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THE EFFECTS OF FAMILY AND WORKPLACE ON THE BURNOUT LEVELS OF RADIOGRAPHERS WORKING IN ONCOLOGY PATIENT CARE

COMPARISON OF STANDARD DIAGNOSTIC AND RADIOTHERAPY PLANNING PROTOCOLS IN LUNG CANCER TREATMENT ON PET/CT SCANNER

ANODE HEEL EFFECT ATTENUATION IN LUMBAR SPINE RADIOGRAPHY: CAN THE USE OF ALUMINIUM FILTERS IMPROVE THE CLINICAL PRACTICE OF RADIOGRAPHERS?

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Slovenia
Tel.: 01/300-11-51
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E-mail: nejc.mekis@zf.uni-lj.si

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The articles are professional and scientific: results of research, technological assessments, descriptions of cases, etc.

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ANODE HEEL EFFECT ATTENUATION IN LUMBAR SPINE RADIOGRAPHY: CAN THE USE OF ALUMINIUM FILTERS IMPROVE THE CLINICAL PRACTICE OF RADIOGRAPHERS?

Dear colleagues,

We are introducing you to the second issue of the Medical Imaging and Radiotherapy journal, volume 37 (2020). The news about our journal has already spread across Europe, which is evident from the mentioned issue, as in addition to the article by Slovenian authors, there is also an article by Hungarian and an article by Portuguese authors. The journal remains free and freely available to all readers on the journal's website and in the databases that index the journal.

We invite you to view the journal's website, which is available at http://mirtjournal.net. On the mentioned website, you will find all the necessary information to prepare and submit the article.

On behalf of the Slovenian Society of Radiographers, I would like to thank all the radiographers who are professionally and proudly pursuing their vocation, despite the very difficult situation in the country and around the world caused by the COVID-19 pandemic.

Stay safe and healthy,

Nejc Mekis
Editor-in-chief of MIRTJ

Spoštovane kolegice in kolegi!

Pred Vami je druga številka revije Medical imaging and Radiotherapy journal, letnik 37 (leto 2020). Informacija o naši reviji se je že razširila po Evropi, kar je razvidno iz omenjene številke, saj sta poleg članka slovenskih avtorjev tudi članek Madžarskih in članek Portugalskih avtorjev. Revija še vedno ostaja brezplačna in prosto dostopna vsem bralcem na spletni strani revije in v bazah, ki revijo indeksirajo.

Vabimo vas, da si ogledate spletno stran revije, ki je dostopna na povezavi http://mirtjournal.net/index.php/home. Na omenjeni spletni strani najdete vse potrebne informacije za pripravo in oddajo članka.

V imenu društva bi se rad zahvalil vsem radiološkim inženirjem, ki trenutno profesionalno in s ponosom opravljajo svoj poklic, kljub zelo težkemu stanju v državi in po svetu, ki ga je povzročila pandemija COVID-19.

Ostanite varni in zdravi,

Nejc Mekiš
Glavni urednik MIRTJ

Original article

THE EFFECTS OF FAMILY AND WORKPLACE ON THE BURNOUT LEVELS OF RADIOGRAPHERS WORKING IN ONCOLOGY PATIENT CARE

Dávid SIPOS [1,2,3], Csaba VANDULEK [2], Attila András PANDUR [1], Péter KOVÁCS [2,3], Szabolcs CSEH [1], András KEDVES [1,2,3], József TOLLÁR [2,3], Árpád KOVÁCS [1,2,4], Imre REPA [1,3], Melinda PETŐNÉ CSIMA [1,5]

1 Doctoral School of Health Sciences, University of Pécs, Pécs, Hungary

2 Department of Medical Imaging, Faculty of Health Sciences, University of Pécs, Pécs, Hungary

3 Dr. József Baka Diagnostic, Radiation Oncology, Research and Teaching Center, "Moritz Kaposi" Teaching Hospital, Kaposvár, Hungary

4 Department of Oncoradiology, Faculty of Medicine, University of Debrecen, Hungary

5 Faculty of Pedagogy, Szent István University Kaposvár Campus, Kaposvár, Hungary

Corresponding author: Sipos Dávid; e-mail: cpt.david.sipos@gmail.com

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ABSTRACT

Purpose: The aim of the study was to explore the burnout rate of radiographers working in oncology patient care.

Materials and methods: Cross-sectional and targeted non-random sampling research was conducted from June 2018 to September 2018. We used the Maslach Burnout Inventory supplemented with our own questionnaire for online data collection. In addition to demographic aspects, we collected data on job characteristics to examine the predictors of burnout. Statistical analysis was performed using descriptive statistics. A two-sampled t-test, analysis of variance, the Mann-Whitney test and the Kruskal-Wallis test were used at a 95% confidence level (p=0.05).

Results: We analyzed data of 72 radiographers working in oncology patient care (n=72) and 332 radiographers working in other areas of patient care (n=332). The value of emotional exhaustion (p=0.001) was significantly higher in radiographers working in oncology patient care. Respondents who were single, provided monthly on-call duty and held university degrees showed signs of depersonalization (p=0.001). Having a second job, working over 40 hours per week and participating in on-call duty services had a negative effect on emotional exhaustion (p=0.001). The value of personal accomplishment (p=0.001) was significantly better in respondents with more than one child in their household. The subjective assessesment of poor financial status had a negative effect on all three dimensions of burnout (p=0.001).

Conclusion: The mean values of emotional exhaustion in radiographers working in oncology patient care increased significantly. The observed higher value of personal accomplishment demonstrates the positive feedback given by patients to radiographers.

Keywords: radiographer, burnout, oncology, Maslach Burnout Inventory

INTRODUCTION

Healthcare professionals are at an increased risk of burnout due to the nature of their work. In their roles, they consistently provide help and care to patients, which requires both emotional stamina and empathy. In order to perform their tasks smoothly, it is essential that they are able to make quick and definite decisions, whilst being professional in any situation. The nature of healthcare work presupposes effective collaboration amongst the healthcare staff, an appropriate level of communication and an empathetic approach towards patients (1).

Burnout

Burnout is defined in the following three dimensions: depersonalization, emotional exhaustion, and an identified sense of decreased personal accomplishment. Previous research in the service sector was based on the internationally validated Maslach Burnout Inventory (MBI), a questionnaire designed to measure the three above mentioned scales (2).

Depersonalization refers to an individual frequently feeling as if they are outside observers of their own lives. Individuals with a depersonalization disorder perceive their self-identity, body, and life in a distorted form that fills them with discomfort (3). Emotional exhaustion is the feeling when an employee is no longer able to provide more on a psychological level. An individual feels that they have reached the physical and emotional limit of their abilities. A sense of decreased personal efficiency results in individuals' negative evaluation of their performance. They might also view themselves as underperforming in comparison with their peers (3).

The emotional burden associated with the care of cancer patients and those with terminal conditions has been previously recognized among those working in oncology patient care. Based on the results of Dougherty et al., healthcare professionals working in acute and oncology patient care demonstrate higher workplace stress and lower job satisfaction rates than those working in other areas of healthcare. This suggests that workplace stress is influenced by the organization and culture of the work environment, and the nature of work. The results of the survey confirmed that high stress levels in acute oncology conditions are associated with a high workload and low control over the work environment (4,5,6,7).

Work-related stress can cause problems in patient care, either because the quality of the provided care deteriorates or because the overburdened healthcare workers' absences from work have a detrimental effect on the rest of the healthcare professionals as they experience an increased workload (8).

The incidence of cancer patients places an increased burden on patient care units (9). Due to complex oncology treatments and close monitoring of patients' health status, healthcare professionals working in oncology patient care are at a particular risk of work-related stress and burnout (10,11).

Recent reviews of burnout suggest that the theoretical foundations of research in the field of oncology need to be strengthened, and that future work should focus more on organizational factors for burnout prevention (12). Burnout can have serious consequences such as substandard performance of health care, effects on the work environment including reduced working hours, taking work breaks more frequently, or a reduced affinity toward employee morale (2,3).

In our research published in 2019, we examined the burnout level of staff working in the radiology department in terms of education, years of service in healthcare and age groups (13). The purpose of our current study was to assess the extent of burnout among radiographers working in oncology care units and to highlight the possible causes of phenomenon that may be related to family and work characteristics in contrast to radiographers working in other fields of patient care.

MATERIALS AND METHODS

Approval for this study was obtained from the Society of Hungarian Radiographers, Budapest, Hungary. Regarding our quantitative, cross-sectional research, we initiated a targeted non-random sampling procedure by sending our questionnaire electronically to nearly 3,000 radiographers registered with the Society of Hungarian Radiographers.

In addition to the internationally validated Maslach Burnout Inventory (MBI), we designed a questionnaire related to socio-demographic and workplace characteristics. With regard to the interpretation of the results of the MBI questionnaire, scores for statements about personal accomplishment were low, while high scores for statements about emotional exhaustion and depersonalization suggest different degrees of burnout (14,15).

Statistical analysis

We used descriptive statistics, a two-sample t-test, analysis of variance (ANOVA), Kruskal-Wallis, and Mann-Whitney test at a 95% confidence level (p=0.05). Data processing was implemented with the Statistical Package for the Social Sciences (SPSS) version 24.0 software.

RESULTS

The questionnaire was completed by a total of 404 respondents (n=404). Based on the aim of our study, our sample was divided into a cohort of radiographers working in oncology patient care (n=72) and radiographers working in other areas of patient care (n=332).

Based on the evaluation of the results of the MBI, it can be observed that the average scores in the dimensions of depersonalization and emotional exhaustion are well above the MBI normal values, which can be negatively interpreted for both groups in our sample. The value of the personal accomplishment dimension also exceeds the normal values of MBI however, which means that radiographers working in oncology patient care and other areas of patient care feel more successful and positive in their efforts. There was a significantly increased value of emotional exhaustion among radiographers working in oncology patient care compared to their peers who were measured in the same dimension (p=0.001) (Table 1).

