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Investigation of radiology professionals' awareness of CT head artifacts

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Abstract

Objective Computerized tomography (CT) artifacts can happen for various causes. It is critical to understand these artifacts because they can mimic disease or reduce image quality to non-diagnostic levels. CT artifacts can be characterized according to their underlying cause. This study aims to evaluate and compare the understanding of CT head artifacts between radiographers and radiography interns, supplemented by insights from a select group of participating radiologists.

Results A cross-sectional survey study included 150 participants. All participants' average knowledge score of CT head artifact was good (77.81%). The most correctly identified CT head artifacts were the metal artifact (86%), ring artifact (84.7%), and motion artifact (81.3%). The beam hardening artifact was correctly identified less frequently (62%). There is significant difference in the recognition of motion artifacts among the participants ($P=0.001$) knowledge of CT head image artifacts improved significantly with more experienced participants ($P=0.001$), where participants with less than 10 months of experience had a higher rate of incorrect responses (85 incorrect vs. 31 correct). The recognition of these artifacts improves with experience and advanced age. Understanding these artifacts is essential to avoid misdiagnosis of various diseases.

Keywords CT image artifacts, Knowledge scores, Radiographers, Motional artifacts, Awareness

Introduction

Axial computed tomography (CT) is the standard acquisition method of most radiology departments for regular head examinations. In computed tomography (CT), the term artifact refers to any systematic difference between the CT numbers in the produced image and the true attenuation coefficient of the item [1]. Previous studies stated that multi-detector CT (MDCT) has significantly reduced artifacts due to improving detector technology and imaging protocols. For example, the newer photon-counting detector (PCD) type has been reported to lessen metal artifacts while improving diagnostic CT image quality by increasing spatial resolution and decreasing beam-hardening effects [2, 3].

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Artifacts can significantly degrade CT image quality, potentially rendering them non-diagnostic. To enhance image quality, it is essential to comprehend the causes of artifacts and the methods for their prevention or suppression. These artifacts can be detected through other imaging techniques such as iterative reconstruction algorithms, diverse acquisition geometries for image reconstruction, and post-processing procedures that enhance the detection and characterization of the artifact [4]. CT images are intrinsically more prone to artifacts than traditional radiography because the image is reconstructed from millions of individual detector data. The reconstruction technique assumes that all of these data are consistent. Therefore, any measurement inaccuracy will usually reflect an error in the produced image [4].

Various variables, including patient, scanner, and post-processing conditions, can cause artifacts, which can cause diagnostic errors by obscuring findings or mistaking them for genuine lesions [5]. Additionally, CT artifacts can be defined as any systematic contradiction between the true attenuation coefficients of the object and the CT numbers in the reconstructed image [4]. Artifacts presented in conventional CT are still present in modern CT despite the recent improvements (Barrett et al.,2004). Radiologists, CT radiographers, and physicists must understand these artifacts as they can mimic diseases and lead to misdiagnosis. The CT technologist can explain the appearance and source of CT artifacts [6–8]. Therefore, understanding the distinct categories of CT artifacts enables radiologists and radiographers to distinguish between genuine pathology findings and imaging inaccuracies. This understanding is crucial for evaluating subtle lesions where nuanced alterations must be precisely evaluated.

No studies regarding the awareness of CT head image artifacts in our region exist. Even while there is no way to eliminate CT head image artifacts from occurring, understanding their root cause gives reading physicians the ability to recognize and interpret their presence. Furthermore, protocol modifications can be made to enhance a site's overall imaging practice using this knowledge. Therefore, this study seeks to evaluate and compare the knowledge of CT head image artifacts among radiographers and radiography interns, while also incorporating feedback from a limited cohort of radiologists to offer a more comprehensive perspective.

Materials and methods

Study design and sampling

A cross-sectional study was performed among radiology professionals in hospitals around Saudi Arabia in Al-Madinah region from June to October 2024.

Participants

The study population comprises radiographers, radiologists, and radiography student interns. They were different in age, gender, and experience. The data collection sheet was designed to include the following information: age, gender, employment status, duration of experience, institution, and qualification. The data was submitted by radiographers, radiologists, and radiography student interns who worked in hospitals and clinics under the control of the Ministry of Health and Prevention (MOHAP) and were willing to participate during the study period. The study did not include participants who did not complete the survey by the deadline.

