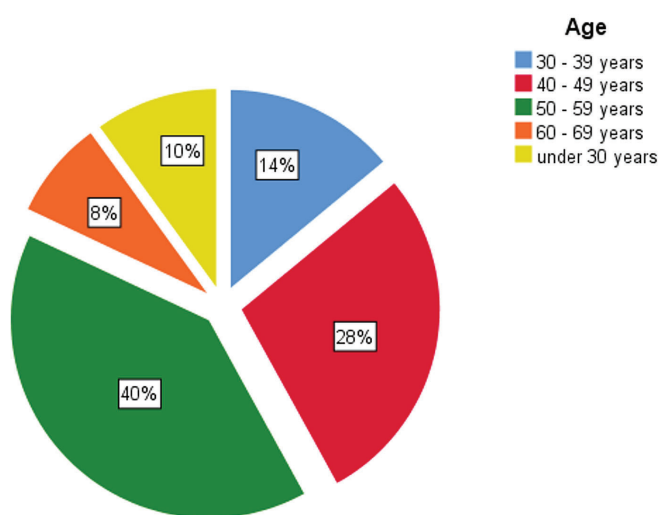


Figure 1: Age of respondents

The highest percentage of respondents have a master's degree (42%), while 28% of women have a doctorate and 26% have a university degree. A total of 4% of the women have a primary or secondary school degree. Some 74 % of the women surveyed work in a teaching position, while the rest work as support staff.

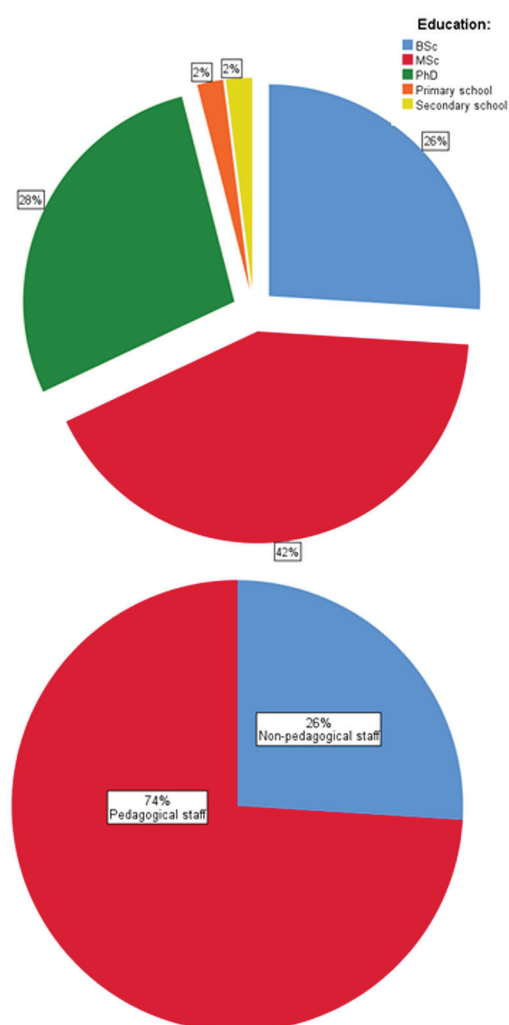


Figure 2: Education (left) and work position (right) of the respondents

Awareness of mammography and examinations for the DORA programme

The survey asked questions such as what the DORA programme is, who it is for, what diagnostic imaging is used to detect cancerous changes, what the risk factors are and whether women self-examine.

All respondents (100%) knew what the DORA programme is and that its aim is to detect precancerous lesions at an early stage, regardless of age, education level and work position.

Most respondents (96%) knew that the DORA programme uses mammography as an imaging diagnostic procedure.

Respondents were generally aware of the risk factors. Only one woman gave one of the two incorrect answers. Only eight women (16%) marked all the risk factors correctly at the same time. The others chose the correct answers, but not all of them together.

A total of 58% of respondents perform self-examination as often as recommended, while 10% perform self-examination once a year and 12% perform them five times a year. A somewhat worrying finding is that five (20 %) women answered that they never perform breast self-examinations.

Of the 50 women surveyed, 47 (94%) have responded or will respond to the invitation to the DORA programme. Two women have not responded to the invitation and one woman does not yet know if she will respond when she receives the invitation.

We also compared the answers to the questions between women of different ages, education and professional status. The questions for which there were differences in the answers are analysed below.

Age

When asked which age group the DORA programme is intended for, we found little difference between the responses: 98% of women answered that the programme is intended for women over 50, while 2% of women answered the question incorrectly.

When asked which diagnostic imaging technique is used to detect precancerous lesions, 4% of women answered incorrectly (one woman under 50 and one over 50). The answer they marked as correct was ultrasound. The rest (96%) answered the question about the diagnostic imaging used in the DORA programme correctly.

The question about risk factors was answered correctly slightly more often by women over 50.

However, all women over 50 surveyed examine their breasts frequently (once a month or five times a year), while some women under 50 examine their breasts less frequently (29% of women under 50). A total of 24% of women over 50 and 16.7% of women under 50 have never self-examined their breasts. From this we can conclude that more women in the over 50 age group carry out the recommended self-examination than in the under 50 age group.

For the first two questions, women over 50 responded slightly better, but the differences are not statistically significant for any of the questions (Fisher's exact test, $p > 0.05$).

Education

When asked which age group the DORA programme is intended for, only one woman (2%) with a college or university education answered incorrectly.

When asked about the type of diagnostic imaging used in the DORA programme, two women answered incorrectly, one (2%) with a master's degree and one (2%) with a college or university degree.

All risk factors were correctly reported by five women (10%) with a master's degree, one (2%) with a doctorate and two (4%) with a college or university degree.

The largest percentage of women with a doctorate perform a self-examination once a month (71.4%). This also applies to women with a master's degree (61.9%). One woman (7.1%) with a doctorate and two women (9.5%) with a master's degree have never performed a self-examine. The same number of women with higher education undergo a self-examination once a month or never (38.5% each). A total of 100% of women with secondary education do not perform self-examination, while 100% of women with primary education perform self-examination once a month. From this we can conclude that women with higher education perform self-examination more frequently. For women with primary and secondary education, the sample is too small for comparison.

When analysing the data and checking the correct answers to the questions, we found that there are no statistically significant differences between women with different levels of education (Fisher's exact test, $p > 0.05$).

Work position

A woman from the support staff answered the question of which age group the programme was aimed at incorrectly.

One educational staff member and one support staff member answered the question about the method of detecting precancerous lesions incorrectly.

All correct risk factors were selected by 13.5% of educational staff and 23% of support staff, meaning support staff scored slightly better on this question.

The largest proportion of both groups examined their breasts once a month.

DISCUSSION

We set ourselves the goal of determining the general level of awareness of screening mammography. When asked about the purpose of the screening programme, the correct answer is that it is for the early detection of precancerous lesions and is intended for breast cancer. Women between the ages of 50 and 69 are screened using mammography. The level of awareness of these four questions is excellent, with more than 90% of respondents answering correctly.

When asked about the frequency of breast self-examination, the answer was that it is recommended once a month. This answer was given by 58% of women. According to these answers, awareness is moderate (between 50% and 70% of correct answers).

