

ASSESSING Z-AXIS COVERAGE COMPLIANCE IN COMMON CT SCANS ACROSS SAUDI ARABIAN HOSPITALS: A CLINICAL AUDIT



Haney Alsleem¹ ✉, Abdulrahman Almutairi², Mousa H. Alsleem³, Mujtaba Al Khamees³, Mohammed Alatiyah¹, Mohammed Alkhalifah¹, Mohammed Almohaisen⁴, Abdullah Alothman⁵ and Faisal Mohammed Al-Qahtani²

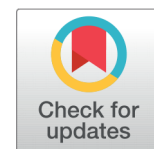
¹Department of Radiology, Imam Abdulrahman bin Faisal University, Saudi Arabia.

²Department of Radiology, King Fahad Specialist Hospital, Saudi Arabia.

³Department of Radiology, King Faisal University, Saudi Arabia.

⁴Department of Radiology, King Fahad Hospital Hofuf, Saudi Arabia.

⁵Department of Radiology, King Fahad University Hospital, Saudi Arabia.



ABSTRACT

Objectives: This study aimed to evaluate the adherence to the standard CT examination scanning length and investigate the degree of any over- or under-scanning field.

Methods: Computed Tomography (CT) scout images of the head, neck, chest, and abdomen/pelvis from three hospitals (H1, H2, H3) were retrospectively obtained from PACS system and reviewed. The scan range protocol was determined and compared to the actual scan range. Incidence of over-scanning and under-scanning were assessed and calculated.

Results: Over-scanning occurred in a substantial number of the four CT examinations among the three hospitals. Almost 50% of the collected examinations showed over-scanning superiorly at start point. Moreover, a 19% under-scanning and 47% over-scanning at scanning end points. Dose-length product (DLP) and CT dose index (CTDIvol) were collected, however, this data wasn't adequate to calculate unneeded radiation received in each scan for patients included in the samples as a result of over-scanning.

Conclusion: High percentage of over-scanning and under-scanning indicates that many technologists aren't complying with the protocol parameters which proposes the necessity to educate and increase radiation dose awareness for technologists. Their awareness regarding the important of complying the protocol start and end-scanning field should be also raised. Written protocols manual for all examinations, the routine and modified protocols should be provided for technologists to minimize the problem of over-scanning field.

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الأهداف: أجريت هذه الدراسة من أجل تقييم مدى الالتزام بنطاق المسح لفحص الأشعة المقطعية والتحقيق في درجة الزيادة أو النقصان في نطاق للمسح

الطرق: تم جمع بيانات الصور المقطعية المحوسبة للفحوصات المستهدفة والتي تشمل التصوير المقطعي المحوسب للرأس والرقبة والصدر والبطن/الحوض من ثلاثة مستشفيات (AC) بأثر رجعي من نظام الباكس "PACS" ومراجعتها. تم تحديد البروتوكول المتبع لنطاق الفحص حيث تم تحديد نقطة بداية النطاق للمسح ونقطة نهاية النطاق ومقارنة ذلك بنطاق الفحص الفعلي للفحص. ومن ثم تم تقييم وحساب حالات الزيادة والنقصان عن نطاق المسح المفترض.

النتائج: يوجد افراط في طول نطاق المسح في عدد كبير من فحوصات الأشعة المقطعية الأربعة بين المستشفيات الثلاثة. أظهرت النتائج ما يقرب من 50% من الاختبارات التي تم جمعها زيادة في نطاق المسح بشكل متفوق عند نقطة بداية النطاق. علاوة على ذلك، هناك نقصان عن النطاق المفترض للمسح بنسبة 19% والزيادة في نطاق المسح بنسبة 47% عند نقاط نهاية المسح. تم جمع طول الجرعة (DLP) ومؤشر جرعة الأشعة المقطعية (CTDIvol) لحساب الجرعة الإشعاعية الناتجة من الزيادة في نطاق المسح للفحوصات المشمولة في الدراسة. لكن البيانات المطلوبة ناقصة وغير كافية لحساب الجرعة الإشعاعية الزائدة نتيجة للمسح الزائد النطاق ولذلك تم استثناءها من الدراسة.