Instrument for data collection

A self-administered questionnaire in English was prepared, evaluated, and piloted by five senior radiographers and three faculty members. This questionnaire was developed for this study. During the pilot, the readability and appropriateness of the survey, as well as the questions' definition, comprehension, and consistency, were all checked. The information statements and authorization forms were also reviewed. A pilot study was undertaken to check that the questionnaire was understandable. Prior to distributing the survey questionnaire, the reliability and validity were evaluated using Cronbach's alpha methods, resulting in a value of 0.70, indicating moderate internal consistency.

The questionnaire consists of two parts: the sociodemographic data (age, gender, experience, and institution) and the second part composed of CT head images with artifacts chosen based on the most commonly routine artifacts that faced the radiographers during their usual routine work. Nine CT images of the head with known artifacts were displayed to the participants, who were surveyed using Google Forms (https://docs.google.com/forms/d/e/1FAIpQLSdNu5mpKwbLE3doL2eBIo0Yviewform). Each CT question had five to six choices to respond to the identity of the displayed CT image artifact. The questions were formed to ask the participants how to identify the selected CT head image artifacts correctly. Therefore, they had two options: correct or incorrect answers. All participants were given the same questions in the same order. Google form was used to write the questionnaire and test the participants.

The sample size (n) was calculated using the G*Power sample size calculator, employing an effect size of 0.25 and an α error probability of 0.05, with a power of 0.95, yielding a sample size of 164. A total of 150 participant responses were obtained, resulting in a response rate of 91.4%, which was necessary for inclusion in the data analysis.

Table 1 Distribution of demographics characters of the study participants

Demographic characteristics		*n*	%
Gender	Female	49	32.7
	Male	101	67.3
Age Category/years	19–29	112	74.7
	30–39	26	17.3
	40–49	8	5.3
	50–55	4	2.7
Specialty	Computerized Tomography	45	30.0
	General radiography	68	45.3
	Interventional Radiology	3	2.0
	Magnetic Resonance Imaging	17	11.3
	Nuclear Medicine	3	2.0
	Ultrasound	14	9.3
Employment	Radiographers	124	82.7
	Radiography Student Intern	18	12.0
	Radiologist	8	5.3
Institution	Governmental	61	40.7
	Others	18	12.0
	Private	71	47.3
Qualification	B.Sc.	123	82.0
	Diploma	15	10.0
	Fellowship	2	1.3
	M.Sc.	7	4.7
	Ph.D.	3	2.0
Years of experiences	No experience	12	8.2
	1 month – 10	116	78.9
	11–20	12	8.2
	More than 20	7	4.8
Total		150	100.0

The statistical data analysis

The data was analyzed using SPSS version 23 (IBM, Armonk, NY, USA) and the DATA tab Online Statistics Calculator (DATA tab e.U. Graz, Austria). Descriptive statistics were utilized, employing frequency and percentage to represent categorical data such as demographic characteristics. The mean total score of the knowledge of radiology professionals regarding CT head artifacts was evaluated through 9 CT head images, with responses categorized as correct or incorrect (each correct answer scored 1 point, and incorrect answers scored 0 points) using descriptive statistics. A percentage of knowledge in the range of 55– 60% was considered acceptable.

The Kolmogorov-Smirnov and Shapiro-Wilk tests were performed to assess the data's normality before analysis. The results indicated that the mean scores were not normally distributed, with *P*-values showing significant differences (Kolmogorov-Smirnov: $P < 0.001$; Shapiro-Wilk: $P < 0.001$). The Kruskal-Wallis and Mann-Whitney tests were employed to compare the mean scores of perceptions and knowledge based on participants' demographic factors (age, gender, years of experience, and qualification levels), with *P*-values of ≤ 0.01 and 0.05 considered statistically significant for the identified differences.

Ethics approval and consent to participate in the study

The Institutional Review Board—Scientific Research Ethics Committee of Taibah University approved this study (project no. SREC/AMS 2019/34/DRD). Participants were notified before the official survey, and their agreement was obtained. The participants were instructed to complete the questionnaire in its entirety. All participants were informed about the purpose of the study, and completion of the questionnaire was regarded as implied consent. No identifying information was gathered to maintain anonymity and confidentiality.

Results

The study included 150 individuals with a mean age of 29 years. 67.3% were male, while 32.7% were female (Table 1). The predominant age group among participants is 19–29 years, comprising 74.7%, with general radiography and CT being the most prevalent specialties at 45.3% and 30%, respectively. Most respondents were radiographers (82.7%), with 47.3% employed in the private sector, the majority possessing a B.Sc. degree and having up to 10 years of experience (Table 1).