In terms of the risk factors, only eight women selected all the correct answers. This corresponds to 16% of the correct answers and thus a low level of awareness of the risk factors (up to 50% of the correct answers).

On average, 78% of all questions were answered correctly. This corresponds to a good level of knowledge among all working women at the Faculty of Health Sciences (between 70% and 90% correct answers).

In a comparison of similar studies, we found that women employed at the Faculty of Health Sciences in 2021 were better informed than women in the general population in a 2014 thesis, which showed that 57% of the women surveyed were aware of the DORA national screening programme and 83% of women were informed about the purpose of the national programme (10).

Results similar to our study were found in a study conducted by the University of Malaysia in 2017 (11). In 2017, the University of Malaysia conducted a survey of 100 non-teaching staff. The study found that most non-academic staff had average knowledge of breast cancer and screening, which could be due to possible easy access to information. A correlation was also found between the age and education level of respondents and knowledge about breast cancer. Respondents with a secondary level of education were more likely to perform clinical breast examinations than their counterparts with a tertiary level of education. Low breast screening success rates were also cited, likely due to lack of awareness and misconceptions about the need for and benefits of such screening (11).

The results of our study are significantly better than surveys conducted in the United Arab Emirates in 2013 (12) and Saudi Arabia in 2018 (2), as our study shows a generally good level of knowledge, while in the two foreign surveys mentioned, only 5% (United Arab Emirates) and 6% (Saudi Arabia) of respondents were well informed. The authors from the United Arab Emirates state that the reason for these low results could be the difficult language and mistrust of the healthcare system.

A comparison of a slightly older survey conducted in Canada in 2005, which surveyed 180 women from the general population aged 25 to 45 (14), found that women employed at the Faculty of Health Sciences are better informed. While they note that half of the participants did not know how to perform a breast self-examination and many participants did not know enough about the risk factors, the results are difficult to compare with the survey conducted 16 years ago when the screening programme was not as well developed.

The biggest advantage of our study is that we now know how well informed the women at the Faculty of Health Sciences are. Based on the results, we can improve the situation through lectures and other projects. According to the literature review, our study is one of two surveys on this topic in Slovenia and will help to compare and monitor awareness in other similar studies in the future. The disadvantage of our study is the insufficient sample of respondents and thus the difficult and poor comparison between different groups. With such a small sample, it was difficult to compare the results with other similar surveys in Slovenia and abroad due to large differences in the number of respondents. If the survey was conducted again, a larger number of people would be interviewed. We would also include a few more questions in the survey, both demographic questions and questions about the DORA screening programme and breast cancer.

CONCLUSION

Breast cancer is one of the most common cancers in women. To detect cancer more quickly, women should have their breasts examined regularly every month and undergo clinical examinations and diagnostic tests, such as ultrasound and mammography, if they detect changes or have a hereditary predisposition. With the screening programme, we try to detect precancerous changes, which contributes to faster and more successful treatment.

The aim of our study was to determine the level of awareness of the DORA screening programme among women employed at the Faculty of Health Sciences and to compare the results by specific groups. Using a survey and data processing, we found that women were well informed about some topics (general topics) and poorly informed about others (risk factors). More than half of the women undergo a breast self-examination once a month, while 20% of the women have never done so, which corresponds to a moderate level of knowledge. Overall, we found that the women were well informed about the DORA programme. There were no statistically significant differences when comparing different groups (work position, age, education).

In our opinion, women are well, but not yet sufficiently informed about the importance of cancer prevention and the risk factors that significantly influence the development of cancer. To improve this, the educational and non-educational staff of the Faculty of Health Sciences could be offered additional training, lectures and other opportunities to raise awareness about breast cancer.

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Review article

RADIOGRAPHERS AND WORKPLACE VIOLENCE – A SYSTEMATIC REVIEW

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ABSTRACT

Purpose: The aim was to investigate workplace violence affecting radiographers by examining forms of violence, perpetrators, vulnerable groups, risk factors and responses. This article provides recommendations to reduce workplace violence and explores whether country-specific conditions influence the occurrence of violence among radiographers.

Methods: A systematic literature search was conducted via Google Scholar, PubMed, Springer Link and ScienceDirect, and focused exclusively on studies involving radiographers and the incidence of violence against them. Included documents were available entirely in English and Slovene.

Results: From a total of 4,512 results, we selected 11 articles based on the exclusion criteria. We categorised them by author, title, year of publication, country of publication, number of participants, purpose, working methods and findings.

Discussion and conclusion: Verbal abuse, especially by patients, is the most common form of violence faced by radiographers, with women and those with less experience being most at risk. Key risk factors include long waiting times, staff shortages and substance abuse. While many radiographers ignore these incidents, others report them to their superiors or family. The consequences are often depression, anxiety, reduced work performance and in some cases even suicidal thoughts. Suggested solutions include hiring more staff, introducing safety protocols and running awareness campaigns. The economic conditions of the country and the hospital environment also play an important role in workplace violence, with low wages and poor conditions exacerbating the problem. Understanding this violence is important for developing prevention strategies and ensuring a safe workplace.

Keywords: workplace violence, radiographer, mobbing, aggression

IZVLEČEK

Namen: Namen raziskave je bil raziskati nasilje na delovnem mestu, s katerim se soočajo radiološki inženirji, ter preučiti oblike nasilja, storilce, ranljive skupine, dejavnike tveganja in odzive. Članek vsebuje priporočila za zmanjšanje nasilja na delovnem mestu in raziskuje, ali razmere v državi vplivajo na pojav nasilja med radiološkimi inženirji.

Metode: Sistematično iskanje literature je bilo opravljeno s pomočjo podatkovnih baz Google Scholar, PubMed, Springer Link in ScienceDirect, pri čemer smo se osredotočili izključno na študije, ki vključujejo radiološke inženirje in pojavnost nasilja nad njimi. Vključeni dokumenti so bili v celoti na voljo v angleškem in slovenskem jeziku.

Rezultati: Izmed 4512 rezultatov smo na podlagi izključitvenih meril izbrali 11 člankov. Razvrstili smo jih po avtorju, naslovu, letu objave, državi objave, številu udeležencev, namenu, metodah dela in ugotovitvah. Razprava in zaključek: Verbalna zloraba, zlasti s strani pacientov, je najpogostejša oblika nasilja, s katero se srečujejo radiološki inženirji, pri čemer so najbolj ogrožene ženske in tisti z manj izkušnjami. Ključni dejavniki tveganja so dolge čakalne dobe, pomanjkanje osebja in zloraba drog. Mnogi radiološki inženirji te incidente ignorirajo, drugi pa o njih poročajo nadrejenim ali družini. Posledice so pogosto depresija, tesnoba, slabša delovna učinkovitost in v nekaterih primerih celo samomorilne misli. Predlagane rešitve vključujejo zaposlitev večjega števila osebja, uvedbo varnostnih protokolov in izvajanje kampanj za ozaveščanje. Pomembno vlogo pri nasilju na delovnem mestu imajo tudi gospodarske razmere v državi in bolnišnično okolje, saj k temu prispevajo nizke plače in slabi pogoji. Razumevanje tega nasilja je pomembno za razvoj strategij preprečevanja in zagotavljanje varnega delovnega mesta.