الاستنتاج: تشير النسبة العالية من المسح الزائد النطاق والمسح الناقص النطاق إلى أن العديد من التقنيين لا يلتزمون بمعايير البروتوكول المفترض اتباعه مما يجعل الضرورة ملحة لتثقيف التقنيين وزيادة الوعي بالجرعة الإشعاعية. وينبغي أيضاً زيادة وعيهم بأهمية الالتزام بنطاق المسح من نقطة بدء المسح ونقطة نهايته. أيضاً تشير إلى ضرورة وجود دليل مكتوب يوضح بروتوكولات التي يجب اتباعها لجميع الفحوصات، يجب توفير البروتوكولات الروتينية والمعدلة للتقنيين لتقليل مشكلة الزيادة في نطاق المسح.

1. INTRODUCTION

Computed tomography (CT) scan is widely requested as the role of CT scan is increasingly expanded and extended in diagnosing, following up and staging of disease. Consequently, the radiation dose delivered to patients has been increasing. Thus, radiation dose optimization in CT scan examinations must be considered. One of the most important parameters of radiation minimization is keeping the appropriate scan length in CT [1–3]. In their study, Badawy et. al. found that increasing of 6 cm on top of the prescribed scan length could increase 1 mSv of radiation dose [4]. Therefore, scan length of any CT scan Examination should be selected carefully, and over-scanning should be avoided.

For head CT scans, the scanning range starts from the superior aspect of just below the skull base and ends at the inferior aspect of just above the vertex. For neck CT scans, the scanning range is determined from mid-orbit (inferior sphenoid sinus) for the start point to the inferior aspect of clavicular heads (the aortopulmonary) for the endpoint of the scan [5]. For chest CT scans, the scanning range is determined from the just above lung apices for the start point to just below costophrenic angles for the endpoint of the scan. For abdomen/pelvis CT scans, just above diaphragm is used as the start point of the scan. The

inferior aspect of the pubic symphysis is used as the endpoint of the scan to measure the over and under-scanning length [4, 6–8].

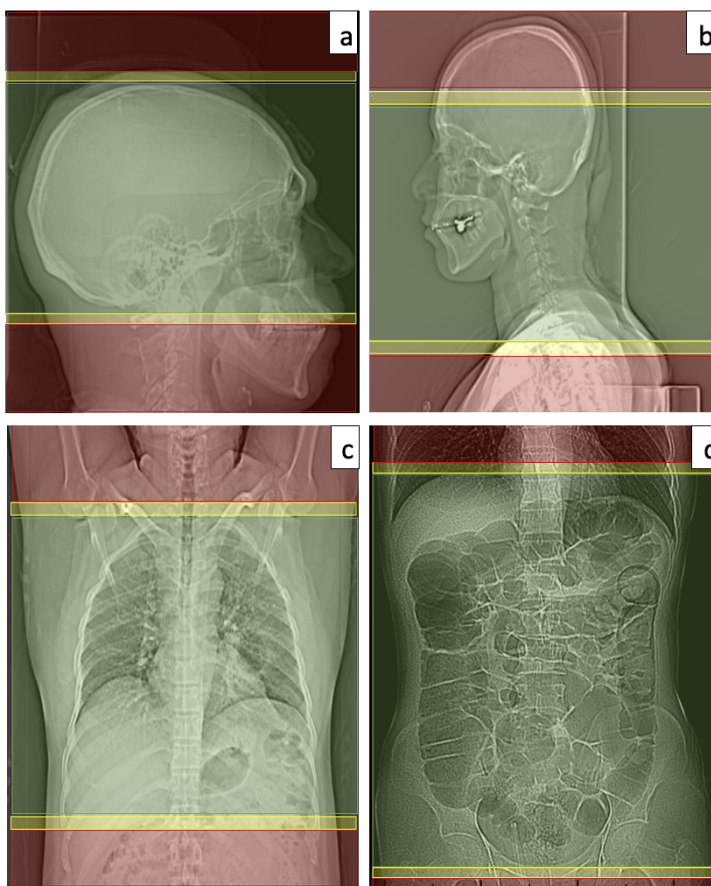


Figure 1 Head CT scan (a), Neck CT scan examination (b), Chest CT scan examination (c), Abdomen/Pelvis CT scan examination (d). Green shaded area is the protocol scanning field. Yellow shaded area is the 2cm forgiven area. Red shaded area is the over-scanning

CT technologists bear the full responsibility to select the appropriate scan length to comply with the CT protocol of the department for each CT study to maintain the radiation dose delivered as low as possible [9]. Hence, technologists’ practices are vital in radiation dose optimization through scan length control.