It was found that males had more knowledge of CT head artifacts than females (average rank 77.81 vs. 70.73, $P = 0.351$, $r = 0.08$), as shown in Table 2. The Mann-Whitney U test results suggest that there is a very small effect size in the difference in total between males and females, with insignificant differences. Furthermore, the mean score of knowledge in males was higher than that of knowledge in females (6.08 vs. 5.82), Fig. 1; Table 2.

There were no significant differences were observed among the categories of the independent variables (qualification, specialty, institution of employment, current position, years of experience, and age) concerning the mean rank and median score related to knowledge of CT head artifacts from the provided images ($P > 0.05$). Regarding qualifications, participants with a Ph.D. had a higher mean rank (135.83) than those with an M.Sc. (81.71), B.Sc., and Diploma. In terms of specialty, those working in CT had the highest mean rank (90.13), followed by magnetic resonance imaging (MRI) (82.82) and interventional radiography (73.67) as shown in Table 3.

Table 2 Impact of gender on knowledge of CT head artifacts

Gender		*n*	Mean Rank	Mean (median)	U	z	*P*-value	*r*
Knowledge score	Male	101	77.81	6.08(6.0)	2241.0	-0.95	0.351	0.08
	Female	49	70.73	5.82(6.0)				

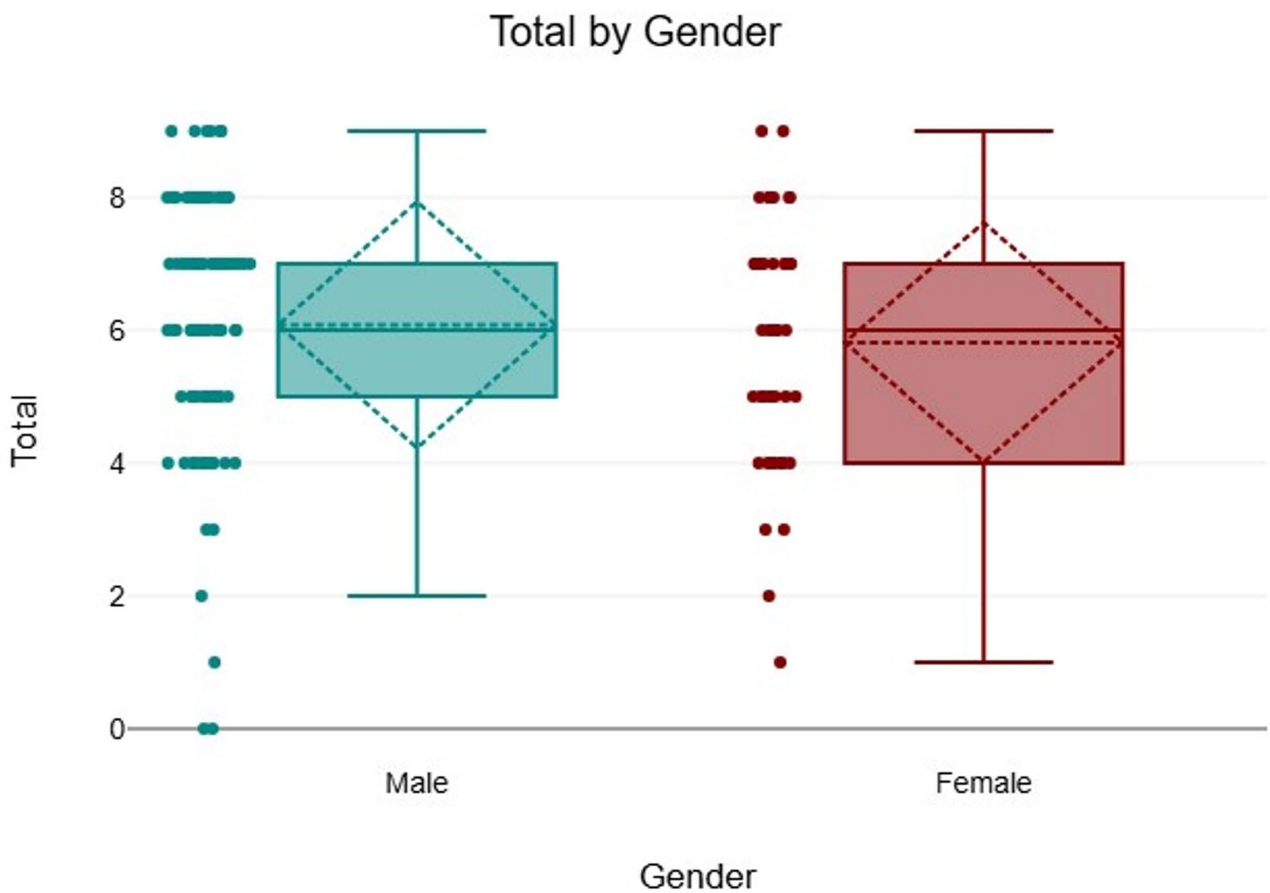

Fig. 1 Knowledge score in males and females

At the same time, general radiography and ultrasound exhibited the lowest knowledge scores (66.05 and 66.82, respectively). Additionally, radiographers demonstrated a superior knowledge rank to interns and radiologists (79, 57.11, and 62.56, respectively).

The average score for individuals in private hospitals was 6.18, surpassing that of public hospitals and others, which were 5.82 and 5.83, respectively (Fig. 2).

Participants with 11–20 years of experience possess a higher average knowledge rank (91.38) compared to those with no experience or minimal experience. Furthermore, the age group of 50–55 years exhibits a higher average mean rank (113.0) than other age groups (Table 4). The average score rose with age, recorded at 5.79, 6.35, 6.88, and 7.5 for the age groups 19–29, 30–39, 40–49, and 50–59 years, respectively, as illustrated in Table 3; Fig. 3. In general, the participants recognition of CT head artifacts increased with advanced age without significant variations among the groups ($P < 0.05$) (Table 4).