Ključne besede: nasilje na delovnem mestu, radiološki inženir, mobing, agresija

INTRODUCTION

Workplace violence is defined as any incident in which a person is insulted, threatened or assaulted in the context of their work; this can include verbal abuse, threats and physical attacks (1). Violent behaviour is distinguished from other forms of maladaptive behaviour by the intention to cause distress, discomfort, pain or injury to another living being. Violent behaviour can be directed against oneself, others or the environment. Inwardly directed violence can lead to self-harm, while outwardly directed violence can lead to damage to others, objects and property (2).

Healthcare workers are important to society as a whole. Due to their importance and the nature of their work, they are exposed to various forms of violence. It can be perpetrated by medical staff, patients themselves, the patient's family, companions, colleagues and superiors (3). Violence by patients or visitors against healthcare workers can take many forms. In the most basic explanations, violence can take the form of verbal threats and aggressive language, or escalate to physical assault. Violent behaviour can occur in all areas of patient care, regardless of the setting. However, most cases are reported by paramedics, emergency departments and inpatient psychiatric facilities (4). The most common risk factors for patient violence are the presence of mental illnesses such as dementia and schizophrenia, drug and alcohol abuse, and weapon possession. Common causes of violence are the stress of coping with an illness, disagreement with a treatment plan and long waiting times (5). Violence by family members against healthcare professionals is most often due to restrictions on visiting the patient, coping with a prognosis and grieving a patient's death (6). Family members often run out of time to communicate or feel that they are not given enough attention. They may also have unrealistic and thus excessively high expectations regarding the course of treatment and the outcome of an illness, and are uncritical of the need for treatment and the actual state of health of the person they are accompanying or seeking information about. The aim was to explore the issue of workplace violence among radiographers, i.e. what types of violence occur, who perpetrates it, which groups of radiographers are more vulnerable, risk factors, the reactions and consequences of violence, suggestions for reducing violence and whether country-specific conditions have an impact on the occurrence of workplace violence among radiographers.

METHODS

A systematic review of literature regarding violence against radiographers was conducted. We searched for literature and scientific articles that were available in full text in English or Slovene. The focus was on articles dealing with workplace violence involving radiographers internationally.

References of the documents

Firstly, we selected the keywords that matched the title of the search. Where necessary, we used Boolean operators (AND/OR). We conducted our search using PubMed, Springer Link and ScienceDirect.

Methods used to identify documents

All articles were retrieved using the following keywords: workplace violence, healthcare, radiographer OR radiological technologist, bullying OR workplace violence. The documents found were assessed by their titles and summaries. Any documents deemed irrelevant to the review were excluded. When reviewing the studies, we ensured that only radiographers were involved. We strove to obtain the broadest possible range of countries in which studies were conducted. All duplicate documents were eliminated. All articles were then read. The criteria for an article's inclusion in the analysis were articles published between 2005 and 2024, articles published in English or Slovene, articles that were available in full text and articles that addressed the topic of violence against radiographers in the workplace. Exclusion criteria were all articles published before 2005, articles that were not published in English or Slovene, articles that were not accessible in full text, articles whose topic did not concern violence against radiographers in the workplace and duplicate studies.

RESULTS

Applying all inclusion and exclusion criteria, we found a total of 4,512 articles: 1,419 in the PubMed database, 463 in ScienceDirect, 2,630 in Google Scholar and 148 in Springer Link. After eliminating duplicates, we were left with 632 articles. After reviewing the titles and abstracts, we were left with 28 articles that we read in detail. We used 11 articles for the final analysis. To achieve a better overview, we created a flowchart, which is shown in Figure 1.

After analysing the articles and conducting a systematic review, the results were categorised according to the types of violence, the perpetrators and the groups of radiographers who are more prone to violence, factors contributing to violence, reactions and consequences, and suggestions for reducing violence. We also aimed to investigate whether country-specific conditions have an impact on the occurrence of workplace violence among healthcare professionals.

Figure 1: Flow chart of included studies

Table 1: Main features of studies included in the analysis

Research	Country	Number of participants	Aim of the study	Research method and equipment	Results and conclusions
Ng et al., 2009: Workplace violence – A survey of diagnostic radiographers working in public hospitals in Hong Kong (7)	Hong Kong	150 radiographers from seven regional hospitals in Hong Kong	To assess the prevalence of workplace violence involving radiographers in Hong Kong, to evaluate underlying factors and their impact, and to propose improvements in the management and training of radiographers.	Quantitative study, survey questionnaire	<p>More than half of radiographers have experienced violence in the past three years.</p> <p>The most common form was verbal abuse from patients, followed by physical violence.</p> <p>Main causes of violence: long waiting times, communication issues and staff shortages.</p> <p>Negative consequences of violence: increased work stress, higher absenteeism, and depression.</p> <p>Suggested improvements: enhancing communication, increasing staff, and raising awareness about workplace violence issues.</p>
Reem et al., 2011: Workplace Violence – A Survey of Diagnostic Radiographers in Ismailia Governorate Hospitals, Egypt (8)	Egypt	94 radiographers from hospitals in Ismailia	To determine the prevalence, types, and perpetrators of violence, as well as risk factors for violent incidents against radiographers and the impacts they have, with the aim of developing suggestions for appropriate preventive measures.	Cross-sectional study, survey questionnaire	<p>The majority of radiographers have experienced violence, mostly verbal abuse, less often physical violence, and rarely sexual violence.</p> <p>Perpetrators of violence are most often the patient's relatives, less frequently the patients themselves, and occasionally superiors or colleagues.</p> <p>Risk factors: insufficient staff, long waiting times, inadequate staff training on the topic, and the influence of alcohol and drugs.</p> <p>Most radiographers reported the incident to a superior, while a minority attempted to defend themselves.</p> <p>Consequences of violence: lack of motivation to work, recurring headaches, job dissatisfaction, and concentration difficulties.</p>
Chinene et al., 2022: Disruptive behaviours involving radiographers that impede a survey at central hospitals in Harare Metropolitan Province, Zimbabwe safe work environment (9)	Zimbabwe	102 radiographers from Harare Metropolitan province	To determine the frequency and types of violent behaviour against radiographers in Harare, Zimbabwe, to understand this issue from radiographers' perspective and to identify the perpetrators of such behaviour.	Quantitative study, survey questionnaire	<p>More than 8 out of 10 radiographers have experienced violence, most commonly verbal abuse, followed by sexual and physical violence.</p> <p>Perpetrators of violence are primarily relatives, as well as other healthcare workers.</p> <p>Suggested improvement guidelines: implementing appropriate educational campaigns and establishing security protocols.</p>
Youngblood et al., 2021: Bullying in the Nuclear Medicine Department and During Clinical Nuclear Medicine Education (10)	United States of America (USA)	113 radiographers from the email database of the Nuclear Medicine Technology Certification Board in the USA	To examine the occurrence and impact of violence in nuclear medicine departments during clinical training, gain insight into workplace bullying, and propose measures to reduce it, with the aim of improving satisfaction among employees and students.	Quantitative study, survey questionnaire	<p>Approximately 70% of radiographers reported experiencing at least one form of bullying, most commonly verbal abuse, discrimination, ignoring, and constant criticism.</p> <p>The higher the job position of the person, the greater the likelihood of experiencing bullying.</p> <p>Suggested measures: establishing clear anti-bullying protocols and promoting a positive work culture.</p>