The dosage indices typically appeared on the CT scanner console should be understood and carefully monitored by technologists. The volume weighted volume CT dose index ($CTDI_{vol}$), which represents the dose through a slice of an appropriate phantom, while the dose length product (DLP) which is a measure of CT tube radiation exposure and account for the length of radiation output along the z-axis are the main representatives of these indices. Therefore, to avoid unintentional over-exposure, the dosage indices shown on the control panel for each protocol chosen and for each patient should be closely monitored

and confirmed to be within acceptable range. Converting the DLP to effective dose in CT is a crucial step in assessing the potential radiation risk associated with medical imaging procedures. DLP represents the radiation dose delivered to a patient during a CT scan, but it doesn't directly reflect the biological impact of that radiation. To calculate the effective dose, various conversion factors are applied, taking into account the specific CT scanner, the type of examination, and the patient's anatomy. This conversion process allows radiologic practitioners to estimate the relative risk of radiation exposure, enabling them to make informed decisions about optimizing scan protocols and ensuring that patients receive the diagnostic benefits of CT imaging while minimizing radiation-related health concerns [10].

Unfortunately, there are limited studies in Saudi Arabia that explore the incidence of over-scanning examinations and the associated radiation dose with these examinations. This study aimed to assess common CT examination length adherence and to investigate the extent of over-scanning and/or under-scanning if any exists.

2. MATERIALS AND METHODS

This retrospective study was approved by institution's ethical review board at three different hospitals in Saudi Arabia with waiver of informed consent. CT images of the head, neck, chest, and abdomen/pelvis examinations were obtained from the PACS system for the last two months. Scans with scout images that were found to miss either the upper or lower scan borders were excluded, as were studies that were conducted either for research purposes or for clinical justifiable necessitating boarder extension. The patient demographics, including gender, age, and weight/size, as well as scanner and examination details, such as scanner model, type, study exam name, CTDIvol, DLP, and the length scanned beyond the hospital protocol, were collected and subjected to analysis.

The start and end points of the scanning filed for each selected examinations were collected from the protocol manuals within the radiology department of each perspective practice. The actual start point and end points for scanning field of each exam were then determined and compared with the protocol manuals to examine the adherence of this information with performed scans.

Over-scanning and under-scanning have been calculated using two methods. First method was by using the measurement tool on the PACS software. To measure over-scanning superiorly or inferiorly the ruler is placed from actual scan start point on the scout to the protocol start location. Similarly, when calculating over-scanning inferiorly, the ruler is placed from the protocol end location to the last slide in the scout. The distance between the two points is then noted in cm as over-scanning or incase of the scan

not extending to the protocol start or point it is noted as under scanning.

Second method was by depending on the number of slices keeping in mind the slice thickness and interval thickness which are added together to give the over-scanning or under-scanning. By calculating the number of slices from the first slice of the scout until protocol start location and from the protocol end location until the last slice of the scout. Slice thickness in cm added to the interval thickness in cm, then multiplied by the number of slices will give the distance to determine the amount of over-scanning or under-scanning.

The measurements were conducted by an investigator for each examination. The measurements then were checked by a second CT scan experienced investigator to ensure reliability.

3. STATISTICAL ANALYSIS

Statistical software that was used to analyze the results of this study is SPSS. A one-way ANOVA was used to detect statistical significance at $P < 0.05$ between the data of different hospitals and examinations the study. A post hoc Tukey's multiple comparison tests was conducted when a statistically significant difference is found. A chi-squared test is also used for the significance of categorical values to assess the difference in patient demographics between the different phases. The data for continuous variables was presented as mean (standard deviation).

4. RESULTS

The protocol parameters from the three hospitals are summarized in [Table 1](#). A total of 467 CT scans were analyzed, with media patient age was 56 years (range from 18 to 95 years), 30.2% were for head protocols, 17% were for neck protocols, 21.8% for chest, and 31% were for abdomen and pelvis protocols. These were obtained from three hospitals: H1 contributed 201scans; H2 provided 123 scans; and H3 added 145 scans. [Figure 2a](#) illustrates the data distribution of collected CT scan examinations, showing both over and under-scanning ranges at the starting points for each hospital, while [Figure 2b](#) presents the same data for end points.

Among the 467 CT scans analyzed, over-scanning from the starting location was observed in 240 scans (51.5%), while the remaining 226 scans (48.5%) fell within the accepted scanning range. The highest occurrence of over-scanning was at H2 (55.8%), while the highest frequency of appropriate scanning start locations was observed at H1 (50.3%) ([Figure 2a](#)).