Table 1: Relationship between mean MBI values of radiographers working in oncology patient care and other fields of patient care compared to normal MBI values (normal values represent the mean values of physicians and nurses)

			Depersonalization (Mean ± SD)	*Emotional exhaustion (Mean ± SD)*	*Personal accomplishment (Mean ± SD)*
Radiographers working in oncology patient care		72	13.62 ± (7.74)	40.28 ± (11.94)***	43.00 ± (7.02)
Radiographers working in other fields of patient care		332	12.64 ± (6.35)	32.98 ± (12.85)***	40.60 ± (8.98)
MBI values	USA	11.067	8.7 ± (5.9)	22.0 ± (10.8)	34.6 ± (7.1)

*** $p<0.001$

Relationship between family composition and burnout

The majority (93.1%) of the radiographers working in the field of oncology were female (n=67). Among them, the depersonalization subscale value was lower than that of the male radiographers; nevertheless, the female radiographers were more affected in the dimension of emotional exhaustion. The male radiographers' personal achievement subscale value proved to be significantly lower compared to the mean value of the female radiographers (p=0.01). The marital status of the sample reveals that 40.3% (n=29) live with a spouse/ partner; however, the average value of the depersonalization dimension of those respondents who are single (n=16; 22.2%) was significantly lower than in other categories of marital status (p=0.01). Marital status had no significant effect on either emotional exhaustion nor personal accomplishment. The results show that 61.1% (n=44) of the respondents have no children. Respondents with one or more children in their family had significantly lower mean emotional exhaustion (p=0.05) and also a significantly higher personal accomplishment value (p=0.01).

The results show that female respondents were also overrepresented by 84.3% (n=280) among the radiographers working in other fields of patient care. There was no significant gender difference in respect to the three dimensions of burnout. The mean values also showed similar distribution in every dimension. Regarding the family composition, a significantly lower sense of personal accomplishment was observed in those who lived with other family members/ individuals (n=29; 8.7%) compared to those with a different type of family composition (p=0.01). Regarding the number of children in the family, significantly higher burnout was observed in the dimensions of depersonalization (p=0.01) and emotional exhaustion (p=0.05) for respondents who did not have children in their family; values of personal achievement (p=0.05) were also significantly lower.

Subjective financial situation assessment and the relationship between education and burnout

The results for the radiographers working in oncology patient care show that 63.9% (n=43) of the sample consider that they live well from their salary and are able to make regular savings from their income. Those respondents (8.3%, n=6) whose salary was not sufficient to make a living, (based on their own subjective judgment), had a significantly higher mean of depersonalization and emotional exhaustion. Furthermore, their mean value measured on the personal accomplishment subscale was significantly lower compared to other respondents (p=0.001; p=0.001; p=0.05).

Radiographers with a Bachelor's degree predominated in the sample at 69.4% (n=50). Those respondents who hold a Master's degree (n=14; 19.4%) had a significantly higher mean value of depersonalization compared to respondents with tertiary vocational education (n=8; 11.1%) (p = 0.001). Respondents with a completed high school education had a significantly lower level of emotional exhaustion compared to those with a completed higher education (p=0.01).

Based on their subjective judgment, respondents who did not have enough monthly income to make a living and did not work in oncology patient care, had a significantly increased emotional exhaustion value (p=0.01) and had a significantly lower value of personal accomplisment (p=0.01).

In terms of educational level, more than half of the respondents in the sample had a university degree (n=188; 56.6%). This group showed a significantly elevated value in the depersonalization subscale compared to respondents with completed tertiary vocational education (n=109; 32.8%) and secondary education (n=35; 10.5%) (p=0.05) (Table 2).

The effects of workplace characteristics on burnout

The results show that 13.9% of the respondents (n=10) had a second job. The average emotional exhaustion value of this group was significantly higher than the average value of those without a second job (p=0.001). Respondents who worked more than 40 hours per week (n=64; 88.9%) were significantly more prevalent in the dimensions of depersonalization and emotional exhaustion (p=0.001; p=0.001). The majority of the respondents in the sample (n=65; 90.3%) did not participate in on-call shifts; nevertheless, those radiographers (n=7; 9.7%) who provided on-call shifts (1-3 times per month) had depersonalization and emotional mean values which significantly deviated in the negative direction (p=0.001; p=0.001). We also measured a significant difference between the above two groups in the average value of the dimension of personal achievement, with the result showing that the on-call staff have a positive experience in relation to the way they judge the success of their efforts at work.

The assessment examined how the radiographers view their relationship with their colleagues. Based on the results of the study, the majority (n=52; 72.2%) of the sample experienced a good relationship with their colleagues. The mean value

Table 2: Respondents' values measured by the MBI burnout questionnaire on the subscales of depersonalization, emotional exhaustion, and personal accomplishment in relation to gender, family status, number of children in the family, financial situation and level of education.

		Radiographers working in oncology patient care				Radiographers working in other fields of patient care		
Value	**n (%)**	**Depersonalization**	**Emotional exhaustion**	**Personal accomplishment**	**n (%)**	**Depersonalization**	**Emotional exhaustion**	**Personal accomplishment**
Gender								
Men	5 (6.9)	16.60 (SD=6.98)	36.80 (SD=16,34)	34.60 (SD=12.03)**	52 (15.7)	15.63 (SD=4.67)	32.08 (SD=9.72)	38.29 (SD=9.46)
Women	67 (93.1)	13.40 (SD=7.80)	40.54 (SD=11.67)	43.63 (SD=6.20)	280 (84.3)	12.08 (SD=6.46)	33.14 (SD=13.35)	41.04 (SD=8.83)
Family status								
Living with spouse/ partner	29 (40.3)	13.66 (SD=7.70)	41.66 (SD=11.21)	44.45 (SD=5.83)	127 (38.3)	11.96 (SD=4.76)	31.73 (SD=12.97)	40.79 (SD=8.59)
Living with spouse/ partner and with children	18 (25.0)	15.97 (SD=7.43)	38.17 (SD=11.70)	40.28 (SD=10.19)	82 (24.7)	12,05 (SD=6.64)	34.70 (SD=11.32)	42.16 (SD=7.83)**
Single	16 (22.2)	9.88 (SD=7.58)**	40.81 (SD=13.41)	43.31 (SD=4.34)	94 (28.3)	13.89 (SD=7.36)*	32.95 (SD=13.95)	40.45 (SD=9.22)
Living with other person/ family member	9 (12.5)	15.56 (SD=7.43)	39.11 (SD=13.42)	43.22 (SD=6.11)	29 (8.7)	13.17 (SD=7.0)	33.66 (SD=12.75)	35.90 (SD=11.41)**
Number of children								
One	16 (22.2)	13.44 (SD=8.31)	42.31 (SD=12.13)	39.81 (SD=10.39)	82 (24.7)	11.91 (SD=6.70)	31.13 (SD=12,84)	42-65 (SD=8.5)*
More than one	12 (16.7)	11.92 (SD=7.15)	33.08 (SD=11.22)*	47.50 (SD=4.70)**	107 (32.2)	11.22 (SD=6.32)	32.53 (SD=13.20)	40.69 (SD=10.09
None	44 (61.1)	14.16 (SD=7.80)	41.50 (SD=11.59)	42.93 (SD=5.35)	143 (43.1)	14.10 (SD=5.87)**	34.36 (SD=12.53)*	39.36 (SD=8.26)*
Current financial state								
Living well	4 (5.6)	12.50 (SD=5.10)	39.25 (SD=15.50)	43.50 (SD=7.00)	13 (3.9)	15.54 (SD=717)	29.15 (SD=16.24)	43.62 (SD=13.25)
Living good, is able to save	46 (63.9)	11.70 (SD=7.65)	38.11 (SD=11.23)	44.20 (SD=6.30)	182 (54.8)	11.99 (SD=5.65)	31.36 (SD=12.08)	40.26 (SD=9.15)
Just enough to make a living	16 (22.2)	14.94 (SD=7.57)	38.13 (SD=10.21)	41.31 (SD=9.31)	109 (32.8)	13.40 (SD=7.39)	34.31 (SD=13.77)	41.36 (SD=8.81)
Not enough for living	6 (8.3)	19.14 (SD=4.45)***	49.10 (SD=5.11)***	38.00 (SD=4.15)*	28 (8.4)	12.64 (SD=5.67)	42.12 (SD=11.16)**	37.72 (SD=6.25)**
Level of education								
Secondary -education	8 (11.1)	11.50 (SD=8.38)	29.63** (SD=12.48)	45.88 (SD=7.31)	35 (10.5)	12.63 (SD=6.96)	32.17 (SD=13.04)	42.69 (SD=7.04)
Higher vocational education	14 (19.4)	8.86 (SD=4.78)**	36.86 (SD=13.49)	46.79 (SD=6.47)	109 (32.8)	10.94 (SD=6.06)	31.52 (SD=12.93)	41.34 (SD=9.11)
University degree (BSc., Msc.)	50 (69.4)	15.30 (SD=7.79)***	42.91 (SD=10.35)	41.48 (SD=6.69)	188 (56.6)	15.54 (SD=5.79)*	30.19 (SD=11.1)	42.66 (SD=8.67)

*p ≤ 0.05 **p ≤ 0.01 ***p ≤ 0.001

of the emotional exhaustion subscale of those respondents who state that they have poor collegial relationship (n=16; 22.2%) showed a significantly increased value compared to those who assumed as to having good collegial relationship (p=0.010). The values of those who felt that they had excellent collegial relationship (n=4; 5.6%) were significantly higher (p=0.010; p=0.001) on the depersonalization and emotional exhaustion subscales.

Those radiographers who work in various other non-oncology patient care and have a secondary job (n=81; 24.4) showed significantly higher depersonalization and emotional exhaustion values (p=0.001; p=0.001). Respondents who worked more than 40 hours per week (n=225; 67.7%) also showed a significant increase of depersonalization and emotional exhaustion (p=0.001; p=0.001). Monthly on-call duty had no significant effect on the dimensions of burnout. Based on the answers to the questions related to the subjectively judged employee relationship, 63.9% of the respondents (n=212) assumed that they had a good relationship with their colleagues. Depersonalization and emotional exhaustion were significantly higher in those radiographers with poor collegial relationships (n=52; 15.7%) and were significantly lower in the dimensions of personal accomplishment (p=0.001; p=0.001; p= 0.001) (Table 3).

DISCUSSION

The majority of research in Hungary focusing on the quality of life and burnout of healthcare professionals is related to healthcare professionals working with severely ill patients. According to our knowledge, there has not yet been a survey on burnout conducted among radiographers working in oncology patient care units.

