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Analysis of exposure indices from digital radiography exams

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Abstract: Radiography is a crucial diagnostic imaging modality in clinical practice, with persistent challenges in digital radiography regarding the level of exposure. The International Electrotechnical Commission standardized the Exposure Index (EI) and Deviation Index (DI) in digital systems, aiming to improve the assessment of radiation exposure. Each exam has an associated Target Exposure Index (EI_T), representing the balance between radiation dose and image quality. This study analyzed the EI and DI of digital radiographs at a university hospital, using a database of 71,760 radiographs. The analysis considered the action limits as suggested by the American Association of Physicists in Medicine (AAPM). The group of exposures carried out in radiography rooms presented a DI of 1.2, while that of exposures carried out on mobile equipment, 2.4. In contrast, the first group presented standard deviation values between 1.5 and 3.9, while the second, between 1.8 and 2.6. These results suggest that exposures performed using Automatic Exposure Control (CAE) differ less from EI_T, however, radiographic techniques were more standardized among exams with mobile equipment, performed with manual selection of exposure parameters, as these exams presented a smaller DI dispersion range. The creation of an automated tool in Google Looker Studio facilitated interactive data analysis, presenting information by anatomical region and view, with the potential to continuously monitor radiological practices. For certain incidences, the average DI values obtained differed substantially from the ideal value, which requires optimization actions, investigation into the definition of adequate EI_T and calibration of the CAE. The study provided a detailed overview of local radiographic practices, highlighting priorities for optimization and standardization actions.

Keywords: radiography, exposure index, radiation exposure.

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Análise dos índices de exposição de exames de radiografia digital

Resumo: A radiografia é uma modalidade de diagnóstico por imagem crucial na prática clínica, com desafios persistentes na radiografia digital quanto ao nível de exposição. A Comissão Eletrotécnica Internacional padronizou o Índice de Exposição (IE) e o Desvio do Índice (DI) em sistemas digitais, visando melhorar a avaliação da exposição à radiação. Cada exame possui associado um Índice de Exposição Alvo (IE_T), que representa o equilíbrio entre a dose de radiação e a qualidade da imagem. Este estudo analisou o IE e o DI de radiografias digitais de um hospital universitário, utilizando um banco de dados de 71.760 radiografias. A análise considerou os limites de ação sugeridos pela Associação Americana de Físicos em Medicina (AAPM). O grupo de exposições realizadas em salas de radiografia apresentou um valor de DI igual a 1,2 e o de exposições realizadas em equipamentos móveis, 2,4. Em contrapartida, o primeiro grupo apresentou valores de desvio padrão entre 1,5 e 3,9, enquanto o segundo, entre 1,8 e 2,6. Esses resultados sugerem que as exposições realizadas utilizando o Controle Automático de Exposição (CAE) diferem menos do IE_T, contudo, as técnicas radiográficas foram mais padronizadas dentre os exames com equipamentos móveis, realizados com seleção manual de parâmetros de exposição, já que estes exames apresentaram um menor intervalo de dispersão de DI. A criação de uma ferramenta automatizada no Google Looker Studio facilitou a análise interativa dos dados, apresentando informações por região anatômica e visualização, com potencial para monitorar continuamente as práticas radiológicas. Para determinadas incidências, os valores médios de DI obtidos diferiram substancialmente do valor ideal, o que requer ações de otimização, investigação para definição de IE_T adequada e calibração do CAE. O estudo forneceu uma visão geral detalhada das práticas radiográficas locais, destacando prioridades para ações de otimização e padronização.

Palavras-chave: radiografia, índice de exposição, exposição à radiação.

1. INTRODUCTION

Radiography is an imaging examination modality widely used in clinical practice, being essential for the diagnosis and monitoring of various medical conditions. Throughout much of the 20th century, screen-film radiography systems were dominant, but with technological advancement, digital radiography has emerged as the favorite technology in diagnostic imaging departments [1,2].

The transition to digital radiography brought significant advantages, such as the elimination of the use of radiographic films and immediate access to digital images. However, adapting to digital technology presents specific challenges in relation to correct patient exposure to radiation and obtaining high-quality images. Due to the narrow latitude of screen-film systems, situations of overexposure and underexposure become evident when viewing the optical density of the exposed film, which can be considered an immediate exposure indicator. Digital image receptors have a wide exposure latitude, a characteristic that, combined with the post-processing potential of these systems, makes it possible to obtain visually similar images at different exposure levels. In this sense, overexposed images can go unnoticed, causing an unnecessary increase in radiation doses, increasing risks for patients [2,3].