Regarding over-scanning at end points, it was noted in 46.3% of all scans, with H2 exhibiting the highest incidence at 53.8%, and H3 showing the lowest at 40%. Meanwhile, over-scanning at H1 was observed in 46.4% of CT scans (Figure 2b).

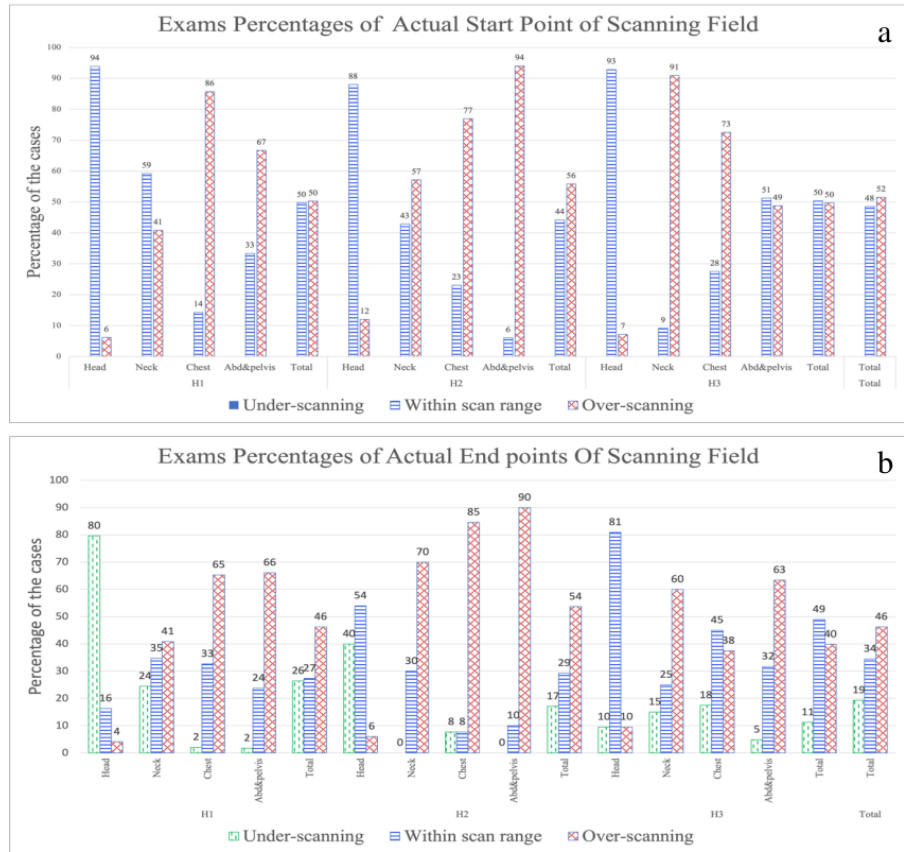


Figure 2 shows the differences between four CT examinations from three hospitals in term of their compliance percentage to the protocol scanning field at start points (a) and end points (b). Hospital H2 exhibits the highest over-scanning range.

Among the CT routines analyzed, abdominopelvic CT scans revealed the highest prevalence of over-scanning at 75% at end scanning points. In stark contrast, head CT scans exhibited the least at 6.3%. Over-scanning in chest and neck CT scans was found to be 56.8% and 49.3% respectively, indicating a significant disparity in over-scanning prevalence across various routine CT scans at end scanning point (Figure 3b). Figure 3 shows the differences between four CT examinations collected from different hospitals in term of the frequency of adherence to the protocol scanning at start (a) and end points (b) with three categories including under-scanning, within scanning.

For more detailed information, over-scanning has been divided into two categories: over-scanning and excessive over-scanning. This categorization is based on area scanned beyond 40 mm superiorly and inferiorly from the protocol’s start and end scanning loca-