The impact of experience on recognition of CT head artifacts was shown in Table 5. The outcomes presented outline the effect of participants' experience on their awareness of CT head artifacts. Of particular note is the statistically significant difference in the recognition of motion artifacts ($P = 0.001$) where participants with less than 10 months of experience had a higher rate of incorrect responses (85 incorrect vs. 31 correct). More experienced participants (≥ 11 years) were more accurate in recognizing motion artifacts. Other types of artifacts such as hardening, ring, tube arcing, metal, and staircase artifacts did not demonstrate any statistically significant differences in recognition by level of experience ($P > 0.05$). These results indicate that while recognition of artifacts generally improves with experience, motion artifacts are particularly problematic for more inexperienced participants.

Figure 4 demonstrates the relationship between participants' employment status and their ability to accurately identify CT head artifacts. The findings reveal that employment status plays a critical role in artifact recognition as most of the artifacts have been correctly identified without significant variations among the participant ($P < 0.05$).

Discussion

This study aimed to assess the knowledge of radiographers, radiologists, and radiography student interns regarding CT head image artifacts. Evaluation of the

Table 3 Impact of qualification, specialty, institution of work, current job, and years of experience and age on knowledge of CT artifact

Demographics	Groups	*n*	Median	Mean Rank	Chi^2	*P* value
Qualification	B.Sc.	123	6	73.48	7.13	0.129
	M.Sc.	7	7	81.71		
	Ph.D.	3	8	135.83		
	Diploma	15	7	80.1		
	Fellow ship	2	4.5	52.75		
Specialty	General radiography	68	6	66.05	9.7	0.084
	Computerized Tomography	45	7	90.13		
	Ultrasound	14	6	66.82		
	Magnetic Resonance Imaging	17	7	82.82		
	Nuclear Medicine	3	5	71		
	Interventional Radiology	3	6	73.67		
Job	Radiographer	124	6.5	79	4.98	0.087
	Radiography Student Intern	18	6	57.11		
	Radiologist	8	5	62.56		
Experience years	No experience	12	5	56.58	4.31	0.23
	1 month – 10	116	6	74.39		
	11–20	12	6.5	91.38		
	More than 20	7	6	67.57		
Age groups/ years	19–29	112	6	70.62	7.40	0.06
	30–39	26	7	84.81		
	40–49	8	7	94.81		
	50–55	4	8	113.0		
	Total	150	6			