Research	Country	Number of participants	Aim of the study	Research method and equipment	Results and conclusions
Sethole et al., 2019: Workplace Abuse: A Survey of Radiographers in Public Hospitals in Tshwane, South Africa (11)	South Africa	37 radiographers from Tshwane, South Africa	To determine the prevalence of work-related abuse of radiographers, examine types of violence, and identify perpetrators. To gather empirical evidence on the occurrence of violent incidents, raise awareness and develop measures to manage violence effectively.	Quantitative study, survey questionnaire	<p>Verbal abuse was the most prevalent form of violence, followed by emotional abuse.</p> <p>The most common perpetrators of violence were patients, who were predominant as the perpetrators of physical violence.</p> <p>Colleagues of radiographers were predominant as the perpetrators of verbal and emotional abuse.</p> <p>The study suggests conducting additional research to assess the effects of violence and to compare the prevalence and impact of violence in private and public hospitals.</p>
Amkongo et al., 2019: Workplace violence involving radiographers at a state radiology department in Windhoek Namibia (12)	Namibia	13 radiographers from a hospital in Windhoek	To determine the frequency of violence against radiographers, identify the perpetrators, and assess the emotional state and coping mechanisms following experienced violence.	Quantitative study, survey questionnaire	<p>More than half of radiographers have experienced workplace violence: mostly threats, while a minority have been victims of physical attacks and stalking.</p> <p>The perpetrators were mostly patients or their relatives, as well as colleagues.</p> <p>The most frequent victims were radiographers aged 36 to 40, with the incidence decreasing with age.</p> <p>More than half of the cases of violence were not reported. In most cases, victims felt anger, anxiety, humiliation, and fear after the incident.</p>
Turk B, 2010: Mobing med radiološkimi inženirji po Sloveniji/ Mobbing among radiographers in Slovenia (13)	Slovenia	113 radiographers	To present a study on the prevalence, causes and consequences of mobbing.	Quantitative study, survey questionnaire	<p>Eighteen out of 113 radiographers have experienced bullying. Most frequently, it involved verbal abuse and humiliation, often perpetrated by doctors.</p> <p>The causes include a hierarchy with poor communication and the undervaluation of staff</p> <p>The consequences of bullying are a decline in work self-esteem, concentration and memory disturbances, and it can lead to suicidal behaviour.</p> <p>Most affected radiographers turned to their superiors for help; some attempted to talk to the person who was bullying them, while others took no action at all. Among all radiographers who approached their superiors, more than half reported that no action was taken.</p>
Magnavita et al., 2012: Violenza I: Prevalenza e misure preventive contro i radiologi (14)	Italy	992 radiographers	To assess the prevalence of violent behaviour toward radiologic engineers (REs) in Italy, analyse the consequences of violence and propose preventive measures.	Quantitative study, survey questionnaire	<p>More than half of radiographers have experienced workplace violence, mostly threats, while a minority have been victims of physical attacks and stalking.</p> <p>The perpetrators were primarily patients or their relatives, as well as colleagues. In the vast majority of cases, the perpetrator was male.</p> <p>Victims of violence were of both genders, with no significant difference. The most common victims were radiographers aged 36 to 40, with the incidence decreasing with age.</p>

Research	Country	Number of participants	Aim of the study	Research method and equipment	Results and conclusions
Tohidnia et al., 2019: Incidence rate of physical and verbal violence inflicted by patients and their companions on radiology department staff of educational hospitals of the medical university, Kermanshah (15)	Iran	121 radiographers	To investigate the causes and incidence of violence against radiographers in radiology departments.	Quantitative study, survey questionnaire	<p>Among 121 radiographers, 88% have experienced workplace violence (verbal abuse).</p> <p>In most cases, the perpetrators of violence were middle-aged relatives of patients.</p> <p>The majority of victims were female, under 40 years old, and had less than 5 years of experience in a clinical environment, occurring during night shifts.</p> <p>The study found that the causes of violence were primarily overcrowding of patients in the department, inadequate security services and an insufficient number of radiographers.</p>
Caruana, E., 2005: Radiographers at risk of assault (16)	Australia	41 radiographers	To gain insight into the frequency and nature of violence and identify contributing factors. To review measures for addressing and preventing violence, and develop a strategy to reduce the risk of workplace violence.	Quantitative study, survey questionnaire	<p>The majority of radiographers have been exposed to verbal abuse from patients and their relatives, with reports of physical violence as well.</p> <p>The main causes of violence include long waiting times, poor communication from radiographers and a lack of respect for healthcare workers.</p> <p>Measures: training for radiographers on early warning signs and techniques for managing conflict situations.</p>
Chinene et al., 2022: Antecedents of disruptive behaviours involving radiographers at central hospitals in Harare Metropolitan Province, Zimbabwe (17)	Zimbabwe	100 radiographers from Harare province	To determine the frequency, causes and factors influencing disruptive behaviour among radiographers.	Quantitative study, survey questionnaire	<p>The most common form of violence was verbal abuse. The most frequent perpetrators of violence were patients, followed by colleagues.</p> <p>The study suggests improving the work environment by enhancing working conditions and reducing waiting times for patients.</p> <p>Findings indicate that a leadership style based on bullying is one of the predisposing factors for the occurrence of workplace violence.</p>

The studies included in our findings examined violence against radiographers, and focused on types of violence, perpetrators, which groups of radiographers are more vulnerable, risk factors for the occurrence of violence, and radiographers' responses and the impact of violence. In all but one study, data collection was conducted using questionnaires, while one study used a systematic literature review. The research participants were all radiographers, and the studies involved radiographers from different workplaces in different countries.

DISCUSSION

The purpose of the research was to examine workplace violence against healthcare professionals, focusing on types of violence, perpetrators and risk factors, as well as the impact on victims and prevention strategies. Findings revealed verbal abuse as the most common form, primarily perpetrated by patients or their relatives, often leaving significant effects on mental health and work performance.

Risk factors, reactions to violence and the consequences thereof

Various studies have been conducted to understand the risk factors that contribute to workplace violence and their impact on radiographers. Long waiting times, communication problems and staff shortages are the main causes of workplace violence in radiology departments. Alcohol and drug abuse are also associated with a higher incidence of violence (7). Easy access, overcrowding, noise, understaffing and inadequate security services are important risk factors for workplace violence (8). Important risk factors also include patients under the influence of alcohol, work in emergency departments and dealing with patients with mental health problems (18). Frustration due to poor working conditions, long waiting times for patients, burnout or fatigue and a dysfunctional organisation are factors that contribute to violence against radiographers (9). Although the risk factors identified in these studies vary, certain patterns emerge again and again. Common factors include long waiting

times, inadequate security, understaffing, and the influence of alcohol and drugs, all of which are associated with higher rates of workplace violence.

Further research is therefore essential to understand and combat workplace violence in radiology departments. An in-depth investigation and understanding of these risk factors can lead to the development and implementation of effective prevention strategies and policies that ensure a safe working environment.