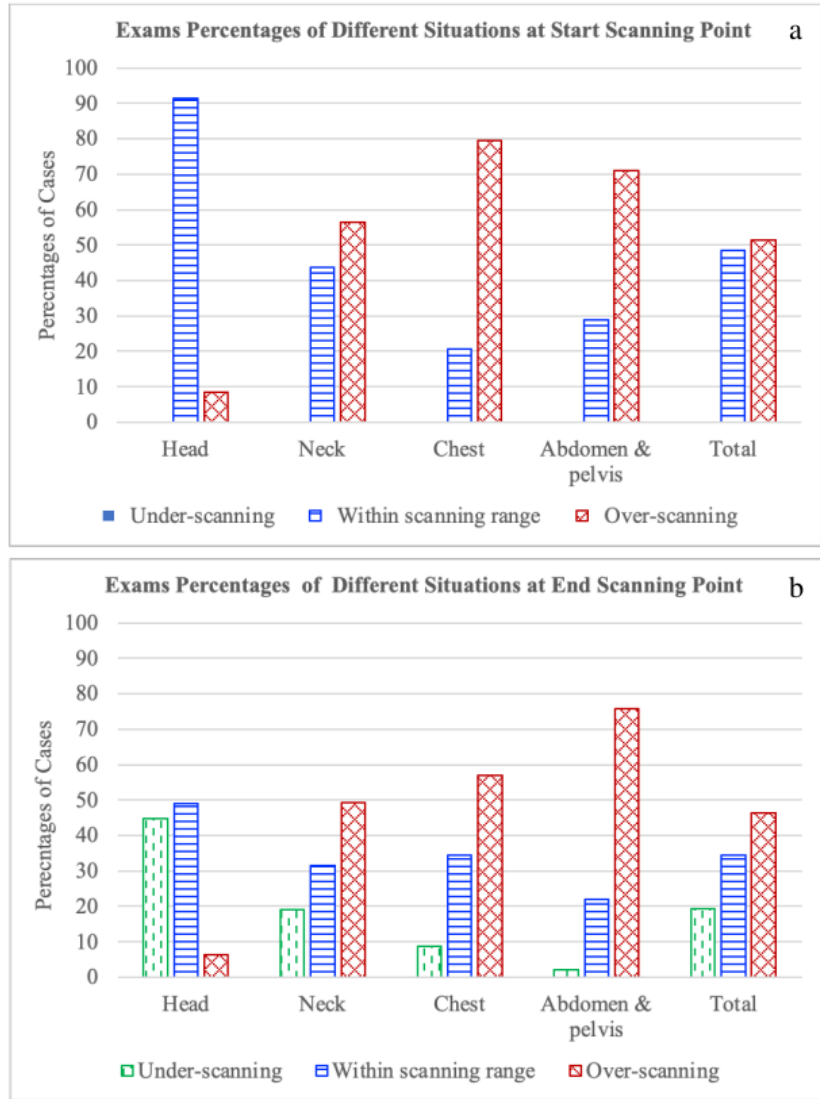


Figure 3 shows the differences between four CT examinations collected from different hospitals in term of the frequency of adherence to the protocol scanning at start (a) and end points (b) with three categories including under-scanning, within scanning

tions. As represented in Figure 4, the percentage of excessive over-scanning CT exams is significant, accounting for approximately 17% of total exams and about 33% of all over-scanning exams at both start and end scanning points. This suggests that the protocol adherence is low, resulting in higher radiation exposure to patients.

Table 1 Protocol Parameters of CT Examinations at Each Hospital

Procedure	Hospital	Patient age	Height	Weight	CT scanner model/manufacturer	Kv	Mas	Ctdivol*mg	DLP mg/cm	FOV mm	Slice thickness mm	Protocol start location	Protocol end location
CT head	H1	19-92	142-180	22-120	Discovery CT750 HD, Revolution HD 128 slice CT, Philips Brilliance 64 CT	120		61-71	244.6-417.9		3	Vertex	Base of the skull
	H2	18-95			Somatom Definition As/siemens, Somatom Definition Flash/siemens		290-345	39.2-52.5	665.2 - 1236.3	157-373	0.6	Vertex	Foramen Magnum
	H3	20-89			Somatom As+/siemens	120	350	50-50.8	848-1467	170-512	3	Vertex	C1
CT Neck	H1	19-88	148-191	46.7-109	Discovery CT750 HD, Revolution HD 128 slice CT, Philips Brilliance 64 CT	120	200	12.9-25.5	436.5-959		2.5	Aortic arch	Top of orbit
	H2	18-63			Somatom Definition As/siemens, Somatom Definition Flash/siemens		165-288	9.9-19.8	257-657	189-300	3	Aortic arch	Top of orbit
	H3	15-84			Somatom As+/siemens		257-343	17.4-23.2	467-737	112-202	2	Frontal sinus	Arch
CT Chest	H1			56-167	Discovery CT750 HD, Revolution HD 128 slice CT, Philips Brilliance 64 CT	120	400	3.24-44	107-2308	218-500	2.5	Lung apex	Cover the adrenal gland
	H2	55-87			Somatom Definition As/siemens, Somatom Definition Flash/siemens		156-204	3.7- 12.7	119-402	251-550	0.6	Lung apex	Lung base
	H3	21-86			Somatom As+/siemens			5.2-22.2	178-884	512-1024	1	Lung apex	Suprarenal gland
CT Abdomen & Pelvis	H1			36.5-108	Discovery CT750 HD, Revolution HD 128 slice CT, Philips Brilliance 64 CT	120	550	4-704	192-1433	320-500	2.5	1 inch above the diaphragm	Pubis symphysis
	H2	17-77			Somatom Definition As/siemens, Somatom Definition Flash/siemens	120-140	85-205	4.7- 37.6	197-2100	297-512	3	Top of Liver	Pubic Symph-ysis
	H3				Somatom As+/siemens	120		5-73.5	239-2340	248-524	3	Diaphragm	Pubis symphysis