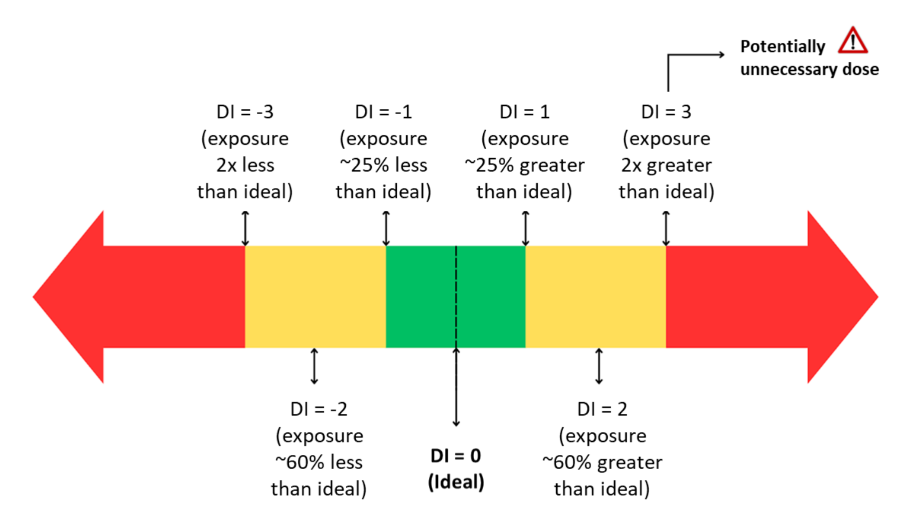
Aiming to improve this aspect, manufacturers of digital radiography systems introduced the exposure index (EI), which represents the level of exposure of the image receptor after each X-ray performed. However, this indicator had peculiarities regarding its definition and scale between different manufacturers [4]. In order to establish an unified exposure indicator for digital systems, the International Electrotechnical Commission (IEC) standardized the definition of the EI of digital systems and the concept of deviation index (DI). EI is defined by IEC as a measure of the detector's response to radiation in the relevant region of an image acquired with a digital X-ray system [5]. DI allows the operator to evaluate if the technique used to acquire the image was adequate for viewing the specific part of the body and view of interest, in relation to the acceptable signal-to-noise in the relevant regions of the image [5,6].

For each type of exam, a target exposure index (EI_T) is assigned, which represents the expected value of the EI when the image receptor is adequately exposed to X-rays, representing the ideal balance between radiation dose and image quality [5,7]. According to the IEC [5], the EI is directly proportional to the air kerma in the image receptor, while the DI, which quantifies the difference between the real EI, obtained during the exam, and the target EI_T value, is defined as:

$$DI = 10\,.\,log_{10}\left(\frac{EI}{EI_T}\right) \tag{1}$$

This definition results in a DI equal to zero when the desired exposure on the detector is reached ($EI = EI_T$), while DI with negative values refer to underexposures and positive values refer to overexposures. The EI_T can be defined by the manufacturer or determined by healthcare facilities according to their local practices. It is important to highlight that the DI is defined based on the EI and EI_T values, following the format standardized by IEC [5], and not on the specific scales provided by detector manufacturers. In Figure 1, a scale is represented with DI values and the respective increment or decrement in the level of exposure that reaches the detector. Although EI values are not suitable for estimating patient doses, their analysis allows the identification of cases of over or underexposure, providing the necessary feedback to support exam optimization activities.

Figure 1: Distribution of DI values and exposure changes received by the detector.



Source: Adapted from Comunicação SPR [8].

The American Association of Physicists in Medicine (AAPM) in Report 232 [9] published general recommendations about the factors to be considered to define meaningful limits of action in relation to DI, suggesting a continuous review process, supported by the radiologist. This process includes the prospective evaluation of cases where the DI is outside the range of ±1SD — where it is recommended to record the occurrence for possible periodic review of the number of cases —, DI > +2SD — where the outcomes can lead from image processing adjustments to correct saturation to adjustments in radiographic techniques and repetition — or in cases where DI < -2SD — when the image must be analyzed to determine if it is clinically acceptable, which may also lead to adjustments in radiographic techniques and repetition — always also recording the incidents for review in both cases. The AAPM Report 232 [9] task group defined new action limits for DI values, when compared to the analysis suggested in AAPM Report 116 [4], centralizing the analysis on the SD of DI clinical data, and highlights that the repetition of a radiography should not be based on DI only, but should be a decision aligned with a review of the image quality.