The incidence of prostate and lung cancer has increased dramatically since the middle of the millennium. The constantly evolving technology allows for a maximum effectiveness of oncology treatments relative to the potential of the workplace and the patient's health status (16,17). In addition to the oncologists working in the oncology patient care unit, radiographers play a key role in the implementation of these treatments. Those working in oncology patient care treat patients with specific characteristics compared to other patient care units. During the course of the disease, oncology patients often experience psychological problems, vulnerability, anxiety, fear, and depression, which may be related to an increased stress factor that may be aimed towards treatment providers. In their analysis, Kubota et al. mention that in addition to these factors, nurses working in oncology care also have to deal with ethically complex clinical decision-making situations such as the complexity of tumor treatments, grief, communicating bad news and death. These situations do not necessarily occur in other services for chronic patients, such as primary care and emergency care, where the contact time with patients is shorter, or services where patients spend most of the time under the effect of sedatives, such as in the operating room. For these reasons, it can be predicted that the burnout of oncology patient care professionals may show elevated values (18,19,20).

In their study, Révay et al. mention that health care workers dealing with severely ill patients are exposed to greater physical and mental strain than those working in other areas of health care. Their survey that analyzed burnout and coping strategies of hospice workers found that hospice workers were overworked as nearly 50% of the respondents in the sample worked 12 hours a day, had self-esteem disorders, and more than 70% of respondents remembered having difficulty sleeping at work. It should be emphasized that, in addition to physical and mental strain, satisfaction arising from compassion is also present in the examined job, which means that employees are also satisfied with their profession, but the negative impact of difficulties in the workplace should not be overlooked (21).

Table 3: Relation of workplace characteristics with the mean values of the dimensions of the Maslach Burnout Inventory

		Radiographers working in oncology patient care				*Radiographers working in other fields of patient care*		
Value	***n (%)***	***Depersonalization***	***Emotional exhaustion***	***Personal accomplishment***	***n (%)***	***Depersonalization***	***Emotional exhaustion***	***Personal accomplishment***
Second job								
Yes	10 (13.9)	13.40 (SD=7.23)	53.60*** (SD=3.09)	41.60 (SD=4.64)	81 (24.4)	15.10 (SD=7.39)***	39.90 (SD=12.92)***	39.15 (SD=9.13)
No	62 (86.1)	13.66 (SD=7.88)	38.13 (SD=11.44)	43.23 (SD=7.33)	251 (75.6)	11.84 (SD=5.76)	30.74 (SD=12.03)	41.07 (SD=8.89)
Number of hours worked per week								
Less than 40 hours	8 (11.1)	12.92 (SD=7.57)	39.13 (SD=12.12)	41.25 (SD=9.54)	107 (32.2)	11,22 (SD=5.31)	27.16 (SD=10.84)	39.80 (SD=9.07)
More than 40 hours	64 (88.9)	19.25 (SD=7.18)**	49.50 (SD=3.92)**	43.22 (SD=6.70)	225 (67.7)	15.25 (SD=6.79)***	39.06 (SD=12.59)***	39.06 (SD=8.90)
On-call duties								
none	65 (90.3)	12,28 (SD=6.89)	39.05 (SD=11.92)	42.74 (SD=7.34)	134 (40.4)	12.30 (SD=6.10)	33.29 (SD=13.23)	41.12 (SD=8.39)
more than one	7 (9.7)	26.14 (SD=3.06)***	51.71 (SD=2.13)***	45.43 (SD=3.53)**	198 (59.6)	12.94 (SD=6.32)	33.32 (SD=12.04)	40.35 (SD=8.89)
Collegial relationship								
Excellent	4 (5.6)	15.13 (SD=5.90	51.12 (SD=6.18)***	46.50 (SD=4.45)	68 (20.5)	10.31 (SD=5.64)	25.31 (SD=7.96)	43.00 (SD=7.71)
Good	52 (72.2)	12.67 (SD=7.91)	38.08 (SD=11.68)	43.54 (SD=6,16)	212 (63.9)	12.13 (SD=5.75)	32.65 (SD=12.55)	41.54 (SD=8.53)
Bad	16 (22.2)	19.10 (SD=7.14)**)	44.25 (SD=11.58)**	40.38 (SD=9.61)	52 (15.7)	21.99 (SD=5.64)***	50.36 (SD=7.52)***	33.8 (SD=5.90)***

*p ≤ 0.05 **p ≤ 0.01 ***p ≤ 0.001

The results do not suggest a significant difference in the dimensions of depersonalization and personal accomplishment between radiology professionals working in oncology patient care and other areas of patient care. However, there was a significant difference in the dimension of emotional exhaustion among radiographers working in oncology patient care (p=0.001). This result may be attributed to the increased mental burden associated with the care of terminally ill patients, which is characteristic of oncology patient care (4,5).

Sale et al. examined the burnout rate of those working in oncology care units in Canada. The study analyzed the findings of physicians, nurses, physicists, and radiotherapists. With physicians and radiotherapists, the rate of depersonalization and emotional exhaustion increased in parallel with the time they spent at work (22). In our previously published results, we examined the effect of age and time spent working in healthcare in relation to burnout. We found that radiographers aged between 31–35, as well as those radiographers who have worked in the healthcare system for 16–20 years, were the ones most at risk considering all three dimensions of burnout (22).

Daugherty et al. examined the burnout level of sonographers whose emotional exhaustion was affected by the number of examinations performed weekly. A correlation was found between the type of job and emotional exhaustion, showing that the value of those working in the public sector increased compared to those working in private health care. In addition to workplace factors, male radiographers showed an increased value in the dimension of depersonalization (23).

In light of our own results, male radiographers working in oncology patient care showed increased depersonalization values and decreased emotional exhaustion values compared to female respondents. Regarding the dimension of personal accomplishment, the mean value of men was significantly lower than that of women (p=0.01). The depersonalization value of radiographers working in other areas of patient care also showed an increased value. No significance was detected in the dimensions of emotional exhaustion and personal accomplishment.

A study published by Jaspers et al. found that emotional exhaustion of the non-doctoral workforce in radiotherapy and radiology units is greater than that of physicians, oncologists, and radiologists. The survey also analyzes that those working in the public health sector are more emotionally exhausted than those working in the private sector. The results show that the high workload, the presence of patients and organizational stressors increase emotional exhaustion. Finally, the study found that less work experience and an increased workload significantly affected emotional exhaustion and feelings of depersonalization (24).

When examining our results, we observed a significant increase of emotional exhaustion compared to radiographers working in other areas of patient care. The increased values may be due to the emotional burden characterictic of everyday oncology patient care, a secondary job, participation in monthly on-call duties, the quality of relationships with colleagues, and the perception of a negative financial status.

In his publication, Hegedűs mentions that one of the negative conditions for healthcare workers dealing with critical patients is the lack of the chance to regenerate physically and mentally; therefore he emphasized the importance of implementing methods of burnout prevention. In their survey published at the turn of the millennium, medical training contained only a limited (0.7%) number of courses dealing with the issues of death, dying, and mourning. From a mental hygiene point of view, it is of paramount importance that a medical student is able to interpret and process the fate of terminally ill patients with the help of evidence-based literature. According to the author, a time interval of a quarter of an hour a day may be sufficient to settle ones physical and mental condition, which may greatly contribute to the improvement of the quality of the mental load of care for patients (25,26).

The first step in treating the burnout syndrome could be to change the working conditions of the affected staff, with an aim to reduce work overload, yet this is not always possible due to the lack of healthcare staff. However, problems arising at work and in private lives should be resolved and focused group discussions, regular rest periods incorprated in the work schedule, and vacation may be some of the useful methods. Scheiderman et al. discuss the importance of stress-reducing activities and intermittent relaxation in their research to reduce burnout, with some of the most effective activities being group lectures and group discussions in a workplace environment (27,28,29).

According to Szényei et al., primary, secondary and tertiary prevention can play a key role in alleviating and avoiding burnout. These methods include relaxation techniques, cognitive-behavioral therapies, and stress management, the positive effects of which are unquestionable. It is important to emphasize that strategies to reduce burnout need to be interpreted in a rather complex way, and may therefore vary from individual to individual (30).

Kovács et al. studied the emotional exhaustion of those healthcare professionals who work with severely ill patients. They realized that a significant relationship of trust is generated with patients in their daily work and that this relationship grows with personal communication, which can be a positive significant factor regarding burnout. Based on their results, emotional dissonance appears as a significant stress factor among those working in oncology patient care, which may be contributed to the healthcare workers' need to regularly show understanding and express compassion towards patients during their work (31).

Czeglédi and Tandari-Kovács examined the burnout of nurses and concluded that the reason for the shortage of nurses in Hungary is career abandonment and migration. The low degree of social esteem and the increase in both physical and emotional strain also play a role in this phenomenon. Professional psychological help could help professionals, as well as continuous professional development and participation in research activities (32).

Our results show that the burnout syndrome of healthcare professionals working in oncology patient care requires serious attention, mainly due to increased values of depersonalization and emotional exhaustion subscales. It should also be emphasized that various workplace and personal factors such as pay, childlessness, education, having a second job and working more than 40 hours per week, may increase the risk of burnout. To confirm our results, further research is necessary to assess the radiographers working in oncology patient care. Our results suggest that increased attention should be paid to the burnout syndrome among professions related to oncology. Our findings of the risk factors may also help establish burnout preventions for healthcare professionals working in high-risk oncology care. Limitations of the study include the impossibility of making a substantive statement about causal relationships due to the retrospective nature of our survey. Also, to the best of our knowledge, a study focusing on burnout has not been conducted among radiographers working in oncology patient care in Hungary. Based on these facts and in light of our results, we propose that decision-makers and management support the development of psychological interventions that contribute to the prevention of burnout of those working in oncology patient care.

CONCLUSION

In our study of radiographers working in oncology patient care, we examined the significant increase of burnout subscales. Sociodemographic and occupational variables, workplace overcrowding, and workplace-related factors were observed as having a significant influence on the development of the burnout syndrome.