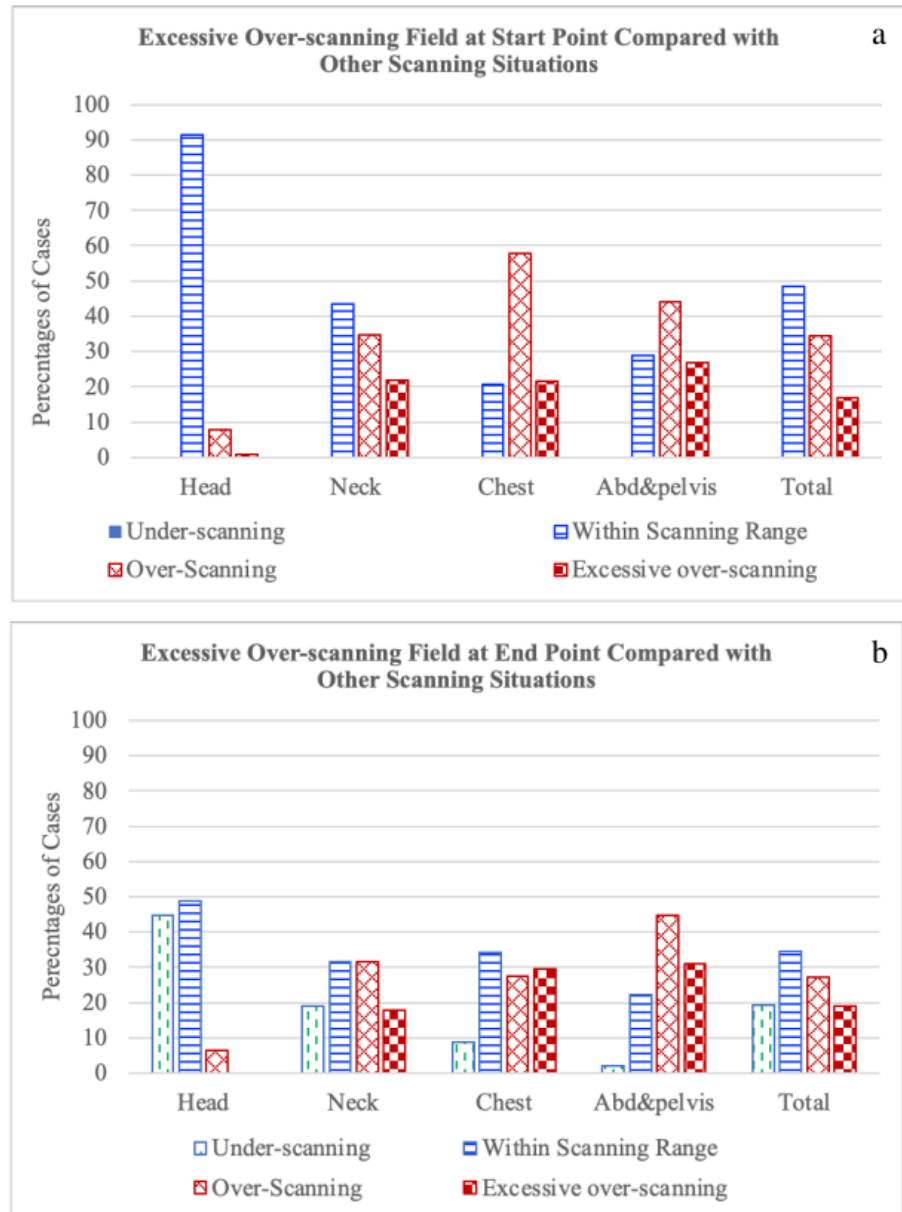


Figure 4 shows the differences between four CT examinations collected from different hospitals in term of the frequency of adherence to the protocol scanning at start (a) and end points (b) with four categories including under-scanning, within scanning, over-scanning, excessive over-scanning.