There are some factors that affect the calculation of the EI value and, consequently, the DI, that may involve: inadequate selection of acquisition parameters; patient positioning;

incorrect identification of the region of interest; situations in which collimation margins are not detected by the software, generating erroneous recognition of the exposure field when selecting the relevant region of the image; presence of unexpected material in the imaging field, generating the inclusion of different density in the data set to be processed, which ends up interfering with the histogram analysis; inconsistency in the selection of anatomical region and view when taking the exam, since the processing of image data is resized in the histogram according to this selection, for adequate adjustment of specific ideal gray scale and brightness level; among others [9,10].

In this context, the present study has the objective to analyze exposure index through the DI of digital radiography exams carried out in a university hospital. In order to implement a routine for analyzing these parameters, to integrate it into the institution's Quality Assurance Program, an automated tool was developed with Google Looker Studio for this purpose, enabling a detailed and interactive analysis of EI and DI, providing important insights for optimizing radiographic exams.

2. MATERIALS AND METHODS

This is a quantitative, cross-sectional and retrospective applied research in databases. The institution's technology park consists of six radiographic rooms with Multix Top X-ray equipments, manufactured by Siemens, with integrated Carestream digitizers and eight mobile X-ray units, intended for bedside examinations, one of which is dedicated to the surgical suite and its recovery room. The mobile equipments are manufactured by Shimadzu, six of which have digitizing systems from Carestream, with models DRX-1, DRX PLUS 2530C and DRX PLUS 3543C, and two from Canon, with models CXDI-701C and CXDI-702CW. Radiographic exams are carried out by a staff of approximately 70 radiology technologists, who have their work schedules shared with others modalities of the Institution's Radiology Department.

EI and DI data were obtained from X-ray examinations with DR technology, performed in a university hospital between January 1st and December 31st, 2022. Data extracted from the six digitizing systems of radiographic rooms and six mobile X-ray units, all of them from Carestream manufacturer, were included in the analysis. The two mobile X-ray units with Canon digitizing systems, however, were excluded from the analysis, because they did not record the EI and DI values in the data file. Therefore, initially, the database contained information referring to 90,708 radiographs images.

We do not include data from rejected images and with DI outside the range of -9.9 to +9.9. Values outside this range may correspond to exposures carried out in quality control tests and possible errors in calculating the DI value, as defined by AAPM Report 116 [4] and considered by Creeden and Curtis [7]. Other data exclusion criteria was data relating to exposures without description of anatomical region or incompatible anatomical region related to the study description, for example, an exposure with anatomy classified as chest, but the study description referred to an abdominal X-ray. Finally, exams from the ten most frequent anatomical regions in radiographic general rooms were selected to compose this study. For mobile equipment, the sample was constructed exclusively from chest and abdominal X-rays, since these exams are more frequent in this condition. Thus, the database was reduced to a sample of 71,760 X-ray information to be analyzed for EI and DI.

The accuracy of the EI of all detectors that generated the images included in the sample was tested according to the methodology proposed by the Spanish Protocol for Quality Control in Radiodiagnosis [11] and were in compliance with the recommended tolerance.

In order to draw the general scenario of the database, exposures were quantified, in absolute and percentage terms, for each anatomical region and view selected. The data were grouped according to the significant action limits suggested by AAPM Report 232, determined through the standard deviation (SD) of the DI values for each data subgroup. As an initial study, in this article a retrospective evaluation was carried out, surveying the number and percentage of exposures with DI values outside the ranges -1SD to +1SD, DI greater than +2SD and DI less than -2SD.

A dashboard was developed with the Google Looker Studio tool to automate the analyzes of EI and their DI, allowing interactive visualizations of DI values by anatomical region and view, fed directly from a Google Sheets database. This panel allows the presentation of data as quality indicators of the radiographic techniques applied in the institution and can be customized by the user, capable of incorporating tables and graphs in an interface that is easy to use and interpret.

3. RESULTS AND DISCUSSIONS

The analysis carried out in the present work covered the quantification of exposures by anatomical region — among the chest, abdomen, hands, hip, knee, feet, cervical spine, lumbar spine, ankle and femur — and view — among anteroposterior (AP), posteroanterior (PA), lateral and AP oblique. Two tables were structured that outline the general scenario of the analyzed database: one for radiographs carried out in rooms with X-ray equipment (Table 1) and another for examinations carried out at the bedside (Table 2). This distinction is made because exams carried out in bed, that is, using mobile X-ray equipment, are carried out using manual techniques 100% of the time, as they do not have automatic exposure control (AEC). Regarding exams carried out in examination rooms with X-ray equipment, it is not possible to say exactly when the exposure was obtained manually or automatically, as this information is not integrated into the database. However, considering the observation of clinical practice, it was found that these exams are mostly carried out using automatic exposure techniques.