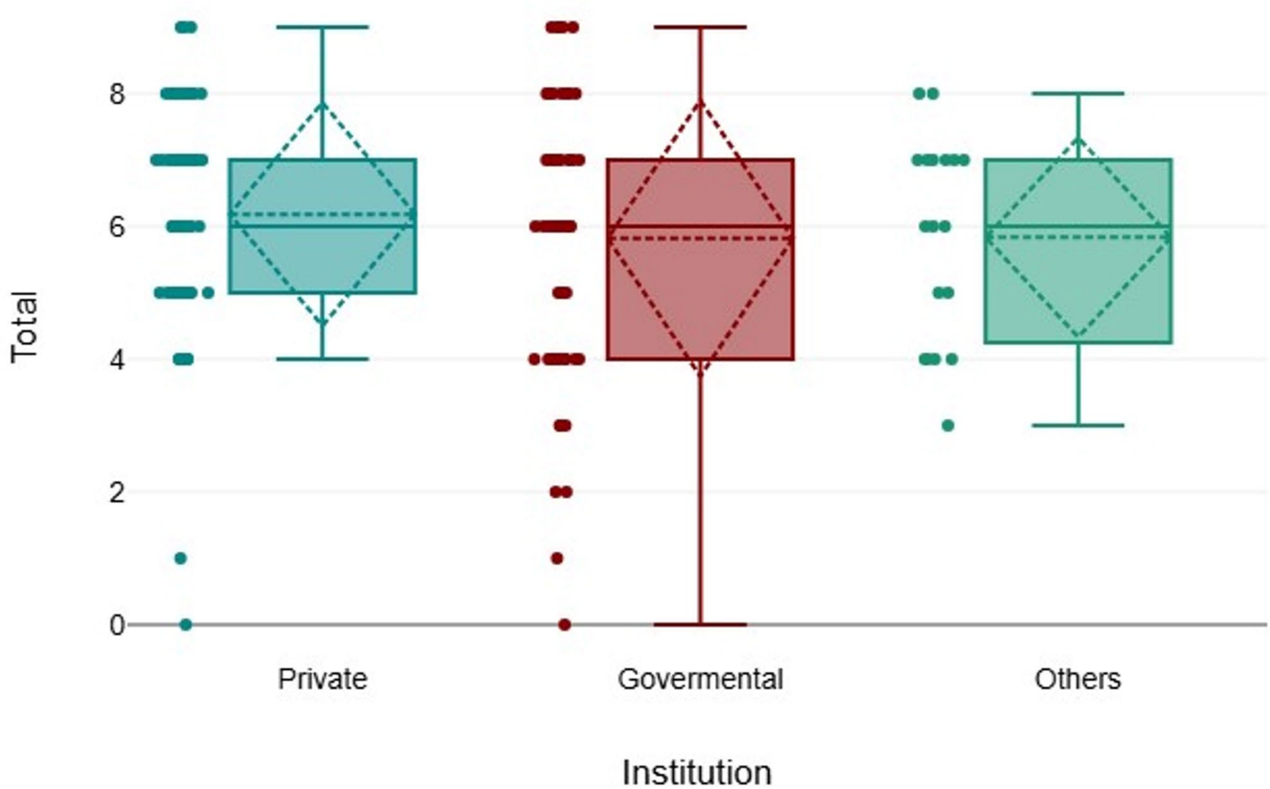

Fig. 2 Shows the score of knowledge among the participants in different institutions

Table 4 Distribution of participants responses of CT head artifacts according to age groups

Artifacts		Age groups				Total	*P* value
		19–29	30–39	40–49	50–55		
Beam hardening artifact	Incorrect	43	10	3	1	57	0.961
	Correct	69	16	5	3	93	
Motion	Incorrect	23	5	0	0	28	0.389
	Correct	89	21	8	4	122	
Beam hardening artifact	Incorrect	77	13	6	3	99	0.287
	Correct	35	13	2	1	51	
Ring artifact	Incorrect	17	4	1	1	23	0.95
	Correct	95	22	7	3	127	
Tube-arcing artifact	Incorrect	33	2	1	1	37	0.109
	Correct	79	24	7	3	113	
Metal artifact	Incorrect	17	4	0	0	21	0.547
	Correct	95	22	8	4	129	
Stair-case artifact	Incorrect	41	8	3	0	52	0.473
	Correct	71	18	5	4	98	