5. DISCUSSION

The results of our study align with the high rate of CT over-scanning demonstrated in previous studies of current literature [5, 6, 11–13]. The increase in scanning range results in unnecessary radiation dose to the patients. One of the essential parameters contributing to

reducing the radiation dose is the scanning range. In this study, we evaluated CT technologists' practices in selecting scanning field. The study revealed that over-scanning occurred in a significant number of the four CT examinations across the three hospitals. Out of 467 scans, 49% of cases showed CT scanning field errors at both start and end scanning range. Over-scanning at the start point accounted for nearly half of all CT scans across the three hospitals. Moreover, there was no under-scanning at the start point. Similarly, a study performed by Uldin et al., our study found a higher incidence of over-scanning [11].

Our study observed lower occurrence of under-scanning (19%) with almost half of the examinations showing over-scanning, from the endpoint in all CT scans from the three hospitals. This contrast with study by Gervaise et al., which identified a higher rate of CT under-scanning in CT kidney, ureter, and bladder (KUB) scans [14]. The rationale for this lies in the requested for a specific area of interest. The optimal starting point of CT KUB or CT Kidneys is the uppermost portion of kidneys, as including upper organs such as the liver and spleen is unnecessary and can lead to excessive scanning. Strikingly, despite observed changes in scanning parameters, only one hospital justified the modification in superior or inferior scan location.

Among the four examinations, head CT examination had the lowest percentage of over-scanning (less than 9%) from the start point across all hospitals. This high compliance may or may not indicate protocol adherence, even with a clearly identifiable landmark (vertex). In contrast, head CT scan had the highest of compliance within the protocol from the start point among the other CT exam types (91%). However, protocol compliance from the scan endpoint was (49%) and over-scanning from endpoint was just over (6%). Surprisingly, under-scanning from the endpoint was almost 45% suggesting the need for improved protocol adherence. Over-scanning was more common errors than under-scanning, and as scan extent is operator dependent, there is room for improvement in these results.

In the neck CT scans, over-scanning from the start point occurred more frequently than under-scanning inferiorly. This results in a scan parameter that cover a large area of interest than necessary, exposing patients to unnecessary radiation [15]. Another recent study highlighted that for most examinations, CT scan extents were significantly larger, with the cervical spine and lumbar spine extending from 4 cm to 6 cm (as per specific protocol disc space disorders) to a mean of 11 cm to 15 cm [16]. Data collected for the neck CT scan faced difficulties when procedures weren't correctly named and labeled. For example, a topogram named "Neck CT without contrast" might show a C-spine CT or even a neck CT with contrast. Such errors were not explained in the reports, but technologists stated that these changes as such were made according to the case's needs.

In our study, Chest CT examinations showed almost 80% over-scanning from the protocol's start location. Zanca et al. reported that up to 80% of thoraco-abdominal CT exam-

inations suffered from over-scanning, with an average of 1.8 and 2.9 cm extra scanning length at the superior and inferior directions, respectively [12]. A study by Schwartz et al. observed a significant variation among institutions, with a maximum of 60% incidence of over-scanning in chest CT, leading to dosage increases of up to 50% in certain organs [13]. Similarly, in the CT scan endpoint, the percentage for over-scanning is almost 57% while under-scanning was approximately 9%. A significant over-scanning range (31 +/- 24) mm was observed in clinical settings for over 95% of the cases [17].