Table 1: Detail of exposures carried out in general radiographic rooms.

ANATOMY	VIEW	NUMBER OF EXPOSURES	% IN SAMPLE	GROUP DI	P-VALUE
Chest	AP	4986	8.0%	1.4 (-0.9 – 3.7)	< 0.001
	PA	11371	18.3%	-1.4 (-2.7 – 0.8)	< 0.001
	Lateral	14540	23.4%	0.3 (-1.1 – 2.2)	< 0.001
Abdomen	AP	4066	6.5%	2.2 (0.0 – 4.3)	< 0.001
	Lateral	17	0.0%	3.6 ± 3.9	0.181
Hands	AP	181	0.3%	1.3 ± 1.6	0.099
	PA	3572	5.8%	1.1 (0.1 – 2.3)	< 0.001
	Lateral	1368	2.2%	1.3 (0.2 – 2.4)	< 0.001
Hip	AP	4216	6.8%	3.8 (2.6 – 5.0)	< 0.001
	Lateral	42	0.1%	6.1 ± 2.4	0.106
Knee	AP	2185	3.5%	3.5 (2.1 – 4.9)	< 0.001
	PA	2266	3.6%	2.9 (1.7 – 4.5)	< 0.001
Feet	AP	2156	3.5%	1.1 (0.1 – 2.1)	< 0.001
	AP oblique	1641	2.6%	1.1 (0.3 – 2.1)	< 0.001
	Lateral	644	1.0%	1.4 (0.5 – 2.5)	< 0.001
Cervical Spine	AP	1676	2.7%	2.4 (0.7 – 4.2)	< 0.001
	Lateral	1853	3.0%	2.5 (0.9 – 3.8)	< 0.001
Lumbar Spine	AP	1230	2.0%	1.7 (0.0 – 3.2)	< 0.001
	Lateral	748	1.2%	2.8 (0.6 – 4.7)	0.001
Ankle	AP	646	1.0%	1.3 (0.0 – 2.8)	< 0.001
	AP oblique	621	1.0%	2.0 (0.8 – 3.4)	0.013
	Lateral	601	1.0%	3.0 (1.9 – 4.1)	< 0.001
Femur	AP	804	1.3%	3.9 (1.8 – 6.5)	< 0.001
	Lateral	660	1.1%	4.6 (2.5 – 7.0)	0.004
Total		**62090**	**100%**	**1.2 (-0.7 – 3.1)**	**< 0.001**

Notes: Data were expressed as mean ± standard deviation, median and interquartile range. Kolmogorov-Smirnov statistical normality test was applied.

Table 2: Detail of exposures carried out with mobile equipment (bedside examinations).

ANATOMY	VIEW	NUMBER OF EXPOSURES	% IN SAMPLE	GROUP DI	P-VALUE
Chest	AP	6976	72.1%	2.1 (0.5 – 3.6)	0.020
	PA	286	3.0%	2.6 ± 1.9	0.067
	Lateral	214	2.2%	1.8 ± 2.6	0.200
Abdomen	AP	2106	21.8%	3.6 (1.7 – 5.4)	0.004
	PA	56	0.6%	3.4 ± 1.9	0.058
	Lateral	32	0.3%	3.4 ± 2.2	0.200
Total		**9670**	**100%**	**2.4 (0.7 – 4.0)**	**< 0.001**

Notes: Data were expressed as mean ± standard deviation, median and interquartile range. Kolmogorov-Smirnov statistical normality test was applied.

Table 1 presents the most frequently performed exams, of which incidences such as lateral abdomen (N = 17), AP hands (N = 181) and lateral hip (N = 42) represent less than 1% of the total sample and do not have a significant volume for analysis. The same occurs for the PA abdominal (N = 56) and lateral (N = 32) examinations in Table 2. Approximately 24% of the exposures generated underexposed images (DI<0). On the other hand, exams such as the femur, for example, show an opportunity for optimization due to high average DI value.

In order to compose the analysis based on the action limits recommended by AAPM Report 232, Tables 3 and 4 were structured: one for exposures carried out in radiographic rooms and another for those carried out using manual techniques (bedside examinations), respectively.

Table 3: Distribution of the number of exposures among different SD ranges, carried out in general radiographic rooms.