Inaction was a common response to experiencing workplace violence (7, 18). Radiographers often ignored verbal violence, suggesting that they saw it as an integral part of their work. In some cases, they defended themselves verbally or asked the attacker to stop. In the case of physical violence, victims were more likely to defend themselves physically or seek help from colleagues. It was found that the type of violence influenced the radiographers' reactions. Those who had already experienced violence considered it unavoidable, while others believed it could be prevented. Only a minority of respondents felt that support from the department was adequate or that they were aware of existing policies on violence. Up to 90% of staff had not received any training (7). They also mentioned sharing experiences with colleagues and family members, reassuring perpetrators, seeking help from colleagues, self-defence, anger and seeking legal action as coping strategies against workplace violence (18). On the contrary, some radiographers did not ignore the violence, with most reporting the incident to a supervisor or security, while a minority attempted to defend themselves. The vast majority also felt that the incidents could have been prevented, but none reported seeking psychiatric help or resorting to alcohol. There were few cases of violence reported to the authorities, emphasising the need for improved measures to prevent and treat such incidents (8). Some participants felt degraded and humiliated by negative comments, while others reported this to the head of the department. However, action was taken in only one case. Some remained calm and professional and controlled their emotions, while others felt strong emotions such as shock, disgust, anger and the desire for revenge (11). It is evident that the type of response to each type of harassment and violence plays a key role, including the sensitisation and education of radiographers and all staff in health facilities, and that the consequences for the perpetrator can be clearly determined in relation to the violence (12).

Negative consequences included depression and anxiety, as well as a lack of willingness to work. Violence also reduced enthusiasm for work, increased sick leave, work stress and job dissatisfaction. (7). Radiographers suffered from severe headaches, concentration problems, increased irritability, forgetfulness, and a decrease in energy and self-esteem. A minority also experienced prolonged sick leave as a result of violent incidents (8, 18). Many lost enthusiasm and commitment to their work, leading to absenteeism, low morale and stress (11). One respondent was even driven to suicide due to violence (13). In addition to reduced concentration, lower job satisfaction, an increased desire to leave the workplace, burnout, and physical and mental health problems, they also reported poorer work skills and less empathy towards patients. For example, almost half of respondents reported that they or others had cared less about patient care after experiencing or witnessing violence (10). Although the physical injuries

associated with violent incidents are usually only moderately severe, the emotional consequences are much more intense and can lead many victims to want to change careers. This raises the question of the potential impact of these acts of violence on the psychophysical well-being of those affected, on their stress levels and job satisfaction, on their clinical and diagnostic skills and on their commitment to their work (14). Similarly, a lack of willingness to work and reduced enthusiasm for the job could increase sick leave and reduce the quality of services, which could further exacerbate the problems of understaffing and increase pressure on staff (7).

Suggestions for reducing violence

Some possible improvements to reduce violence in the workplace include improving communication between employees, increasing staffing levels and implementing violence prevention measures by introducing additional protocols (7). It is important to conduct awareness campaigns, establish safety protocols, increase the presence of security personnel and engage more with different occupational groups (9). The way in which education providers and organisations deal with violence in the workplace can significantly reduce the incidence and impact of violence. Students and employees must be educated about workplace violence, engaged in discussions about it and encouraged to overcome the barriers of shame and embarrassment that prevent them from gaining the necessary skills and confidence to report incidents. When there is a culture of violence in the workplace, patient care is jeopardised and teamwork on the ward is undermined; when care is inadequate, it is the patients who suffer the consequences (10). It has been suggested that more questionnaires based on the WHO (World Health Organisation) Workplace Violence Questionnaire and training on early warning signs of violent behaviour and techniques to manage conflict situations should be provided. Encouraging reporting of any incident and offering support to victims is crucial (18).

Do country-specific conditions influence the incidence of workplace violence among radiographers?

Differences in the survey results on workplace violence can be attributed to differences between countries, levels of healthcare services, professions and patient characteristics. Hospital factors, such as geographic location, size and population, also affected the level of violence. Larger hospitals that serve more patients and populations with less education and lower socioeconomic status tend to experience higher levels of workplace violence, especially in high-intensity areas such as emergency departments and psychiatric wards (8). Zimbabwe, a third-world country, faces serious problems of workplace violence, including against radiographers. Workers face equipment shortages, understaffing and low wages, which leads to frustration and increases the potential for violent behaviour. Low wages are a major factor influencing the behaviour of health workers, even though a safe working environment is provided. The government often uses intimidation in collective bargaining, which further increases tensions. Poor working conditions lead to low morale, stress and dissatisfaction among workers (17).

CONCLUSIONS

The results show that verbal violence is the most common form of violence experienced by radiographers, while physical and sexual violence are less common. The most common perpetrators are patients or their family members, with men being more frequent perpetrators. Younger radiographers with less experience are more vulnerable to violence. Key risk factors include long waiting times, inadequate security, understaffing and alcohol abuse. Radiographers react differently to violence: some ignore it, others seek help from supervisors or security, and others seek support from family members. Violence often leaves lasting effects on mental health such as depression, anxiety and reduced work performance. Given the severity of the problem, measures to improve safety and working conditions are suggested, such as more staff, better communication and conflict management training. Studies also show that poor working conditions, such as low wages, increase the risk of violence, as the case of Zimbabwe shows. It is therefore necessary to develop preventive strategies and measures that protect the health of radiographers and improve working conditions. Almost all articles point out that violence against radiographers is a growing problem, which requires greater awareness of the issue during training and employment. This is the only way to develop effective strategies for the early detection and prevention of violence against radiographers.

A recommendation for further research would be to conduct a survey to determine the level of violence among Slovenian radiographers.

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Review article

COMPARISON OF DIGITAL AND ANALOGUE PET/CT: A SYSTEMATIC REVIEW AND META-ANALYSIS

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ABSTRACT

Introduction: Digital PET/CT detectors are the latest technology in positron emission tomography, where the analogue photomultiplier tube has been replaced by much smaller silicon photomultipliers. These systems allow single photons to be detected with high sensitivity and low noise.

Purpose: The aim of this study was to present digital PET/CT by a systematic literature review, to describe how it compares with analogue systems and to detail the advantages and disadvantages of digital PET/CT scanners.

Methods: Literature was selected according to inclusion and exclusion criteria, focusing only on English-language articles.

Results: The results are presented in two parts. The first part shows the flow of the literature review schematically and the process of how the final number of articles included in the analysis was determined. In the second part, the selected literature was analysed according to the characteristics of the sample, purpose and findings. The literature includes research conducted on phantoms and patients in a clinical setting. The analysis of the articles showed that the digital PET/CT system offers better image quality than analogue PET/CT, the more accurate detection of smaller lesions, in particular, and the possibility of capturing diagnostically useful images while reducing the data acquisition time.

Discussion and conclusion: Most studies focused on exploring the differences in the technical capabilities of a digital system compared to an analogue system. The studies describe the improved image quality of the digital system, which is already noticeable from a subjective visual assessment. Various analyses have demonstrated improved spatial resolution and signal-to-noise ratio, and improved TOF and SUV. The lesion detection capabilities of digital systems have improved significantly, resulting in greater accuracy in disease staging, prognosis and earlier detection. Studies have shown that digital devices also offer the possibility to reduce the time of data acquisition and the activity of the radiopharmaceutical administered, which is particularly useful in specific clinical circumstances requiring faster examinations.