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Original article

COMPARISON OF STANDARD DIAGNOSTIC AND RADIOTHERAPY PLANNING PROTOCOLS IN LUNG CANCER TREATMENT ON PET/CT SCANNER

PRIMERJAVA KLASIČNEGA DIAGNOSTIČNEGA IN RADIOTERAPEVTSKEGA PROTOKOLA V RADIOTERAPIJI PRI RAKU PLJUČ NA PET/CT APARATU

Filip VLAJ [1]***, Katja ŠKALIČ*** [2]***, Valerija ŽAGER MARCIUŠ*** [1,3]

[1] University of Ljubljana, Faculty of Health Sciences, Department of Medical Imaging and Radiotherapy, Zdravstvena pot 5, 1000 Ljubljana, Slovenia

[2] Institute of Oncology Ljubljana, Department of nuclear medicine, Zaloška ulica 2, 1000 Ljubljana

[3] Institute of Oncology Ljubljana, Department of teleradiotherapy, Zaloška ulica 2, 1000 Ljubljana

Corresponding author: valerija.zager@zf.uni-lj.si, vzager@onko-i.si

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ABSTRACT

Purpose: The purpose of the study was to compare the standard diagnostic protocol for computed tomography imaging with a radiotherapy imaging protocol for treatment planning needs in radiotherapy for lung cancer on a positron emission tomography (PET/CT) scanner at the Department of Nuclear Medicine in order to then be able to determine the differences between these two protocols and suggest improvements in dose optimisation for computed tomography imaging in a radiotherapy protocol.

Methods: In a retrospective study, data were collected with the SyngoVia program and statistically analysed according to the patient dose load in computed tomography imaging in standard PET /CT and radiotherapy protocols. The analysis included data of 56 patients for the period from 1 January 2017 to 1 December 2018. We compared data on patient dose load in computed tomography imaging in a standard protocol before and after introducing the improved sinogram-affirmed iterative reconstruction method (SAFIRE).

Results and discussion: Statistically significant differences in dose per patient ($p<10^{-3}$) in computed tomography imaging in standard PET/CT and radiotherapy protocols on PET/CT scanner were found. Statistically significant differences were also established in computed tomography imaging in the standard PET/CT protocol before and after the introduction of the improved iterative reconstruction method (p=0.001). Dose load on the lung in computed tomography imaging was 67.5% lower in the standard protocol with the iterative reconstruction in image space (IRIS) method than in the radiotherapy protocol. The introduction of the improved SAFIRE method additionally lowered the dose per patient by 34.2% compared to the IRIS method.

Conclusion: In the future, the improved iterative reconstruction method should be introduced for the reconstruction of computed tomography images for radiotherapy imaging protocol in lung cancer . The impact of the indirect reduction in the dose, which has an influence on the accuracy of the contouring of tumour target volumes for patient treatment planning, should be taken into account.

Key words: positron emission tomography with computed tomography, iterative reconstruction, dose optimization, lung cancer, radiation treatment planning

IZVLEČEK

Namen: Namen raziskave je bil primerjati klasični diagnostični protokol slikanja z računalniško tomografijo z radioterapevtskim protokolom slikanja za potrebe planiranja v radioterapiji pri pljučnem raku na aparatu za pozitronsko emisijsko tomografijo (PET/CT) na oddelku za nuklearno medicino, ugotoviti razlike med njima in predlagati morebitne izboljšave pri optimizaciji doze prejete ob slikanju z računalniško tomografijo pri radioterapevtskem protokolu.

Metode in materiali: V retrospektivni raziskavi smo s programom SyngoVia pridobili in podatke s statistično analizo primerjali, glede na dozno obremenitev bolnikov slikanih z računalniško tomografijo pri klasičnem PET/CT in radioterapevtskem protokolu. V analizi je bilo vključenih skupno 56 bolnikov v obdobju od 1.1.2017 do 1.12.2018. Primerjali smo tudi podatke o dozni obremenitvi bolnikov z računalniško tomografijo pri klasičnem protokolu pred in po uvedbi izboljšane iterativne rekonstrukcijske metode SAFIRE.

Rezultati in razprava: Ugotovili smo, da pri slikanju z računalniško tomografijo pri klasičnem PET/CT in radioterapevtskem protokolu obstajajo statistično značilne razlike v dozi na bolnika ($p<10^{-3}$) na PET/CT aparatu. Statistično značilne razlike smo ugotovili tudi pri slikanju z računalniško tomografijo pri klasičnem protokolu pred in po izboljšavi iterativne rekonstrukcijske metode (p=0,001). Dozna obremenitev pljuč z računalniško tomografskim slikanjem pri klasičnem protokolu z iterativno rekonstrukcijsko metodo IRIS je bila v primerjavi z radioterapevtskim protokolom nižja za 67,5 %. Uvedba izboljšane iterativne rekonstrukcijske metode SAFIRE je, v primerjavi s predhodno iterativno rekonstrukcijsko metodo IRIS, dozo na bolnika še dodatno znižala in sicer za 34,2 %.

Zaključek: V prihodnje je za rekonstrukcijo računalniško tomografskih slik, možna uvedba izboljšane iterativne rekonstrukcijske metode tudi za radioterapevtski protokol slikanja pri raku pljuč. Pri tem bo potrebno upoštevati vpliv posrednega zmanjšanja doze, ki vpliva na natančnost vrisovanja tarčnih volumnov pri izdelavi obsevalnega načrta za bolnika.

Ključne besede: pozitronska emisijska tomografija z računalniško tomografijo, iterativna rekonstrukcija, optimizacija doze, pljučni rak, planiranje obsevanja

INTRODUCTION

Radiotherapy as a medical science is often the most appropriate treatment method (1) for some types of lung cancer. An important part of radiation treatment for lung cancer is the preparation of the patient for radiation on a computed tomography (CT) simulator at the Department of radiotherapy. Preparation for treatment planning can also be performed on a PET/CT scanner at the Department of nuclear medicine using positron emission tomography with computed tomography (PET/CT) with the standard diagnostic PET/CT scan first, followed by the imaging protocol for treatment planning in radiotherapy, i.e. radiotherapeutic protocol.

The fusion of both image series enables radiotherapists to accurately identify tumour target volumes and critical organs for treatment planning in radiotherapy (2, 3). The accuracy of the identification influences the facilitation of the optimal dose coverage of the target volume and the minimum dose for critical organs and healthy tissue, which consequently reduces the side effects of radiation (4).

PET/CT is a hybrid imaging technique combining positron emission tomography and computed tomography. The fusion of images is obtained by combining both techniques. A PET image shows the distribution of a radiopharmaceutical, while a CT image shows morphology and anatomy. Increased metabolism, glycolysis, protein synthesis and DNA are characteristic of tumours. The most common radiopharmaceutical for PET imaging is [18]F-flourodeoxyglucose (18F-FDG). 18F-FDG is accumulated proportionally to the glucose metabolism, i.e., at the tumour location, modified lymph nodes and potential metastases. A standard PET/CT scan with 18F-FDG is performed one hour after the administration of a radiopharmaceutical. All nuclear medicine examinations show modifications on the cell level and are, therefore, used for the early detection of metabolic changes, the identification of disease, as an aid in radiation planning in radiotherapy and for monitoring the treatment outcome (5, 6).

Each radiation is planned. Anatomic and physiologic data of the area must be collected prior to the lung cancer irradiation on a CT simulator or PET/CT scanner. We obtain a detailed image of the radiopharmaceutical's distribution in the tissue of the imaged area with PET/CT imaging, which was proven more efficient than a separate imaging with a CT simulator or a PET scanner. The identification of target volumes on the images obtained with a PET/CT scanner enables a more accurate detection of tumour volumes than with a CT simulator alone since a PET image provides a clearer differentiation of healthy and cancerous tissue. A decrease in radiation volume contributes to a lower exposure of healthy tissue and thus, less side effects of radiation for a patient (6).

The computer eliminates different physical and electronic disturbances in computed tomography before reconstruction. Reconstruction of the CT image is conducted using different reconstruction algorithms (listed below) that consequently influence the received dose and output image quality (7). One of the analytical reconstruction algorithms is the filtered back projection (FBP). Analytical reconstruction algorithms are simple mathematical methods, where modifications of output images occur due to false presumptions on geometric beam properties and matrix geometry. Analytical algorithms presuppose that the source of X-ray photons and each detector cell are infinitely small and that each voxel has no size or form (8). In the iterative method (statistical and model-based), data do not change and adapt in order to comply with the analytical reconstruction models, but the circular process of obtaining, comparing and updating data is introduced into the reconstruction process, which leads to an improved diagnostic accuracy of output CT images (8). The adaptive statistical iterative reconstruction (ASIR) method is a circular system where artificial data is synthesised based on the estimation of obtained data. These raw data are then compared to realistic data that were obtained in the imaging process. The difference between the two sets of data is used again in the first step, where they are again compared to realistic data. This process is repeated until the difference between both sets of data is at an acceptable interval (8). The model-based iterative reconstruction (MBIR) method proved to be successful in improving image quality due to reduced noise and artifacts. In addition to the components of the adaptive statistical iterative method, the reconstruction algorithm adds models. These models take into account the polychromatic feature of the X-ray beam and geometric features of the detector, and thus accelerate the reconstruction process. Studies have shown that the lung dose load decreased by 79% to 98% when iterative reconstruction was applied (8).

In computed tomography, the dose is applied with the computed tomography dose index (CTDI) and dose length product (DLP). CTDIvol defines the intensity of radiation used to perform a particular CT examination. The CTDIvol is settled for a given CT unit and a set of acquisition parameters, so it does not depend on patient size or scan length. DLP is the product of CTDI and the total length of the imaging area. The methods of calculating the received dose in CT imaging are precisely described in the relevant literature (9).

The purpose of this study was to compare the standard PET/CT imaging protocol with the radiotherapeutic protocol for lung cancer on a PET/CT scanner, to determine the differences between these two protocols and to propose possible improvements in the dose optimisation for CT imaging in the radiotherapy protocol.

METHODS

Scientific literature from the library of the Faculty of Health Sciences and online sources were used. A retrospective study compared data from 56 patients that underwent PET/CT imaging in standard PET/CT and radiotherapy protocols for radiotherapy planning for lung cancer from 1st January 2017 to 1st December 2018 on PET/CT scanner. Data were compared on patient dose in CT imaging in the standard PET/CT protocol before and after implementation of the improved SAFIRE method for dose optimisation (which has been applied since July 2018) and the relevant statistical analyses was conducted. Data were collected using the SyngoVia software, which provides reviewing and processing tools for evaluating all radiology images, including images from hybrid scanners (PET/CT, SPECT/CT).