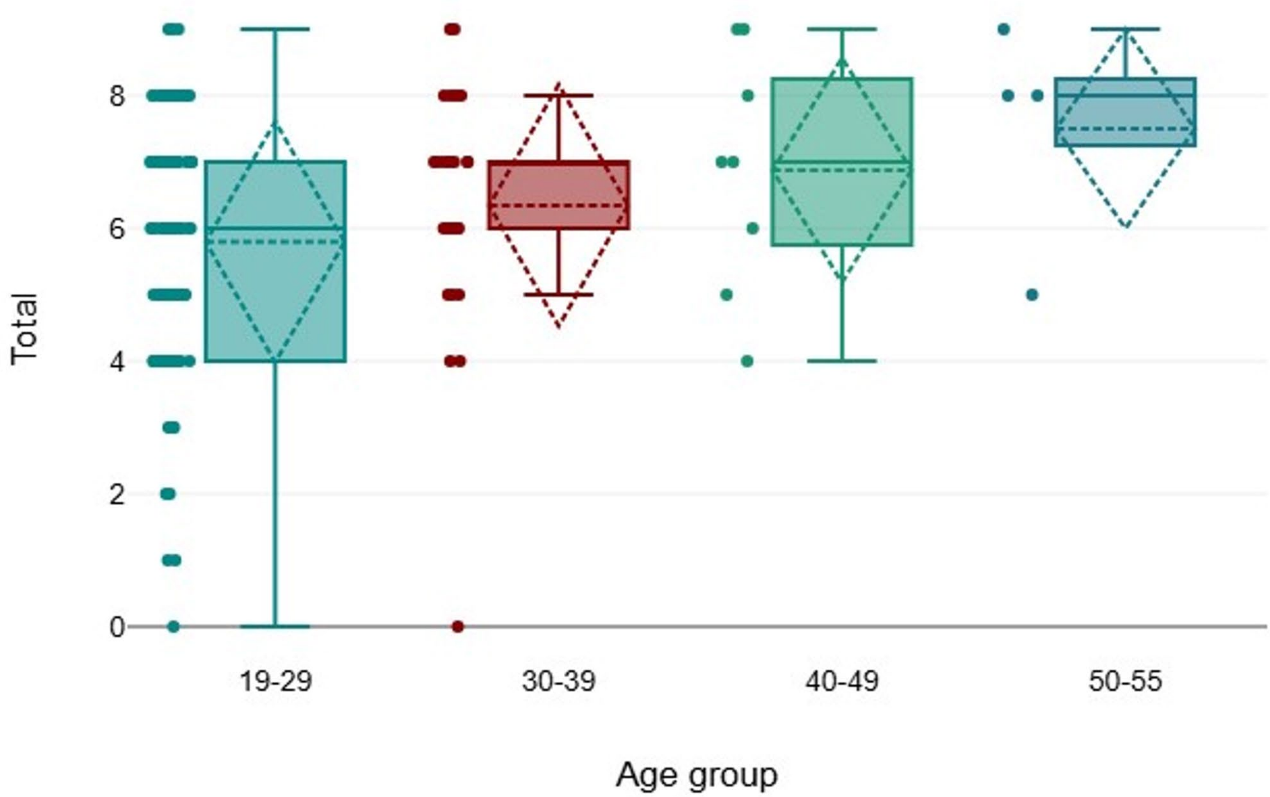

Fig. 3 Shows the score of knowledge among the participants in different age groups

awareness will ensure the delivery of training courses and improving graduate skills. In addition, investigating any knowledge deficiencies will help educational institutes and hospitals design appropriate continuous education and build programs for graduates and radiographers. These artifacts are some of the most often seen in clinical CT applications involving motion, metallic implants and technical limitations. Their existence does not mean there is poor clinical practice but shows the need for understanding and managing these artifacts by proper means of acquisition, optimization of the protocol, and training.

The results presented here showed that the participants were aware of CT head artifacts. Studying the CT artifacts is important to improve image quality and reduce

Table 5 The impact of experience of participants on awareness of CT head artifacts

CT head artifacts	Experience	Responses of the participants		*P*-values
		Incorrect	correct	
Hardening artifact	No experience	4	8	0.532
	1–10 month	47	69	
	11–20 years	4	8	
	> 20 years	1	6	
Motional artifact	No experience	6	6	**0.001**
	1–10 month	85	31	
	11–20 years	5	7	
	> 20 years	1	6	
Ring artifact	No experience	1	11	0.752
	1–10 month	20	96	
	11–20 years	1	11	
	> 20 years	1	6	
Tube arcing artifact	No experience	4	8	0.154
	1–10 month	32	84	
	11–20 years	0	12	
	> 20 years	1	6	
Metal artifact	No experience	4	8	0.165
	1–10 month	16	100	
	11–20 years	1	11	
	> 20 years	0	7	
Staircase artifact	No experience	3	9	0.190
	1–10 month	43	73	
	11–20 years	5	7	
	> 20 years	0	7	

radiation dose by reducing the repetition of the required examinations [9, 10].