Keywords: digital PET/CT, analogue PET/CT, radiopharmaceutical, spatial resolution, sensitivity

IZVLEČEK

Uvod: Digitalni PET/CT detektorji predstavljajo najnovejšo tehnologijo v pozitronski emisijski tomografiji, kjer so analogne fotopomnoževalke nadomestili bistveno manjši silicijevi fotopomnoževalci. Ti sistemi omogočajo zaznavanje posameznih fotonov z visoko občutljivostjo in nizkim šumom.

Namen: Namen dela je predstaviti digitalni PET/CT s sistematičnim pregledom literature, opisati njegovo primerjavo z analognimi sistemi ter podrobneje predstaviti prednosti in slabosti digitalnih PET/CT skenerjev.

Metode: Literatura je bila izbrana glede na vključitvene in izključitvene kriterije, pri čemer so bili upoštevani le članki v angleškem jeziku.

Rezultati: Rezultati so predstavljeni v dveh delih. Prvi del shematsko prikazuje potek sistematičnega pregleda literature in proces, kako je bil določen končni nabor člankov, vključenih v analizo. V drugem delu smo izbrano literaturo analizirali glede na značilnosti vzorca, namen in ugotovitve. Literatura vključuje raziskave, izvedene na fantomih in pacientih v kliničnem okolju. Analiza člankov je pokazala, da digitalni PET/CT v primerjavi z analognim omogoča boljše kakovost slike, natančnejše zaznavanje manjših lezij ter pridobivanje diagnostično uporabnih slik ob krajšem času zajema podatkov.

Razprava in zaključek: Večina študij se je osredotočila na raziskovanje razlik v tehničnih zmogljivostih digitalnih sistemov v primerjavi z analognimi. Študije opisujejo izboljšano kakovost slik digitalnih sistemov, kar je opazno že pri subjektivni vizualni oceni. Različne analize so pokazale izboljšano prostorsko ločljivost in razmerje signal-šum ter boljše TOF in SUV vrednosti. Zmožnost zaznavanja lezij pri digitalnih sistemih se je bistveno izboljšala, kar omogoča večjo natančnost pri stadiranju bolezni, prognozi in zgodnejšem odkrivanju. Raziskave so pokazale tudi, da digitalne naprave omogočajo skrajšanje časa zajema podatkov ter zmanjšanje aktivnosti apliciranega radiofarmaka, kar je še posebej koristno v specifičnih kliničnih okoliščinah, kjer so potrebne hitrejšje preiskave.

Ključne besede: digitalni PET/CT, analogni PET/CT, radiofarmak, prostorska ločljivost, občutljivost

INTRODUCTION

Nuclear medicine is an area of medical imaging diagnostics that helps diagnose and track the treatment of various diseases. It uses small amounts of radioactive substances called radiopharmaceuticals (RF) to assess body functions and structures. After the intravenous administration of RF, it accumulates in the organ under examination and releases radiation that is detected by radiation detectors, which in turn produce images of internal organs using software. Single-photon emission computed tomography (SPECT) and positron emission tomography (PET) are the most common methods in nuclear medicine (1, 2).

Positron emission tomography has seen many technological advances in the last decade, the most recent being the introduction of digital PET/CT detectors. This latest technology has the potential to have a very important clinical impact and could mean increased accuracy in diagnosis, staging and treatment monitoring in oncology (3).

PET is a nuclear medicine procedure used to assess the metabolism, physiology and biochemical properties of organs. The most commonly used RF in PET is [¹⁸F] fluorodeoxyglucose (FDG), which is used in oncology. Due to its higher metabolic activity, FDG is more intensely absorbed by cancer cells and appears as bright spots on images. The activity of regions of interest is measured using a standardised uptake value (SUV) calculated according to body weight, administered dose and time of administration (4). RF for PET decays by beta plus decay, producing positrons which, when combined with electrons, cause annihilation. This releases two gamma photons of 511 keV energy travelling in opposite directions. Detectors arranged around the subject detect the gamma rays. These react with the scintillation crystals, causing the emission of visible photons, which are converted into electrical signals by the photodetectors. These are computer processed to generate images of the RF distribution in the body (4).

PET is excellent for determining the metabolic activity of tissues, but has drawbacks such as low resolution and limited anatomical features, and needs CT or MRI to complement the information. The first integrated PET/CT machines appeared in the 1990s, with two CT scanners combined in a single gantry – CT in the front and PET in the back – and the examination table in the bay. These devices facilitate the fusion of functional and anatomical information, improving lesion location, diagnosis and accurate attenuation correction on PET images (5, 6).

The development of photomultiplier tubes (in 1934) and the discovery of the scintillation properties of the sodium-iodide NaI/Tl crystal (in 1948) enabled the advancement of ionising radiation detectors in nuclear medicine. The first PET detector (1961) used NaI crystals and photomultiplier tubes (PMTs). Later, Bismuth Germanium Oxide (BGO) crystals with block detectors and PMTs were introduced. With the advent of the LSO crystal, avalanche diodes (APDs) became of interest for their compatibility with MRI, but they remained in the shadow of PMTs and silicon photomultiplier tubes (SiPMs) due to their cost and slowness. Advances in single-photon avalanche photodiode (SPAD) technology have enabled

the development of digital SiPMs, which, in combination with lutetium oxyortho-silicate (LSO) and lutetium yttrium oxyortho-silicate (LYSO) crystals, are becoming standard in modern PET systems (7, 8).

Analogue detectors use scintillation crystals and PMTs, where light photons generate electrical pulses through the photoelectric effect and dynodes. Electron multiplication allows further data processing (4).

Digital detectors replace PMTs with smaller SiPMs composed of SPADs. These facilitate the detection of single photons using p-n junctions, where the photons are converted to an avalanche ionisation process that amplifies the signal and improves sensitivity and reduces noise (7, 8). The key parameters for PET image quality are: sensitivity, spatial and energy resolution, contrast resolution, signal-to-noise ratio (SNR), false event detection and time-of-flight (TOF). Their improvement is limited by technology and a trade-off is needed (9).

PURPOSE

The aim of this research was to present the difference between digital and analogue PET/CT, to identify its advantages and disadvantages, and to investigate how it affects the quality and interpretation of clinical images through a systematic review of literature.

METHODS

We used a descriptive method with a systematic literature review. We searched the worldwide web for peer-reviewed and scientific articles in various databases and journals such as PubMed, PubMed central, Journal of Nuclear Medicine (JNM), Google Scholar and Science Direct. The search and literature review were conducted from October 2022 to March 2023. The search focused on the following keywords: digital PET/CT, digital PET/CT advantages and disadvantages, analogue and digital PET/CT comparison, image quality in digital PET/CT, lesion detectability and digital PET/CT. In particular, we focused on articles comparing analogue and digital systems and on articles that investigated the impact of digital PET/CT on the quality of the examination and the images obtained, as well as the advances it represents in the diagnosis and follow-up of diseases.

The PRISMA method was used to provide a schematic representation of the databases used and to decide on the appropriateness of the sources.