Both scans of the patient were performed on the same day, one after the other, at the Department of Nuclear Medicine (10). The patient was administered a radiopharmaceutical (18F-FDG), followed by the PET/CT standard imaging using the standard PET/CT protocol with an aim to determine the prevalence of the disease. PET/CT imaging was followed by the radiotherapy protocol for radiation treatment planning. Imaging parameters of the protocols differ in terms of the selected voltage (kV), current (mAs) and imaging area size. The patient was prepared for the second part of the imaging according to the preparation protocol for the radiation of lung cancer in radiotherapy (use of flat examination table, selection of appropriate fixation devices, and external laser system for the placement of the patient in the initial isocentre).

Microsoft Excel 2016 and IBM SPSS Statistics 24 were used for the analysis and evaluation of data. Statistically significant changes were p-valued at $p \leq 0.05$ (risk level 5%). The Shapiro-Wilk test was used to determine whether our numerical dependent variables were distributed normally. Based on the result, we then applied parametric or non-parametric tests. The Mann-Whitney U test was used for independent samples to determine differences in the CT dose for 46 patients. We determined whether differences in pivot values between sample groups were statistically significant. To determine the differences in the CT lung dose for 46 patients between the PET/CT standard and radiotherapy protocol, we made a preliminary calculation of the adjustment factor that we used to equalise the length of the imaging area of both protocols (11). The length of the imaging area in the standard protocol is longer as it includes a field from the skull base to the proximal third of the femur. Data on DLP in the PET/CT standard protocol were divided by the aforementioned factor. We thus obtained a DLP that describes the received dose in the area of the same size as the imaging area in the radiotherapy protocol, where the lung is scanned from the thyroid cartilage to the middle of the kidneys (to the lower edge of the ribs). The adjustment factor was calculated based on the table containing DLP values (Figure 1) that were measured on a phantom, and amounts to 3.35. The calculation took into account possible deviations in the imaging area size of each imaging.

To determine differences in the sample of 46 patients before and a sample of 10 patients after the implementation of the improved SAFIRE method, we applied the Wilcoxon test for dependent samples, based on the abnormal distribution of one of the samples.

RESULTS

The CT dose for 46 patients using the radiotherapy protocol without the iterative reconstruction method was compared to the CT dose obtained using the standard PET/CT protocol. Also, the CT dose of the CT scan using the IRIS optimisation dose method and thus the SAFIRE optimisation method were compared. Moreover, to equalise the length image area solely on the thorax, we divided the DLP values of the standard protocol by the calculated adjustment factor to compare the CT dose of the radiotherapy and standard PET/CT protocols. For comparison purposes, the field in both protocols was equalised. The standard PET/CT imaging area was divided by the calculated adjustment factor of 3.35 to arrive at the size of the radiotherapy area protocol.

Patient dose load in CT imaging in standard PET/CT and radiotherapy protocols

We compared data for 46 patients (Figure 2) who underwent CT imaging using the standard and radiotherapy PET/CT protocols. The reconstruction of the CT images of the radiotherapy protocol was conducted without using the iterative reconstruction method, whilst the reconstruction of the standard protocol used the iterative reconstruction method. Women and men accounted for 26.09% and 73.91% of the sample, respectively.

Samples were not normally distributed (radiotherapy protocol ($p=0.030$), standard protocol ($p=0.044$). Using a

Representative $CTDI_{vol}$, DLP, and ED Values for Normal-sized Adults Undergoing Specified Routine CT Examinations

	$CTDI_{vol}$ (mGy)†		DLP (mGy)†		
Body Region*	In 16-cm Phantom	In 32-cm Phantom	In 16-cm Phantom	In 32-cm Phantom	ED (mSv)‡
Head (15 cm)	60	(30)	900	(450)	2.2
Chest (30 cm)	(30)	15	(900)	450	9.0
Abdomen (25 cm)	(40)	20	(1000)	500	8.0
Pelvis (25 cm)	(40)	20	(1000)	500	7.0
Brain (perfusion)	440	(220)	2400	(1200)	5.8

Note.—Most manufacturers use a 16-cm phantom to calculate the CTDI for head examinations and a 32-cm phantom to calculate the CTDI for all body examinations (including the neck) (19).

* Numbers in parentheses are scan lengths.

† Numbers in parentheses are not commonly encountered in clinical practice.

‡ Computed with ICRP publication 103 tissue-weighting factors (7).

Figure 1: Data on dose load on specific body parts for an average adult (11)

non-parametric test for independent samples, we did not identify statistically significant differences in the patient dose load in CT imaging in the radiotherapy and standard PET/CT protocols (p=0.138).

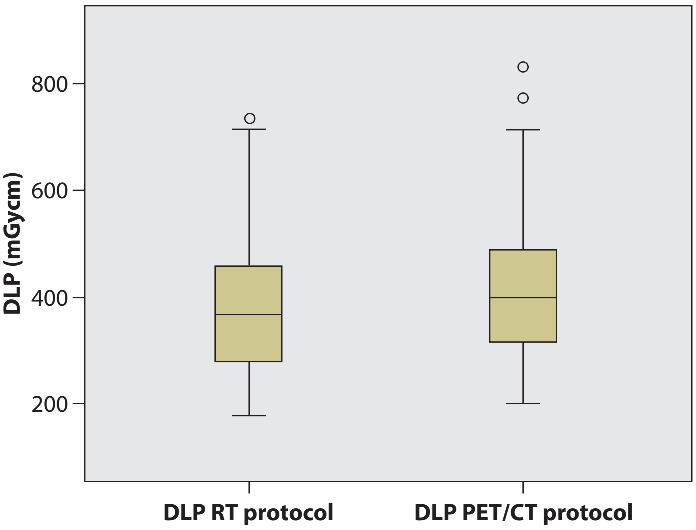

Figure 2: Comparison of the DLP of the radiotherapy (RT) and standard PET/CT protocols

Lung dose load in CT imaging in the radiotherapy protocol without the iterative reconstruction method and in the standard PET/CT protocol with the IRIS method

The sample included 46 patients. The graph (Figure 3) was based on the DLP data. To equalise the field in both protocols, we divided the size of the field in the standard PET/CT protocol by the calculated adjustment factor of 3.35.
Samples were not normally distributed (radiotherapy protocol (p=0.030), standard PET/CT protocol (p=0.044)). Using a non-parametric Wilcoxon signed rank test for dependent samples,

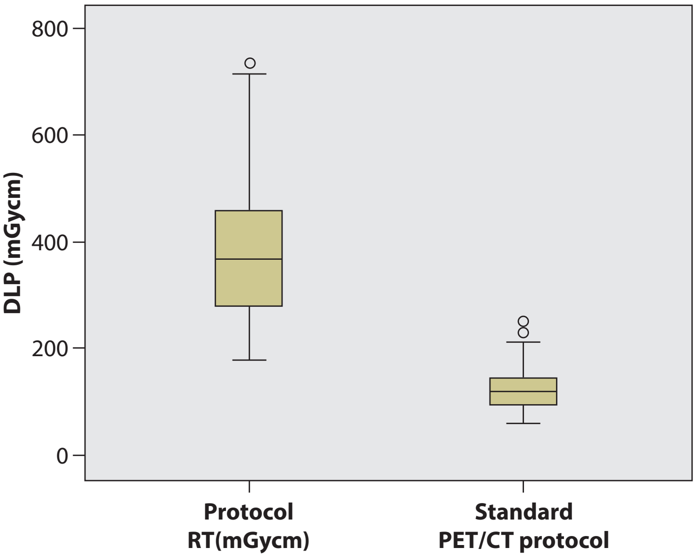

Figure 3: Comparison of the DLP on the lung in the radiotherapy (RT) and standard PET/CT protocols

we identified statistically significant differences in the CT dose on lungs for the mentioned protocols ($p < 10^{-3}$).

Effect on the dose obtained before and after implementation of the improved iterative reconstruction method in the standard PET/CT protocol

The sample included 46 patients (Figure 4) before the improved iterative reconstruction (using IRIS) and 10 patients after the improved SAFIRE method. Data of the improved iterative reconstruction method (SAFIRE) are normally distributed (p=0.266), while the data for which the iterative reconstructed method was used were not normally distributed (p=0.044).

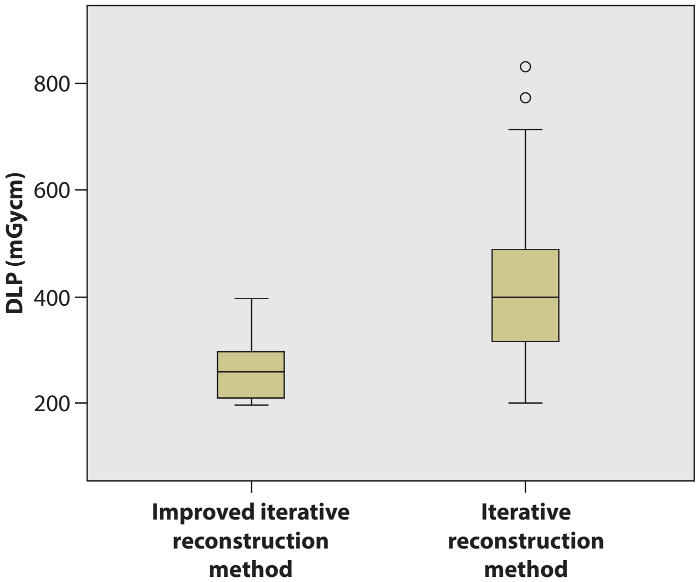

Figure 4: Comparison of the DLP in the standard PET/CT protocol before and after the improved iterative reconstruction method

The Mann-Whitney U test for independent samples showed statistically significant differences in the dose in the standard PET/CT protocol before and after the implementation of the improved iterative reconstruction method (p=0.001).