The participants in our study showed high percentages of correct answers for the CT images containing metallic, ring, motion, and tube arcing artifacts. The metallic artifact was found to be the most correctly identified by the participants. In agreement to this finding, Selles et al. reported that metal artifact is a common CT artifact among the others [11]. On the other hand, a study performed by Alzain et al. et al. reported that motional artifacts were the most common ones, as responded by CT technologists [8]. It is clear that metal artifacts are one of the greatest contributors to the decrease in the quality of a diagnostic procedure. According to several studies, these artifacts may greatly obstruct the site of tumors and any other important features in the neck and head areas, which is further complicated when it comes to assessing the disease and planning the treatment [12, 13].

On the other hand, the artifact's ring, motion, and tube arc were correctly identified. These artifacts were easily identified due to their unique appearance, and the radiographers usually found them in the daily routine CT investigations. Metallic artifacts are identified by their sharp streaks originating from the implanted metals, while ring artifacts create bright or dark shadows centered on the center of the image [14, 15]. The metal artifacts are often the source of incorrect diagnosis. Such happens because these artifacts either mask the pathology or simulate pathological features that do not exist. These contradictions require the search for effective metal artefact reduction techniques.

On the other hand, the ring and motional artifacts were the second and third correctly identified among the participants. Motional appeared as shading or streaking in the displayed image [16]. Beam hardening and Staircase artifacts showed a lower percent of correct identification. The lower knowledge of these artifacts might be attributed to their rarity and similar shadows to other common artifacts.

The current study showed no significant difference in the knowledge scores among males and females for identifying CT image artifacts. This finding reflected no gender difference; they have the same knowledge regarding identifying CT head image artifacts. A study by Abuzaid et al. demonstrates that radiographers have a fair

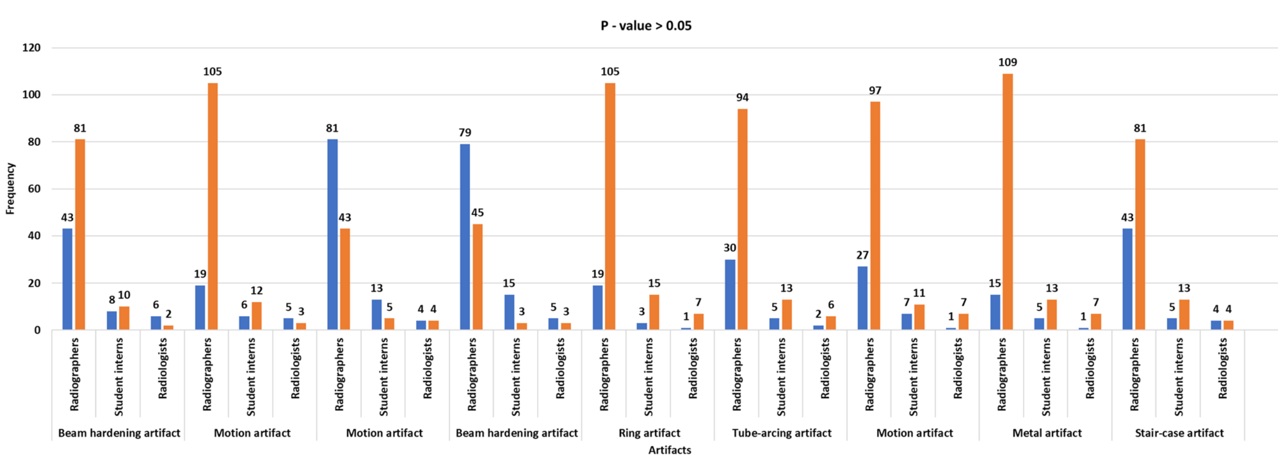

Fig. 4 assessment of participants responses of CT head artifacts in relationship with employment

understanding of CT parameters and related artifacts, with both male and female radiographers exhibiting equal competence [17]. A study by Kang et al. addresses deep learning techniques for CT artifact reduction. It does not report gender differences in the comprehension of conflict relaxation or its application in CT imaging [18].