ANATOMY	VIEW	STANDARD DEVIATION OF DI	DI OUTSIDE OF ± 1SD		DI < -2SD		DI > +2SD	
			N°	%	N°	%	N°	%
Chest	AP	3.2	1277	25.6%	26	0.5%	384	7.7%
Chest	PA	2.5	3791	33.3%	106	0.9%	349	3.1%
	Lateral	2.4	3835	26.4%	253	1.7%	364	2.5%
Abdomen	AP	3.1	1237	30.4%	5	0.1%	428	10.5%
	Lateral	3.9	6	35.3%	0	0.0%	3	17.6%
Hands	AP	1.6	61	33.7%	0	0.0%	17	9.4%
	PA	1.6	1026	28.7%	8	0.2%	332	9.3%
	Lateral	1.5	466	34.1%	0	0.0%	165	12.1%
Hip	AP	2.1	1773	42.1%	17	0.4%	1666	39.5%
	Lateral	2.4	14	33.3%	0	0.0%	27	64.3%
Knee	AP	2.3	943	43.2%	6	0.3%	621	28.4%
	PA	2.5	913	40.3%	19	0.8%	426	18.8%
Feet	AP	1.7	657	30.5%	11	0.5%	146	6.8%
	AP oblique	1.5	510	31.1%	5	0.3%	144	8.8%
	Lateral	1.7	206	32.0%	0	0.0%	71	11.0%
Cervical Spine	AP	2.9	578	34.5%	17	1.0%	175	10.4%
	Lateral	2.3	772	41.7%	12	0.6%	235	12.7%
Lumbar Spine	AP	2.3	368	29.9%	1	0.1%	131	10.7%
	Lateral	2.9	282	37.7%	2	0.3%	93	12.4%
Ankle	AP	2.3	173	26.8%	5	0.8%	55	8.5%
	AP oblique	2.2	199	32.0%	6	1.0%	86	13.8%
	Lateral	2.0	278	46.3%	2	0.3%	153	25.5%
Femur	AP	3.3	277	34.5%	0	0.0%	195	24.3%
	Lateral	3.1	260	39.4%	2	0.3%	207	31.4%
Total		**2.8**	**17545**	**28.2%**	**358**	**0.6%**	**4229**	**6.8%**

Table 4: Distribution of the number of exposures among different SD intervals, carried out in bedside examinations.

ANATOMY	VIEW	STANDARD DEVIATION OF DI	DI OUTSIDE OF ± 1SD		DI < -2SD		DI > +2SD	
			N°	%	N°	%	N°	%
Chest	AP	2.4	2450	35.1%	12	0.2%	800	11.5%
	PA	1.8	116	40.6%	0	0.0%	83	29.0%
	Lateral	2.6	59	27.6%	1	0.5%	23	10.7%
Abdomen	AP	2.6	781	37.1%	2	0.1%	567	26.9%
	PA	1.9	23	41.1%	0	0.0%	21	37.5%
	Lateral	2.2	15	46.9%	0	0.0%	8	25.0%
Total		**2.5**	**3446**	**35.6%**	**15**	**0.2%**	**1399**	**14.5%**