RESULTS

Results of literature search

The results are presented in two parts. The first part presents the results of how articles were found for the systematic literature review. Figure 1 shows a schematic overview of the literature I reviewed for the thesis. I used the PRISMA method to schematically show the databases used and to decide on the relevance of the sources.

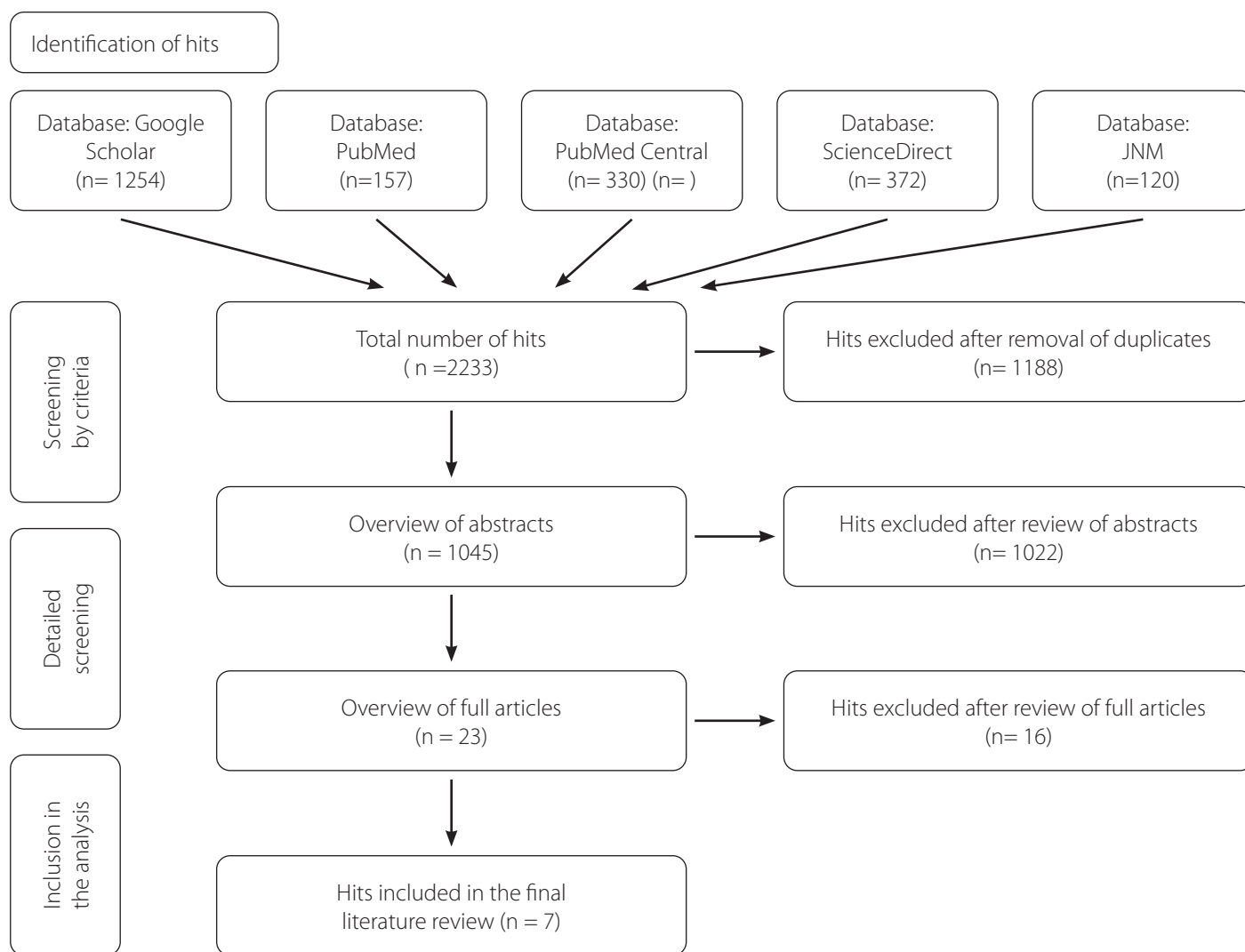


Figure 1: Schematic representation of the literature search shown using the PRISMA method

Results of the literature analysis

In the second part, we analysed seven articles involving research on phantoms and patients. One article included phantom-only research, two included both phantom and patient analysis, while four articles dealt with patients only. Most of the studies looked at the technical improvements of the digital system and how it compares with the analogue system. The results showed

the improved image quality of the digital system, especially in the detection of smaller lesions (less than 10 mm). Two studies also demonstrated that the digital system provides high-quality images with shorter acquisition times and potentially lower RF doses. Table 2 shows the characteristics, purpose and conclusions of the analysed articles.

AUTHORS, YEAR	SAMPLE CHARACTERISTICS	AIM	FINDINGS
1. (Delcroix et al., 2021)	<ul style="list-style-type: none"> – Comparison of digital and analogue PET/CT systems with [18F]FDG phantom. – 89 patients analysed using digital PET/CT. – Comparison of analogue reconstructions with three digital reconstructions (60 s/bp, 90 s/bp and 120 s/bp). – Evaluation of image quality, impact of ITM and lesion detection ability by three nuclear medicine specialists. 	The aim of the study was to assess the image quality and lesion detection of lesions obtained using digital PET/CT compared to a standard system.	<ul style="list-style-type: none"> – Digital reconstructions (60s, 90s and 120s) showed better MIP image quality, sharpness and lower noise than analogue reconstructions. – Improved image quality on digital PET/CT, irrespective of BMI. – Improved lesion detection capability on digital PET/CT, especially at longer acquisition times.