The study found that the awareness of CT head artifacts increased among participants with long experience and advanced age. The study found a statistically significant difference in the recognition of motion artifacts (*P*-value = 0.001), with participants with less than 10 months of experience exhibiting a high rate of incorrect responses. Conversely, those with greater experience (≥ 11 years) had an enhanced capacity to accurately recognize motion artifacts. Having extensive working experience seems to improve recognition of imaging artifacts in CT scans and the operational techniques involved in imaging. It has been reported by Alzain et al. that highly skilled radiologic technologists detect common sources of artifacts and credit a good number to patient scenario-based issues, such as movement along with metallic components [19]. The information corroborates with the belief that more experienced practitioners tend to understand ways in which multiple factors contribute to artifacts during CT imaging.

Another factor that influences the knowledge of the CT artifacts is the age of the respondent. The study found that the participants recognition of CT head artifacts increased with advanced age. In agreement to this finding, a previous study reported that some of the older radiologic practitioners, especially in the range of 50 to 55 years, have a greater understanding of the older imaging methods and the associated artifact problems that older technologies have, which still may affect their imaging outputs to date [20]. This range of experience makes it possible for more seasoned practitioners to identify artifacts due to metal implants as well as other sources better than younger practitioners who have less experience [21].

Despite the academic background of the respondents in this study, they showed good knowledge about identifying the correct responses for the CT image artifacts. It was observed that participants with Ph.D. holders and Master's degrees possessed superior knowledge scores compared to the others. A study by Mahmud highlights the necessity of ongoing education and retraining for radiographers, indicating that individuals with advanced academic qualifications are more inclined to participate in professional development, thus improving their understanding of CT exposure parameters and artifacts [22].

The study found that radiographers demonstrated a superior knowledge rank to interns and radiologists. In recent studies, the knowledge of CT head artifacts among radiographers, radiography student interns, and radiologists has been a comparative topic. The scored results indicated that radiographers are likely to appreciate CT head artifacts better than radiography student interns and radiologists. A study by Abuzaid et al. reported that radiographers had a knowledge level of 72.2% concerning the CT parameters. This implies that radiographers better understand the different factors that may affect the quality of an image and the amount of radiation utilized, which is crucial in reducing artifacts in CT. Therefore, this study's findings were higher than those of previous reports on CT parameters and image quality, which assessed the knowledge of CT parameters that affect image quality. The percentage of 59.5% was debatable for being acceptable or moderate. For instance, "Norwegian radiographers showed a moderate knowledge of CT parameters, at 59.6% [23]. The low or moderate knowledge of CT artifacts or parameters could be attributed to a low level of training. For instance, Malaysian and Iranian studies reported very low knowledge scores about image quality and scan parameters; these low findings were attributed to the participants' low CT experience [24, 25].

In CT, the image artifacts should be considered carefully since they degrade the image quality.

Limitations

The study faced some limitations as other professions, especially radiologists, did not contribute sufficient responses, making it difficult to generalize the findings and may affect the study's ability to collect varied opinions, thus selection bias may arise. The study also used self-reported answers that are prone to faulty memory or knowledge exaggeration. A possible drawback is the online questionnaire distribution, which could have left out people without adequate internet or computer skills, thus creating a selection bias. Another limitation is the sample size is not large enough which may affect the generalizability of the findings. So, larger and more diverse samples are recommended to validate these findings.

The study thoroughly examined the radiology personnel's understanding of CT head artifact identification; however, further studies are needed to explore the causes of these artifacts and evaluate practical solutions for their mitigation, including protocol modifications, acquisition technique training, and the implementation of artifact reduction technologies.

Conclusion

The study concluded that knowledge about CT artifacts was good. The participants were more aware of metal artifacts, ring artifacts, and motion artifacts, respectively. There was no significant difference among radiographers, radiologists, and radiography student interns regarding the total knowledge scores of identifying CT head image artifacts. Knowledge-based practice and continuous periodical training are important to improving CT image quality.

Abbreviations
CT Computerized tomography
MRI Magnetic resonance imaging

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Author contributions
Conceptualization, A.G. and M.G.; methodology, A.A. Q. and A.F.A.; software, A.F.A.; data curation, O.A.A. and A.G.; writing—original draft preparation, M.G., AG, and M.M.A; writing—review and editing, M.G, A.B.A and RA.; visualization, A.O and ME.; supervision, M.G.; Formal analysis, A.G, M.G and AT.A; AFA.; methodology. I.M.M. All authors have read and agreed to the published version of the manuscript.

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Data availability
The data supporting the study's findings are available upon request from the corresponding author.

Declarations

Competing interests
The authors declare no competing interests.

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