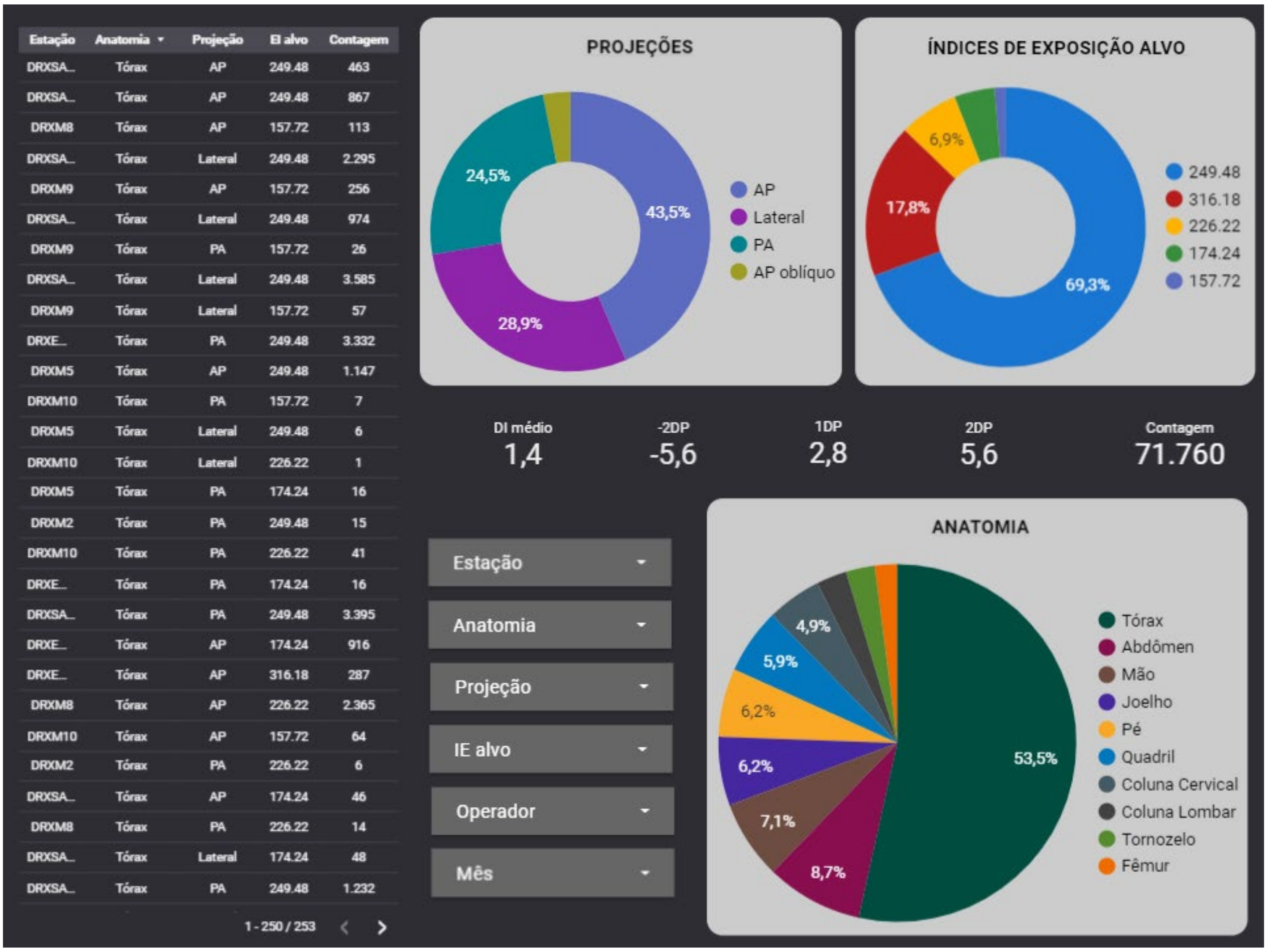
Evaluating all the data in Tables 1 and 2, it is observed that the exams carried out in the general radiographic rooms presents median DI equal to 1.2, closer to zero compared to the median DI of manual techniques, equal to 2.4. This is an indication that, on average, the exposures mostly carried out using the AEC are more appropriate as they differ less from the EI_T. In Table 3, it is observed that 64.4% of the exposures carried out resulted in a DI within the range of ± 1SD, while 49.7% of the exposures carried out with manual techniques, shown in Table 4, remained within the same interval. On the other hand, exposures from mobile equipment using manual techniques presented standard deviations between 1.8 and 2.6, which corresponds to a smaller range compared to the standard deviations of general radiographic rooms, whose range is from 1.5 to 3.9. This shows that radiographic techniques have been used in a more standardized way among exams performed at the bedside, despite the lower number of anatomical regions. In the future, this starting point should evolve towards the adoption of fixed DI ranges specific to each radiographic view, no longer defined by standard deviation, aiming to reduce the variation in the dispersion of DI values through a continuous effort to improve quality, as suggested by AAPM Report 232.

Although it is expected that the EI may be influenced by factors already mentioned above, higher SD values may indicate the need to standardize the radiological techniques practiced in the healthcare facility, in order to reduce the dispersion of DI values. Among the views shown in Table 3, the highest SDs are observed in views of the lateral abdomen, AP femur, AP chest, AP abdomen and lateral femur, suggesting that these incidences can be taken as priorities for optimization actions, aiming to achieve a narrower distribution of DI values and better standardization of the radiographic technique, although the lower sample size for lateral abdominal examinations.

One issue to be noted concerns the selection of the sample for analysis. AAPM Report 232 [9] describes the screening conditions for selecting the sample that was used by the group to analyze the DI, encompassing requirements such as the patient fitting a "typical patient" standard, the acquired image having been processed in accordance with the region and anatomical view irradiated, the patient has been positioned appropriately, the image does not contain patient or other movement artifacts, among others. However, for this study it was considered unfeasible to carry out all the screening as described in AAPM Report 232 [9], due to the large volume of data, of which there is no access to the original images to be able to verify, for example, the adequate positioning of the patient, the presence of prostheses or artifacts, etc.