In the Abdomen and Pelvis CT scans, over-scanning from start point was 71%, representing more than half of the scans with unnecessary radiation exposure. On the other hand, over-scanning and under-scanning inferiorly were at percentages of 75% and 2% respectively. Our results align with a study by Yar et al., which reported that more than 60% of CT examinations had more coverage than the necessary, especially in the inferior direction [18]. The prevalence of over-scanning in abdominal and pelvic scans can be attributed to the challenge of identifying a distinct anatomical landmark. Radiologic technologists are acutely aware of the importance of not missing the upper extent of the liver, particularly in enhanced scans, due to several factors: (1) inadequate tissue contrast beyond the hemidiaphragm. (2) Potential movement of the diaphragm during respiration. (3) The potential for patient motion during the scan. As a result, technologists strive to identify a starting point that is deemed acceptable rather than ideal. It is imperative to recognize that any omission of anatomical details necessitates a subsequent acquisition, leading to increased radiation exposure for the patient.

A study performed by Zhang M et al., where an automated computer model was created to detect situations in which abdomen-pelvis exams may have too much Z-axis coverage. The encouraging outcomes suggest that this instrument may be applied to urography, site-specific CT examinations with set, time-limited durations, and CT scans of the colon and chest [19].

The reasoning behind the over-scanning was unclear, with no justifications reported to clarify why the protocol was modified (Figure 5). From the observation of the researchers who collected the data, two out of three hospitals did not have manual for CT protocol that cover all examinations. The lack of such written protocols might be one reason for the occurrence of over-scanning.

The results from the DLP and CTDIvol were excluded from this study due to insufficient number of cases and unavailable body mass indices values. Water equivalent diameter, effective diameter, weight/height, body mass index and body surface area are essential factors that influence DLP. Thought DLP increases with increasing indices of overall body size, variations in scan length in patients with the same attenuation strength appear to weaken the correlation between the indices of overall body size and DLP [20].

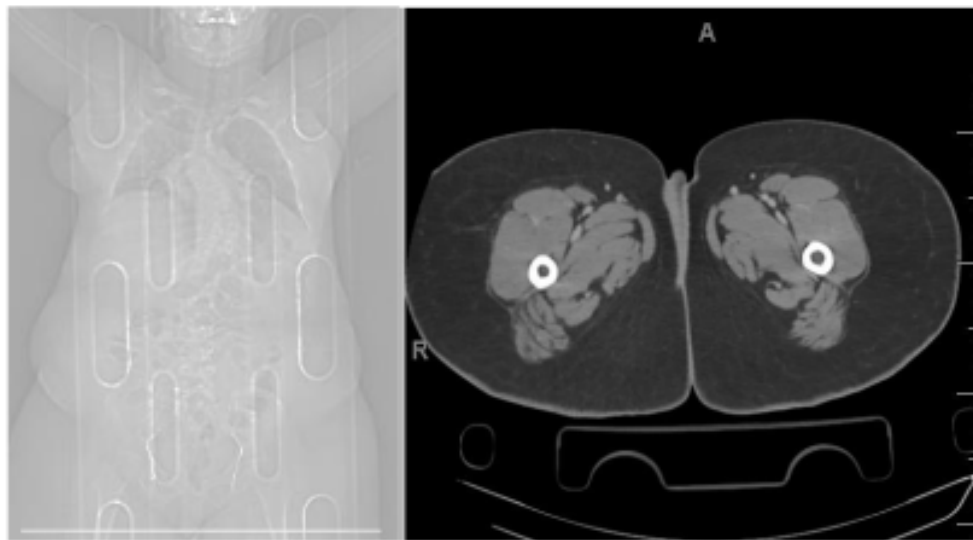


Figure 5 Abdomen & pelvis CT scan exam with contrast, the scanning field exceeded the protocol end marks without mentioning the reasons of changing the protocol scanning range.

6. CONCLUSION

This study's results clearly demonstrate over-scanning beyond protocol parameters in CT scan length, both superiorly and inferiorly, leading to unnecessary radiation exposure to patients. Technologists need to prioritize patient safety by adhering to protocol start and end scanning landmarks to uphold the ALARA principle. Furthermore, they should understand and comply with routine and modified CT protocols, and for any changes to the protocol should be justified and documented with comments. Input information, such as the protocol name and patient size (including weight and height), should also be accurately recorded by the technologists. It is recommended that this study be replicated on a large scale, encompassing a broader range of hospitals and CT examinations.

7. LIMITATIONS

The study may not fully represent common practice because as it was limited to few CT scanners, a restricted number of hospitals, a limited number of patients, and a narrow range of CT exams. Additionally, at the time of scanning, information explaining why longer scan lengths was used than is necessary was not provided. Lastly, patient information such as height and weight were unavailable for most of CT exams.

CONFLICT OF INTEREST

There is no conflict of interest.

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