DISCUSSION

The aim of our research was to determine how the implementation and improvement of an iterative reconstruction method influences the patient dose during CT imaging. We compared the differences in the CT dose in standard PET/CT protocol and radiotherapy protocols in lung cancer, performed on a PET/CT scanner. PET/CT scans using standard and radiotherapy protocols showed no statistically significant difference in the dose received by a patient. However, the protocols have imaging areas of different sizes. As a result, the streaming adjustment must also be implemented. The standard PET/CT scan is at least one time longer than a scan in the radiotherapy protocol.
In order to compare the DLP of the protocols in question, we used data from literature to calculate an adjustment factor (11) that we used to equalise the length of the imaging area of both protocols. The results indicated that the CT dose

differed between the two protocols. The median CT value of the radiotherapy protocol was 367, while the median value of the standard PET/CT protocol was 119.25. The dose received by the patient in the lung area in the standard PET/CT protocol using the IRIS method was 67.5% lower than the dose in the radiotherapy protocol without the use of the IRIS method. There are several potential reasons for deviations in the final estimate of the received dose. The first that should be mentioned is the factor of 3.35 obtained based on a comparison of ratios stated in the literature, which had to be adjusted to our imaging area (11). The size of the imaging area also depends on the patient's anatomy and the length of the imaging area set by the radiographer. The results from a subsequent study were obtained from a phantom and patients. Those results proved that the dose decreases by between 32% and 65% when adaptive iterative reconstruction is used. This coincides with our results (12). We then compared the differences in DLP in the standard PET/CT protocol before and after the implementation of the improved iterative reconstruction method. There were 46 patients in the sample prior to introducing the improved iterative reconstruction method, and 10 patients following the improvement made in the scope of our research. Using statistical analysis, we determined that the median value prior to the improvement of the IRIS method was 399.50, while the median value following the introduction of the improved SAFIRE method was 263, meaning that the dose was reduced by 34.2% following the introduction of an advanced iterative reconstruction method.

We were limited in terms of the number of patients in the sample following the introduction of the improved SAFIRE method, as we began using the reconstruction method at our institution at the beginning of July 2018, which affected the accuracy of the statistical analysis. The SAFIRE method, which is used in the reconstruction of CT images in the standard PET/CT protocol, also effectively reduced the patient dose load. It thus makes sense to ask the question whether the use of this type of reconstruction method could also reduce the patient dose load in CT imaging in the radiotherapy protocol while maintaining an image quality that is suitable for identifying target tumour volumes. Current guidelines indicate that a low-dose CT is not in itself appropriate for radiation treatment planning. In this case, a high-dose CT of a shorter target area for planning following a low-dose CT of a longer imaging area is required to reduce the dose load (13).

We can conclude that it would make sense to introduce the SAFIRE method in the radiotherapy PET/CT protocol for reconstructing CT images. However, when introducing the iterative reconstruction method with an aim of reducing the patient CT dose, it would be necessary to perform an additional analysis of the impact of the indirect reduction in dosage on the precision of the contouring of tumour target volumes and critical organs. It was proven that the resolution in low-dose CT using an adaptive statistical iterative method was poorer than the resolution in low-dose CT using a model-based iterative method. The model-based iterative reconstruction method, which is already used in practice, effectively reduces the dose and image noise, improves spatial and contrast resolution, and eliminates image artefacts (8, 12).

CONCLUSION

In our study we compared the differences in CT dose in standard PET/CT and radiotherapy protocols in lung cancer performed on a PET/CT scanner. In the standard protocol, an advanced iterative reconstruction method was used. That method facilitates lower patient dose loads. We determined that the CT dose is 67.5% lower in the standard PET/CT protocol than in the radiotherapy protocol when the size of the imaging field is the same. Imprecision in the definition of the adjustment factor used to equalise the imaging field must be taken into account. It would make sense in the future to calculate the adjustment factor based on a phantom as this would lead to more precise input data for analysis.

When comparing the effect on the dose obtained before and after the implementation of the improved iterative reconstruction method in the standard PET/CT protocol, we determined that the patient dose load was reduced by 34.2% using the improved iterative reconstruction method. The sample of patients following the implementation of the improved iterative reconstruction method was small during the course of our study, as that method was introduced in July 2018. In the future, the study should be repeated with a larger sample.

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Original article

ANODE HEEL EFFECT ATTENUATION IN LUMBAR SPINE RADIOGRAPHY: CAN THE USE OF ALUMINIUM FILTERS IMPROVE THE CLINICAL PRACTICE OF RADIOGRAPHERS?

Sónia RODRIGUES [1], Luís Pedro Vieira RIBEIRO [1,2,3], Rui Pedro Pereira de ALMEIDA [1,2,4*], António Fernando Caldeira Lagem ABRANTES [1,2,4], Kevin AZEVEDO [1,2,4], Oksana LESYUK [1], Joana SOARES [1], Rúben DORES [1], João ALEIXO [1], Patrick SOUSA [1,2]

[1] University of Algarve, School of Health, Department of Medical Imaging and Radiotherapy, Campus de Gambelas, 8005-139 Faro, Portugal.

[2] CES – ESSUALG (Center for Studies and Development in Health), Faro, Portugal

[3] CIDAF (Research Unit for Sport and Physical Activity), Coimbra, Portugal

[4] CICS.NOVA.UÉvora (University of Évora, Interdisciplinary Centre of Social Sciences), Évora, Portugal

Corresponding author: rpalmeida@ualg.pt

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ABSTRACT

Purpose: The aim of this study was to design an aluminium-based filter to reduce the anode heel effect in lumbar spine radiographs.

Methods: Initially, lumbar spine examinations were observed in a public imaging department to determine standard exposure parameters. Then, the characterization of the anode heel effect was made using the Unfors Xi R/F detector and, based on the data collected, aluminium filters were designed with a wedge shape and thicknesses ranging from 0.1 to 4.0 mm. The assessment of the entrance skin dose (ESD) reduction was performed on the anthropomorphic phantom with and without filters, using the universal dosimeter UNIDOS E equipped with an ionization chamber. Finally, the image quality assessment was performed with the Pehamed Phantom Digrad A+K and image quality surveys were applied to radiographers and radiologists.

Results and Discussion: Uniformity of the beam was achieved, especially with filter number 2, which presents a significant variation of 9% between the cathodic and anodic side. This filter contributes to ESD reduction of 35% and 36% for AP and lateral projection, respectively. Also, according to radiographers and radiologists, it improves the image quality of lumbar spine radiography.

Conclusion: The use of aluminium filters can be advantageous in the clinical practice of radiographers when performing lumbar spine radiographs since it allows the standardization of the anode heel effect, reduces the radiation dose to the patient and does not compromise image quality.

Keywords: anode heel effect, aluminium filters, image quality, radiation protection, radiographers, entrance skin dose.

INTRODUCTION

Healthcare is a fundamental human right and is considered to be of major importance for global development as it is crucial for enhancing the quality of life and extending life expectancy (1). Rather than being only involved in primary care, healthcare has evolved and follows social trends, thus striving for quality and excellence. That is why healthcare services have become increasingly accessible, with a corresponding increase in the number of imaging examinations.

Medical imaging procedures have been playing a key role in current medical care through their use in a variety of modalities. However, those using x-ray have the disadvantage of the radiation dose received by patients and its potential harms. This may be reduced through technological development, scientific research, and proper use of equipment (2).

Due to the risks of radiation exposure and a gradual increase in the number of examinations, reducing the exposure dose to the patient without decreasing diagnostic image quality should be a primary concern.

In the imaging field, the aim is to provide a diagnostic examination with maximum image quality, while keeping the radiation levels as low as possible (ALARA principle) (3). In this sense, there are several parameters that can easily be adjusted, which allows a balance between patient radiation dose and image quality, such as the voltage (kV), the exposure current-time product (mAs), the source-to-image receptor distance (SID) and the proper use of collimators. However, there are other factors that can also interfere with image quality that are not possible to control, such as the anode heel effect (4). This effect is defined as "*the lower field intensity towards the anode in comparison to the cathode due to lower x-ray emissions from the target material at angles perpendicular to the electron beam*" (5). Physical aspects of the construction of the x-ray tube combined with the physical properties of the x-ray radiation cause a non-uniformity of the beam intensity along the anode-cathode axis known as the anode heel effect. The intensity of the radiation emitted at the cathode side is higher than at the anode side. In most radiographic examinations, the radiographer can naturally compensate this effect and take advantage of it by positioning the patient's thicker region at the cathode end. This contributes to obtaining optimal exposures for certain anatomical structures, although it does not completely cancel out the effect and changes in the image quality remain (2).

In mammography modality, the x-ray machine features specific aluminium filters to remove non-useful low intensity x-rays and to enhance contrast sensitivity (4). It also presents a considerable anodic heel effect due to the anode target angle and short SID (6). Thus, in order to take maximum advantage of this effect, the cathode side is positioned at the chest wall.

Incorrect use of this effect in radiographic examinations may result in cathode side overexposure and underexposure on the anode side, decreasing the image quality (7-12). For this reason, issues such as x-ray beam intensity assessment, x-ray beam standardization, dose reduction at patient entrance, and image quality have been continuously under study.

There are recent studies that investigate the influence of the anode heel effect in different anatomical regions that present a greater density divergence along the tube axis (cathode to anode (7,8,13). However, since there is little evidence regarding the attenuation of this effect in lumbar spine radiography, the aim of this research was to evaluate the attenuation of anode heel effect in the lateral lumbar spine examination using a customized aluminium filter, as well as to assess the ESD and image quality.

METHODS

In the first step, an assessment of the baseline exposure parameters for the lumbar spine radiography was conducted. Then, anode heel effect was evaluated and data for the design and construction of a customized filter were gathered. Finally, the viability of the filter, ESD and image quality were assessed.

Step 1: Determination of exposure parameters for lumbar spine examination

A survey of the exposure parameters used to perform the lateral lumbar spine examination in a digital radiology imaging room (*Philips x-ray tube SRO 2550 ROT 350*) from a public hospital was applied. Data collected included the following parameters: kV, mAs, the selection of the automatic exposure control (AEC) mode, room configuration, x-ray field size at image receptor and SID.