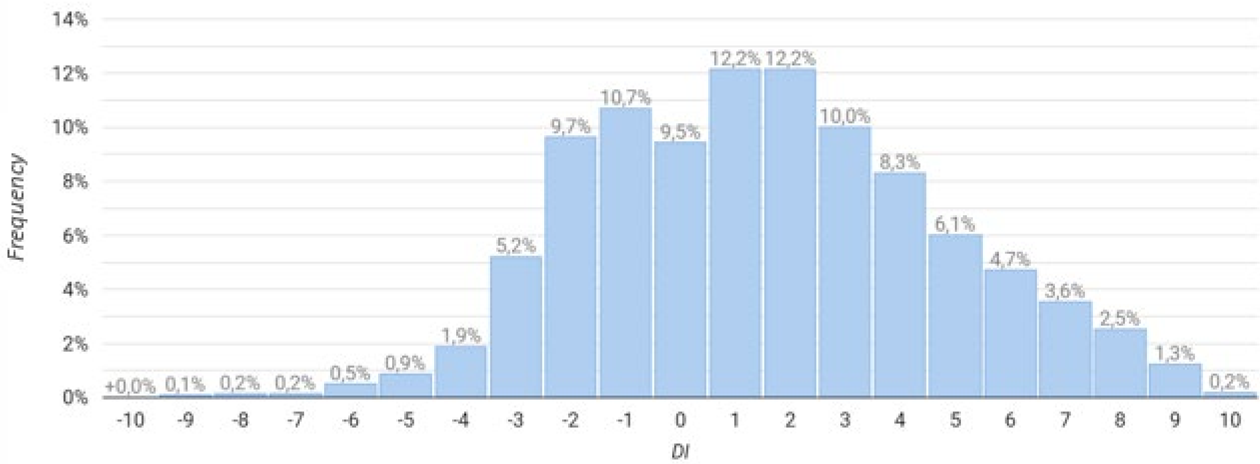
We created in Google Looker Studio an interactive panel to automate EI and DI analyzes (Figure 2). The panel is connected to a Google spreadsheet that contains the database with the technical information of the images generated by the X-ray equipment. With this visual information, the user can analyze, for example, the EI and DI of exams carried out in a given period, making it possible to select equipment or anatomy of interest, a specific operator or even a team. Another broader application is the analysis of productivity, allowing the evaluation of the volume of images acquired in a specific period, as well as the proportion of exposures between different anatomical regions and views. Other more specific variables for analysis regarding radiographic techniques include the SD of exposures, mean DI, EI_T, etc.

Figure 2: Panel developed to automate analysis. The interface can be customized by the user.



The dashboard allows for the automated creation of normalized histograms to analyze the distribution of DI values for any user-selected incidence. Figure 3 shows the histogram generated for AP chest views, acquired in radiographic rooms. It brings visual information from the distribution of DI values and their dispersion in relation to the ideal value (DI = 0). The use of this tool has the potential to be a good way to evaluate the scenario of exposures practiced in a healthcare facility before and after an optimization intervention, where the success of optimization actions could be seen in the histogram as a narrower distribution of values of DI and with a central value closest to zero.

Figure 3: Histogram of DI values for AP Chest view performed in radiographic rooms.



We notice that there is no standardization in the EI_T values defined in the institution. Although all scanners are from the same manufacturer, there are different models and the target indices have not been standardized, which means that the radiology technicians must deal with different EI_T values depending on the equipment being used to perform the radiological examination. Table 5 describes the EI_T values for each scanner included in the sample analyzed in this work.

When breaking down the analysis of the EI_T values of the DRX-1 model, it was observed that, for extremity exposures, the EI_T value is 316.18; for the spine, hip and knee the EI_T is 249.48; while for chest, abdomen and femur exposures, EI_T values can be equal to 174.24 or vary between the other two.

Digitizer L is the only one that presents five distinct EI_T values. In this digitizer, two EI_T values were assigned for abdomen exposures, while for chest, the five values are maintained. More specifically, when breaking down the analysis for each view of chest exposures, we have: for AP chest, five values; for lateral chest, 4 values; and for chest PA 3 values. Digitizers I, J and K present two EI_T values, which are present in both chest and abdominal exposures. More than 90% of exposures carried out on these detectors has an EI_T of 226.22.

Table 5: EI_T values available on each sampled digitizer.

DIGITIZER			EI_T		
A[1]	-	174.24	-	249.48	316.18
B[1]	-	174.24	-	249.48	316.18
C[1]	-	174.24	-	249.48	316.18
D[1]	-	174.24	-	249.48	316.18
E[1]	-	174.24	-	249.48	316.18
F[1]*	-	174.24	-	249.48	316.18
G[1]*	-	174.24	-	249.48	316.18
H[1]	-	-	-	249.48	316.18
I[2]*	157.72	-	226.22	-	-
J[2]*	157.72	-	226.22	-	-
K[2]*	157.72	-	226.22	-	-
L[3]*	157.72	174.24	226.22	249.48	316.18

* Detector used in mobile x-ray equipment, with sample for chest and abdomen.