AUTHORS, YEAR	SAMPLE CHARACTERISTICS	AIM	FINDINGS
2. (López-Mora et al., 2019)	<ul style="list-style-type: none"> 100 patients included in the study. [18F]FDG administered to 94 patients, [18F] fluorocholine to 6 patients. Study performed on analogue and digital PET/CT after one RF application. Image quality assessed by three nuclear medicine specialists using a 4-grade scale (-1 - poor, 0 - fair, 1 - good, 2 - excellent). Counting of lesions with increased RF accumulation was performed by three nuclear medicine specialists. 	The aim of the study was to compare image quality and lesion detection ability between digital and analogue PET/CT.	<ul style="list-style-type: none"> Both systems detected lesions in 80 patients. dPET detected multiple lesions in 19 patients and additional lesions in 3 patients with negative aPET. Additional lesions detected on dPET were smaller than 1 cm. Image quality improved on dPET in 54% of patients.
3. (Alberts et al., 2021)	<ul style="list-style-type: none"> 21 patients with [18F]FDG on dPET were included. Data reconstructed for 2 min/bp, 1 min/bp and 30 s/bp. Images were assessed by two nuclear medicine specialists according to the number of pathological lesions detected. Measured SUVmax, SUVmean and TBR to assess lesion uptake. 	The aim of the study was to investigate the potential of shorter acquisition times (and thus dose reduction) for tumor detection and the impact on lesion contrast in digital PET/CT.	<ul style="list-style-type: none"> dPET identified 100 lesions at 2 min/bp and 1 min/bp, and 98 lesions at 30 s/bp. Average TBR slightly higher at 2 min/bp compared to 1 min/bp; no difference between 1 min/bp and 30 s/bp. SUVmean slightly higher at 2 min/bp than at 30 s/bp. SUVmax with no specific differences between the different capture times.
4. (Surti et al., 2020)	<ul style="list-style-type: none"> Study performed on aPET and dPET with two phantoms: a CTN (torso with lung simulation) and a cylindrical phantom (liver). Activities: 5.2 kBq/ml (CTN) and 5.3 kBq/ml (cylindrical phantom). Spheres of 4.95 mm and 9.89 mm diameter filled with 37-74 MBq to simulate lesions. 20 data sets divided into 10 acquisition times (6, 3, 2, 1.5, 1 and 0.5 min). Results estimated with ALROC matrix. 	The aim of the study was to examine the benefits and impact of the improved physical performance of digital PET/CT systems on clinical performance and lesion detection.	<ul style="list-style-type: none"> Higher sensitivity and improved TOF performance of the digital system. Reduced background noise and improved spatial resolution. Higher measured lesion contrast in the digital system. Higher ALROC of the digital system compared to the analogue system.
5. (Koopman et al., 2020)	<ul style="list-style-type: none"> 66 oncology patients with PET/CT performed on digital and analogue systems on the same day after one RF application were included. Calculated SUVmax, SUVmean, LBR (lesion/background), MTV and lesion diameter for each patient. Counted number of visible and measurable lesions. Images were assessed by two nuclear medicine specialists for image quality and diagnostic reliability (4-grade scale). 	The aim of this study was to evaluate the performance of digital PET/CT compared to analogue systems using HR reconstructions in patients with different types of cancer, and to investigate the impact of the digital PET system on the ability to detect lesions and the impact on TNM staging using semi-quantitative and visual assessments.	<ul style="list-style-type: none"> dPET detected 37 additional lesions in 27 patients that were not visible on the analogue system. SUVmean, SUVmax and LBR higher on dPET; MTV lower. Digital system images better in 65% of cases. Diagnostic reliability of both systems comparable.
6. (Kim et al., n.d.)	<ul style="list-style-type: none"> The study included 30 patients, imaged on dPET and aPET after one 18F-FDG application. The images were assessed by two specialists using a 5-point scale (1 = useless, 5 = perfectly useful). Number of visible lesions counted. Semi-quantitative analysis: measurement of SUV in background and hypermetabolic lesions. Objective assessment of image quality by signal-to-noise ratio (SNR) in the liver. 	The aim of this study was to assess the concordance and equivalence of results between dPET and aPET and to investigate possible differences using visual and semi-quantitative analyses.	<ul style="list-style-type: none"> dPET detected 4 additional lesions in 3 patients. Standard deviation of SUV values in background organs lower with dPET. Improved signal-to-noise ratio with dPET. No significant difference between SUVmax and SUVmean in background organs and lesions.
7. (Lasnon et al., 2020)	<ul style="list-style-type: none"> The study included 19 patients with dyspnea or pain and 9 pediatric patients. Acquisition time reduced from 2 min/bp to 1.5 min/bp. Standard reconstructions and reconstructions for 60s, 30s, 20s and 10s. Noise evaluated in liver, muscle and blood (aorta); TBR used. Five specialists assessed image quality, number of clinically relevant foci and anatomical regions in 60s to 10s reconstructions compared to 90s reconstruction (2 iterations, 20 subsets and PSF). 	The aim of the study was to find the shortest duration of data acquisition on a digital PET system in patients requiring fast FDG PET imaging without compromising image quality and lesion detection ability.	<ul style="list-style-type: none"> SNR at shorter acquisition times (90s and 60s) comparable to the 90s standard reconstruction. Noise reduced at shorter times by removing PSF and reducing the number of iterations to 1. Reconstruction for 10s showed more noise. 11% of patients had fewer lesions at 20s and 30s and 22% had fewer anatomical features than at 90s. No false positive lesions due to noise.

DISCUSSION

The aim of the study was to present the digital PET/CT system and to describe in more detail the advantages and disadvantages of modern digital devices and their clinical impact by means of a systematic review of literature.

We reviewed seven articles and seven different studies, respectively. Five of these investigated differences in the image quality and lesion detection ability of the digital system compared with the standard or analogue system. Two articles focused on the ability to reduce the data acquisition time of the digital system.

Lopez-Mora et al. (2019) found that 54% of patients had better image quality with the digital system, while the rest had no significant difference. The digital system detected more lesions in 19 patients, and in three patients, lesions not detected by the standard system were also detected. In seven patients, this meant a different disease stage. Digital PET improved the detection of lesions smaller than 1 cm, particularly in heterogeneous organs such as the liver (3).

Delcroix et al. (2021) performed a preclinical study using a phantom to determine equivalent parameters to ensure image quality comparable to an analogue system, despite the use of a digital one. They compared analogue and digital reconstructions at 60s, 90s and 120s. The results showed that the quality of the images is better on the digital system, with longer data acquisition times associated with better quality and greater lesion detection capability (10).

Surti et al. (2020) studied the advantages of digital PET/CT systems in lesion detection using ALROC metrics. They found that the digital system allows a 4- to 6-fold reduction in data acquisition time compared with analogue PET, with better detection of smaller lesions (diameter \geq 9.89 mm). The improved spatial resolution of the digital system leads to higher contrast and better quantification (11).

Koopman et al. (2020) found that the digital system detected more lesions than the standard system in 41% of cases and changed the TNM classification in 13%. Digital PET had better image quality scores, while the diagnostic reliability of the two systems was comparable. Most of the additional lesions (78%) were detected by digital PET when performed after analogue PET. Figure 5 shows a case of a patient with breast cancer where digital PET changed the stage of the disease (12).

Kim et al. (2020) investigated the differences between the two systems using visual and quantitative analyses. In three out of 30 patients, dPET detected more lesions than the standard system. The results showed that digital PET/CT systems provide better image quality, which was confirmed by visual assessment and improved signal-to-noise ratio (SNR) (14).

Alberts et al. (2020) investigated the possibility of reducing the time and dose administered with digital PET systems. They found a 98% correlation with 30s/bp for 2min/bp and 1min/bp times, while maintaining diagnostic utility, despite slightly lower image quality with shorter images. Shortening the time facilitated a 75% reduction in RF dose (14).

Lasnon et al. (2020) investigated the shortest data acquisition time on a digital system that does not compromise image quality and lesion detection. They found that a capture time of 30s/bp is suitable for patients requiring fast imaging, but this requires adjustments to the reconstruction parameters. Figure 6 shows an example of a patient with myeloma where the lesion is visible at both 90s and 30s reconstruction (15).

CONCLUSION

We have found that digital PET/CT represents a significant advance in molecular imaging, with many studies confirming its advantages over standard analogue systems.

Studies show the improved image quality of digital systems, which is already evident in the subjective visual assessment. Quantitative analyses have confirmed improved spatial resolution, sensitivity, TOF, signal-to-noise ratio and improved SUV. The focus is on improving the ability to detect smaller lesions, allowing more accurate staging and earlier detection of disease.

Digital devices also allow for a reduction in acquisition time and RF dose applied, which is useful in clinical situations requiring faster examinations. Shorter capture times reduce motion artefacts and allow for greater patient throughput, reducing waiting times. It is important to adjust parameters to achieve diagnostically useful data with minimum activity.

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