Step 2.1: Measurement of the beam intensity along the longitudinal anode-cathode axis

Exposure rates were measured along the longitudinal anode-cathode axis, using the Unfors Ray Safe Xi detector based on a solid-state sensor, in order to plot the distribution of radiation intensity. The mean values of kV collected in step 1 were used, and the mAs value was decreased to 1 mAs to prevent X-ray tube overheating due to the high number of exposures. Room configuration and SID were reproduced. The centre of the exposure field was defined as the zero position and all measured values in the cathode direction were considered to correspond to the negative axis and in the direction of the anode to the positive axis. Several measurements were made with an increment of 1 cm along the longitudinal field length.

Step 2.2 - Uniformization of the beam intensity distribution along the longitudinal anode-cathode axis

In order to uniformize the distribution of the beam intensity, the minimum value of the exposure rate obtained in the previous step was taken as the reference value. Again, several measurements were repeatedly made with an increment of 1 cm and adding aluminium half-value length (HVL) filters (99.5 % of purity) on top of the detector until the exposure rate values reach the reference value, thus counteracting the behaviour of the anode heel effect. At the same time, the required aluminium thickness values were obtained at each longitudinal axis position for subsequent filter design. The thickness of the aluminium HVL filters ranged from 0.1 mm to 4.0 mm. Exposure rate was measured along the longitudinal anode-cathode axis in order to plot the filter design.

Step 2.3: Aluminium filter construction

In this step, the technical drawing for the filter construction was carried out using Autodesk AutoCAD 210. Since the measurements were taken on top of the patient table, it was necessary to scale it to attach the filter to the bottom of the collimator assembly. To design the filter, a 4.0 mm thick aluminium plate, alloy 2024 (T351) with a purity of 91% to 95%, was used. Due to budgetary constraints, it was not possible to match the aluminium purity of this plate with the HVL filters used in the previous step, knowing that this difference would have an impact on the results (10). Regarding the cut of the aluminium plate, two samples were manufactured by CNC turning in two different mechanical workshops facilities that specialized in this type of procedure.

Step 3.1: Evaluation of the anode heel effect behaviour

Measurements from the first step were repeated without a filter and then with each filter sample attached to the bottom of the collimator assembly to check the effect of the filters regarding the beam intensity distribution along the longitudinal anode-cathode axis. All previous configurations were reproduced.

Step 3.2: Evaluation of the ESD reduction

In order to evaluate the ESD on the phantom with and without filters, three exposures for each type of examination were carried out with an ionization chamber placed on top of the phantom in the centre of X-ray field. An important consideration in this work is that ESD is obtained directly from the measurement of the transmitted radiation through the double-faced plane-parallel ionization chamber, which is in contact with the tissue-equivalent phantom, measuring the incident radiation as well as backscatter radiation.

Step 3.3: Image Quality Assessment

Three exposures were performed to assess the image quality using the Pehamed Phantom Digrad A+K. Spatial resolution, grey scale and contrast level were evaluated with this phantom, at SID of 100 cm and the size of the x-ray field was adjusted to the phantom.

Then, a survey was distributed to the radiologists and radiographers of the imaging department to assess the subjective image quality, using the European Guidelines on image criteria for lumbar spine examinations and a visual grading analysis (14,15). The survey included images obtained on the anthropomorphic phantom, with a total of twenty questions.

RESULTS

Determination of exposure parameters for lumbar spine examination

The results obtained from the exposure parameters survey of the AP and Lateral Lumbar spine radiographs were as follows: the use of AEC mode, without additional filtration, SID of 100 cm, source-table distance of 90.2 cm, the size of the x-ray field on top of the table of 40 cm x 20 cm, large focus, and a voltage of 85 (AP) and 90 kV (Lateral).

Measurement of the beam intensity along the longitudinal anode-cathode axis

It is known that the variation of the anode heel effect in terms of relative intensity can vary between 75% to 120% along the longitudinal anode-cathode axis (3). In this study, as expected, the x-ray beam is less intense on the anode side and more intense on the cathode side. A variation of the relative exposure rate up to 58% occurs (Figure 1).

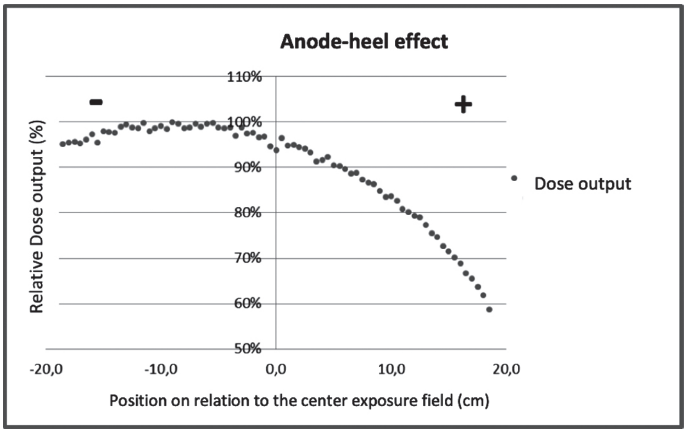

Figure 1: X-ray beam intensity variation (%) as a function of the position in relation to the center of the exposure field

Uniformization of the beam intensity distribution along the longitudinal anode-cathode axis

The thickness of the aluminium required to compensate the beam intensity distribution along the cathode-anode axis was measured and presented in Figure 2. As expected, higher aluminium thickness is needed on the cathode side. Step lines of equal aluminium thickness on this side are visible because the minimum HVL thickness of aluminium filters available for increment was 0.1 mm.

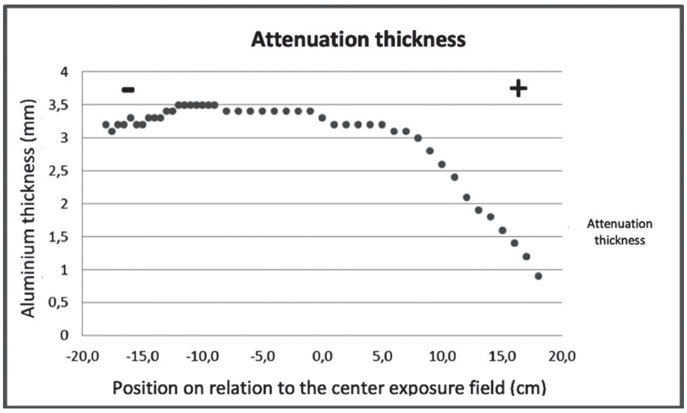

Figure 2: aluminum thickness required to attenuate the intensity of the beam in order to compensate the anode heel effect

Aluminium filter construction

Based on Figure 2, a technical drawing was made scaling the length of the beam at the patient table to the length of the output of the collimator assembly. Two filters were constructed, filter 1 (Figure 3) and filter 2 (Figure 4).

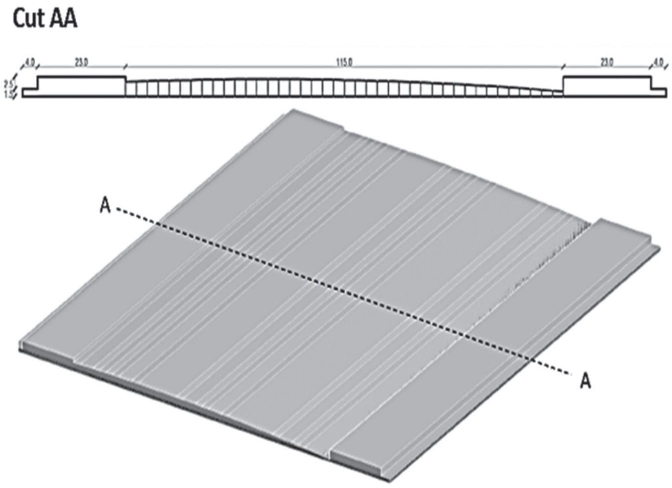

Figure 3: Technical drawing of aluminium filter 1. Top image refers to the cross-sectional view of the piece represents three-dimensional in the image below

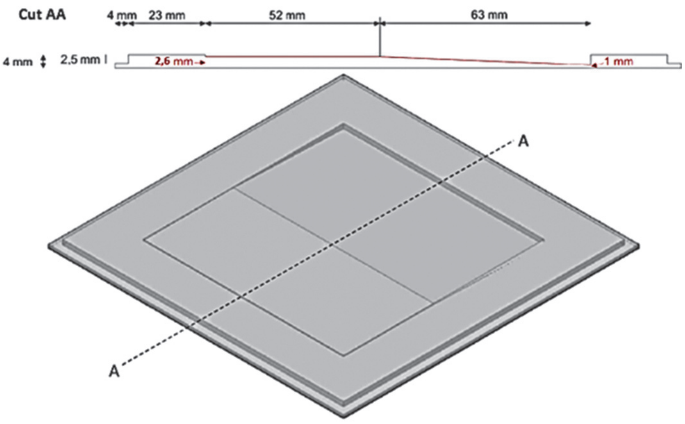

Figure 4: Technical drawing of the aluminium filter 2. Top image refers to the cross-sectional view of the piece represents three-dimensional in the image below

Evaluation of the anode heel effect behaviour

Exposure and dose rates were measured along the longitudinal anode-cathode axis in order to plot the radiation intensity distribution in different configurations: with no filter, with filter 1 and with filter 2, as presented in Table 1. Figure 5 shows the radiation exposure variation along the longitudinal anode-cathode axis at the patient table in the mentioned configurations.

Considering the results obtained with filter 1, a uniformization of the x-ray beam intensity on the cathode side can be observed, and from the central position of the exposure field to the edge of the anode side, the values increase gradually.

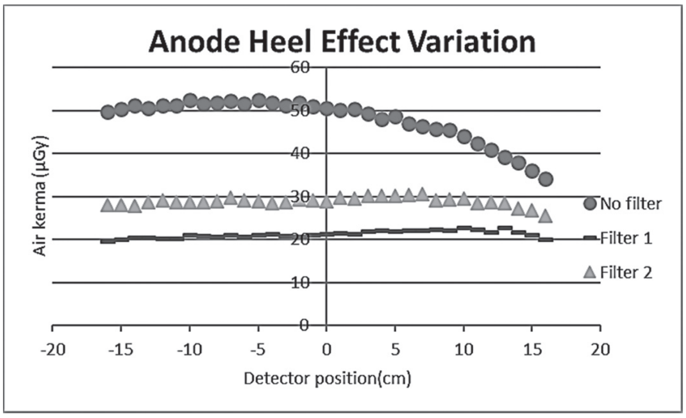

Figure 5: Anode Heel Effect variation without and with filters 1 and 2

There is a significant variation of 17% between both cathode and anode sides.