[1] Model detector DRX-1.

[2] Model detector DRX PLUS 3543C.

[3] Model detector DRX PLUS 2530C.

One point to be considered would be the standardization of EI_T for exams of the same anatomy. In radiographic rooms, the EI_T values are related to the AEC calibration. Therefore, the standardization of target indices requires investigating the AEC's response to the digitizing system, checking the general calibration, an action that must relate the incident air kerma on the image receptor with the visual assessment of image quality supported by the radiologist. In this way, it would be expected the average DI of exposures to shift towards zero.

The definition of EI_T depends mainly on the part of the body and is generally established by the manufacturer of the image scanning system. However, healthcare facilities can also set their own target values, considering various issues related to clinical practice. These considerations include the age range of the patient being examined, the acceptability of the noise level by the radiologists interpreting the images, the specific anatomical part examined, the algorithm used by the image processing software, the quality of the radiation beam applied during clinical exposures and the criteria for selecting the relevant region in the image, among other factors [9].

4. CONCLUSIONS

In this study, a comprehensive analysis of EI in digital radiography was conducted. Using data from radiographic examinations performed in a university hospital during the year 2022, we focused our attention on the DI associated with these procedures. The results of this analysis provided the visualization of a detailed overview of the radiographic techniques applied at the institution, including the quantification of exposures by anatomical region and view, as well as the structuring of data according to the limits of action suggested by the AAPM, through AAPM Report 232 [9]. Thus, a more comprehensive and contextualized understanding of variations in EI across different types of exams was possible.

The interactive panel developed for EI and DI analysis allows periodic updating of the database and an immediate and automated evaluation of it, simplifying data analysis and automating the updating of quality indicators for the radiology department in question. This dashboard also allows a more detailed analysis if any intervention is carried out to optimize the DI, and subsequently, examine how the results turned out, offering an effective and efficient manner of continuously monitoring and optimizing radiological practices, with the potential to contribute to excellence in services provided by the institution.

One of the limitations of this study was the impossibility of integrating all of the institution's equipment due to technical limitations of some digitizing system manufacturers. Another limitation identified is related to the impossibility of implementing all factors considered by the AAPM Report 232 for sample screening. Several of these factors that affect EI could not be considered since the database evaluated does not include the images generated in exams. An example of this limitation would be examinations of patients with prostheses, who were not identified to be excluded from the sample and input significant variations in EI and DI data.

Future actions to improve local radiological practices include configuring digitizing systems to present IE information in the IEC-standardized format during image acquisition. This study identified weaknesses in this standardization among the equipment evaluated. This change would facilitate the standardization of procedures in the radiology department, for a team that works on a rotating schedule between different manufacturers of X-ray equipment. The availability of DI values for the team would also be an important tool for continuous improvement, since which would enable the operator to adapt radiographic techniques in subsequent examinations. It would also be interesting to configure the display of both EI and DI on the radiologist's report monitor, who would be more attentive to the level of exposure resulting from the radiological techniques used in the department. These modifications, ideally, would be added to staff training in the use of these available tools and correct interpretation of the appropriate use of EI and DI when carrying out exams.

According to Creeden and Curtis [7], analyzes regarding the selection of EI_T by the digitizer system during acquisitions, as well as the identification of values most appropriate to the healthcare establishment, are complex and subjective activities. To approach this complexity in defining EI_T values, the American Association of Physicists in Medicine (AAPM) established in 2021 a study committee called Task Group (TG) No. 368 - Methodology for Establishing Exam-Specific Target Exposure Indices in General Radiography [12]. The objective of this committee is precisely to explore the concepts involved in defining EI_T values for protocols that evaluate image quality, which can add value to radiology departments. Therefore, the future perspective of this work is to review the institution's EI_T values, with the support of imminent publications of TG 368 [12].

This work allowed us to analyze the scenario of radiographic techniques used in a university hospital through the deviation of exposure indices. For certain types of exams, the average DI values obtained differed substantially from the ideal value (DI = 0), which requires optimization actions to be taken, as well as investigation into the definition of adequate target indices and calibration of the AEC. Although the majority of exposures performed have resulted in a DI within the range of ± 1SD, periodic review of practices cannot be dispensed. The developed panel showed a potential to automate this and other analyzes in a dynamic and interactive way according to the user's interest.

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CONFLICT OF INTEREST

All authors declare that they have no conflicts of interest.

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