With filter 2, the same observation can be made, although with a variation of 9% between both cathode and anode sides. Thus, with the use of both filters, an almost complete uniformity of the x-ray beam can be observed. Small variations are the result of the difference in the aluminium purity.

Evaluation of the ESD reduction

It is possible to observe an ESD reduction in the AP and lateral projection of the lumbar spine, with the use of both filters compared to the examination performed without a filter. As seen in Figure 6, the ESD values in AP projection were 67.6 µGy; 36.9 µGy and 43.6 µGy for the configurations without a filter, with filter 1 and with filter 2, respectively. The lateral projection values were 109.2 µGy; 57.1 µGy and 69.6 µGy,

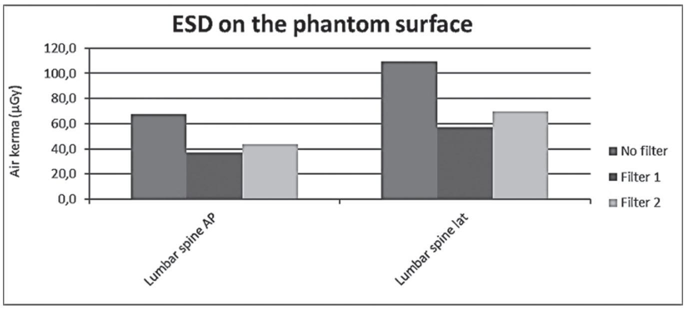

Figure 6: ESD values on the phantom surface

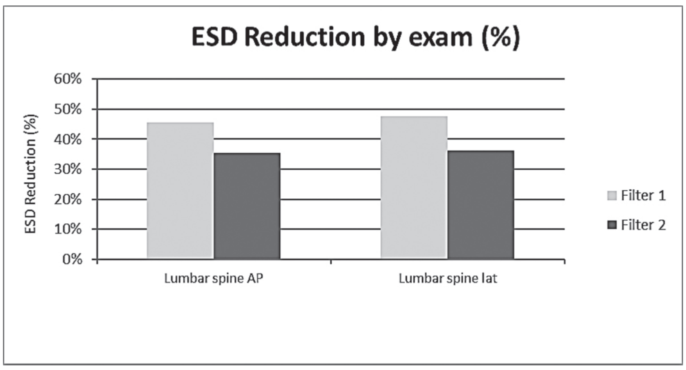

Figure 7: Percentage of ESD Reduction on the phantom

Table 1: Radiation intensity distribution along the longitudinal anode-cathode axis in three different configurations: with no filter, with filter 1 and with filter 2

Detector position in function of FOV centre (cm)	*Exposure (μGy)*			*Dose rate (μGy/s)*		
	No filter	*Filter 1*	*Filter 2*	*No filter*	*Filter 1*	*Filter 2*
-20	47.54	19.56	26.66	22.51	10.35	13.33
-19	47.36	19.30	27.07	23.68	10.22	13.53
-18	49.01	19.39	26.75	23.21	10.91	14.16
-17	48.91	19.37	27.67	24.45	10.89	13.83
-16	49.81	19.65	27.96	23.59	10.40	13.98
-15	50.31	19.99	27.94	23.83	10.58	13.97
-14	51.20	20.42	27.89	24.25	10.81	14.77
-13	50.64	20.38	28.61	23.99	10.79	14.30
-12	51,31	20.25	29.09	24.30	10.72	14.54
-11	51.12	20.31	28.74	25.56	10.75	14.37
-10	52.44	21.04	28.70	24.84	11.14	15.19
-9	51.72	20.89	28.66	25.86	11.06	15.17
-8	51.83	20.73	28.93	25.91	10.97	14.46
-7	52.28	21.07	29.62	24.76	11.15	14.81
-6	51.62	20.59	29.17	25.81	10.90	14.58
-5	52.50	21.12	28.87	24.87	11.18	15.28
-4	51.77	21.27	28.50	25.88	11.26	15.09
-3	51.25	20.84	28.69	25.62	11.03	15.19
-2	51.75	20.64	29.29	24.51	11.61	14.64
-1	51.02	21.10	29.17	24.17	11.17	14.58
0	50.65	21.21	28.93	23.99	11.23	15.32
1	50.17	21.59	29.68	23.76	11.43	15.71
2	50.44	21.27	29.55	23.89	11.26	14.77
3	49.42	21.88	30.18	23.41	11.58	15.09
4	48.05	22.10	30.06	24.02	11.05	15.03
5	48.61	21.96	30.18	23.02	11.62	15.09
6	46.97	22.07	30.28	23.48	11.68	15.14
7	46.36	22.23	30.47	23.18	11.77	15.23
8	45.65	22.36	29.08	22.82	11.84	15.39
9	45.54	22.05	29.32	21.57	11.67	14.66
10	44.00	22.73	29.60	22.00	11.36	14.80
11	42.46	22.27	28.44	21.23	11.13	15.05
12	40.80	21.67	28.59	20.40	11.47	14.29
13	39.17	22.67	28.55	19.58	11.33	14.27
14	37.91	21.78	27.14	18.95	11.53	14.36
15	36.12	21.09	26.79	17.11	11.16	13.39
16	34.06	20.05	25.43	16.13	10.61	13.46
17	30.49	19.33	23.29	15.24	10.23	11.64
18	27.14	18.30	21.75	13.57	9.693	10.87
19	23.57	16.35	18.36	11.78	8.660	9.720
20	17.98	12.66	14.60	8.994	6.706	7.729

respectively. Therefore, as displayed in Figure 7, a reduction of 45% was observed with filter 1 in AP projection and 48% in lateral projection, and lower rates are illustrated with the use of filter 2 (35% and 36%, respectively).

Image Quality Assessment

Dynamic range, spatial resolution and low contrast detectability were tested with the phantom for the same configurations. The results are presented in Table 2. No significant differences were identified between the images with filter 2 and without a filter. Filter 1 presented a higher dynamic range and a better contrast of images, but a lower spatial resolution for diagnostic images.

Table 2: Results from the image quality assessment with Pehamed Phantom Digrad A + K

	No Filter	***Filter 1***	***Filter 2***
Dynamic range	6	7	6
Spatial resolution (Lp/mm)	2.8	2.5	2.8
Low contrast detectability	0.8%	0.8%	0.8%

To assess the subjective image quality, a total of 30 questionnaires were obtained from radiologists and radiographers of the imaging department. Based on the visual grading analysis, 22% of them considered that the images without a filter had better quality and 49% preferred the images obtained with filter 1. The remaining 29% identified no differences in image quality.

DISCUSSION

In this study, the exposure parameters adopted for the examination of the lumbar spine experiments were reproduced from the actual conditions used at the department where the research was conducted, and it was found that they are in accordance with the *European Guidelines on Quality Criteria for Diagnostic Radiographic Images*, as well as similar studies (15-16).

The observed anode heel effect allowed a verification of a variation of 58% in beam intensity along the longitudinal anode-cathode axis. Similar results were obtained by Gilboy with a variation of 55% (4). Also, Terry et al. have investigated the non-uniformity of the x-ray beam and they found a decrease of 16% to 40% in the radiation intensity along the anode–cathode (18). It is well known that the appropriate use of this effect can reduce the effective dose to patients in some common radiological examinations. However, due to the anatomy of the lumbar spine in most patients, the use of specific filters can enable a uniformity of the radiation beam (19-21).

Aluminium alloy 2024 (T351) was used in this study for the design of the filters, which is a cheap material easily found on the market, but it has a lower aluminium purity than the HVL aluminium filters used to determine the radiation attenuation thickness along the anode-cathode longitudinal axis. This is the main limitation of the study due to financial constraints. The results obtained with filter 1 were not satisfactory considering a maximum variation of the x-ray beam intensity of 17%, since a maximum variation of 10% was expected. These results are mostly related to the fact that the purity of the aluminium used for filter manufacturing is low (between 91% and 95%) compared to the purity of HVL aluminium filters (99.5%). The aluminium alloy 2024 (T351) includes 3.8% to 4.9% copper as the primary alloying element, and since copper has much higher density than aluminium, this may explain the obtained results. As mentioned above, filter 2 was designed and built under different conditions than filter 1, due to budget limitations, and a maximum variation of the intensity of the x-rays of 9% was reached, as initially intended. The ESD reduction with filter 1 was higher than with filter 2 due to the larger thickness of aluminium. A reduction of 45% and 48% was observed in AP and Lateral projection, respectively, and lower rates were obtained using filter 2 (35% and 36%). These results are more favorable to those obtained by Fung and Gilboy, where they only assessed the patient's position in relation to the cathode-anode axis, obtaining ESD variations between 12% to 26% (4). In the study by Karami et al, no meaningful difference was found for the measured ESD of pelvis radiography between two groups of patients (anode directed toward the feet of patients, compared to the patients in which the anode was directed toward the head) (22). A reduction on the effective dose (from 0.022 mSv to 0.002mSv) was achieved by Lai et al. using 0.3mm Cu filter in the lateral lumbar spine radiography, maintaining image quality (23). However, since the dose optimization techniques for the routine AP and Lateral lumbar spine projection have not been fully explored in the current literature, it was possible to verify that the use of specific filters can be effective. In addition, other studies revealed ESD values higher than those obtained in the present study, also indicating a good adequacy of the technical exposure parameters (4,17,24).

Regarding the evaluation of the image quality of the radiographs, the results obtained were positive and thus support the use of a filter when performing lumbar spine radiographs in the clinical practice of radiographers. Since the diagnostic value of the radiographic images is highly dependent on the image quality, it was possible to successfully observe the image quality control tests for the dynamic range, spatial resolution and low contrast detectability, similarly observed in other studies (23,25,26).

CONCLUSION

It has been proven that both aluminium filters reduced the anode heel effect, achieving better uniformity of the beam with filter 2 (9% variation).

The use of filters is beneficial for patients in this kind of procedure and is in compliance with the ALARA principle since a significant reduction in ESD was obtained for both filters, without compromising the image quality.

Thus, based on this study, it is recommended that radiographers from this imaging department consider using such filters when performing lumbar spine radiographs.

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