A Technique for Appropriate Inferior Collimation in Chest Radiography of Asymptomatic Negroid Adults

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ABSTRACT

Background: Unnecessary exposure of the abdomen during chest radiography can lead to a substantial increase in radiation dose. **Objective:** To develop a new technique for reducing unnecessary abdominal irradiation during chest X-ray. **Methodology:** The work was designed to radiographically test the hypothesis that the umbilicus which is an external landmark that can both be seen and felt is the most appropriate anatomical landmark to consider as inferior collimation border in chest examinations. Computed tomography was used to confirm L3 and L4 as the corresponding dorsal bony landmark of the lower costal margin and umbilicus, respectively. Participants were radiographically examined with a collimation at an axial plane, 5.5 cm superior to the umbilicus. The maximum distance between the most inferior costophrenic angle and the collimation border on the radiograph was also determined. Data were manually tabulated. **Results:** The radiographs of 222 male and 216 female (n = 438) individuals were analyzed. 5.5 cm collimation coincided with L2 to T11 levels with 61% of individuals having costophrenic angles at T12 while only 3.7% had it high up at T10. No incidence of costophrenic angle cutoff was observed. **Conclusion:** Inferior collimation for chest X-ray in adults is adequate at an axial plane 5.5 cm superior to the umbilicus along the xipho-umbilical line on a patient at full inspiration. This point is a constant landmark when compared to X-ray beam centering point for chest radiography in the same patient which will be variable.

Key words: Collimation; costophrenic angle; lower costal margin; umbilicus; vertebra; X-ray

Introduction

Chest radiography is the most common radiographic procedure performed in medical imaging departments.[1] It is usually the first imaging modality for the assessment of thoracic pathologies, partly owing to the fact that it is widely available and also fairly accessible.[1,2] It is also cheap and relatively noninvasive, and it is very important for diagnosis of chest infective conditions and also in planning for further diagnostic workup.[3,4] A small portion of the gastrointestinal tract should appear in a normal chest radiograph.[3]

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The chest radiograph, however, is also one of the most often repeated exams,[1] and this will potentially increase radiation dose to the abdominal viscera.[5] Excessive beam size has been identified as the principal cause of unnecessary patient exposure.[6,7]

Proper collimation is an aspect of optimization of the radiographic imaging technique and an indicator for radiation protection. It prevents unnecessary exposure of anatomy outside the area of interest, and it also improves image quality

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by producing less scatter radiation from these areas.[5,8,9] Collimation of the chest radiography should include the lung bases[1] and should result in a lower collimation border of 2.5–5 cm below the costophrenic angle.[10]

Accuracy in beam collimation has been noted as a serious challenge to radiographers with two studies in our locality suggesting that as much as 95.30%,[9] and 100% of radiographs are inadequately collimated.[6]

The silver lining which represents the sharp demarcation between processed silver halide and unprocessed, cleared silver halide can serve as a useful radiation protection guide to check for proper field size and to detect unnecessary exposure.[5,8] It is, however, a postexposure quality control tool. There is, therefore, a need for a chest X-ray technique that can keep collimation as low as reasonably acceptable. Although chest radiography is the most commonly performed radiological investigation, there is paucity of literature on the subject matter. A beam collimation protocol which could reduce unnecessary irradiation of the abdomen is what this work is designed to address.

Methodology

This work is both a prospective and retrospective study carried out among adult cases from August to October 2015 at a University Teaching Hospital in Nigeria, West Africa. Departmental approval was obtained for the study. It was designed to radiographically test the hypothesis that the umbilicus, an external landmark that can both be seen and felt, is the most appropriate anatomical landmark to be considered as inferior collimation limit in chest radiography.

Equipment and accessories

The X-ray machine used was a GE silhouette VR, high frequency, 3-phase, static digital unit with a maximum tube potential and current of 140 kVp and 600 mA, respectively, and a total filtration of 2.5 mmAl. It was manufactured in 2007. A potter-bucky couch and erect chest stand were used. Other equipment and accessories were a German-made CR-12-x digitizer installed in 2014 and an AGFA (model CRMD1.0) photostimulable phosphor imaging plates. Chest examinations were done at a focus-film-distance of 150-180 cm. The abdomen was examined in supine position in helical mode at azimuth 180° using GE bright speed 4-slice computed tomography (CT) scanner.

Computed tomography measurements

The anatomical levels of the lower costal margin (LCM) and umblicus corresponded to L3 and L4 vertebrae, respectively, as confirmed by the review of 25 lateral abdominal scanograms done for CT urography [Figure 3]. This was done by tracing these two ventral landmarks dorsally using on-screen cursor to the corresponding vertebrae. The distance between the superior border of L3 and the inferior border of L4 was also measured on lateral scanograms, and an average of 2.75 cm was derived [Figure 1].

Preexamination assessment of radiographs

The total of 328 chest radiographs of both symptomatic and asymptomatic cases which had been passed by the quality control radiographers were assessed to ascertain the maximum distance of the most inferior costophrenic angle to the LCM [Figure 2]. This was done to investigate the possibility of costophrenic angle cutoff at L3. Symptomatic cases were included in the preassessment to give a leeway for extrapolation of results.

Subject recruitment

One-hundred and nine asymptomatic adult cases were sampled from the population of those who came for preemployment chest X-ray. Purposive sampling was used to ensure wide variability in body habitus. From the request cards, the gender of cases was noted. Inclusion criteria included the ability to position subject for posteroanterior radiography only, among others. Participants with pendulous abdomen and or bulbous umbilicus were excluded from the study.

Examination of subjects

The subject was draped in examination gown and positioned to stand erect with the dorsal aspect on the erect chest bucky. The umbilicus was palpated, and a tape rule was used to measure 5.5 cm superior to the midpoint of the umbilicus on the xipho-umbilical line. With the researcher's finger at that point, the subject was gently turned around to face the erect chest bucky. The finger was gradually traced along the waist to the corresponding dorsal vertebrae which represented the inferior collimation border. The subject was subsequently irradiated with appropriate breathing instructions. The imaging plates were processed and assessed for costophrenic

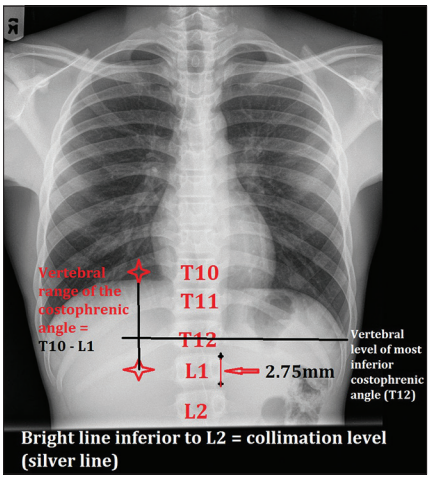

Figure 1: Chest radiograph; the measurement techniques are shown. Also shown is the silver lining which is represented by the linear and homogenously reduced optical density immediately inferior to L2 vertebra

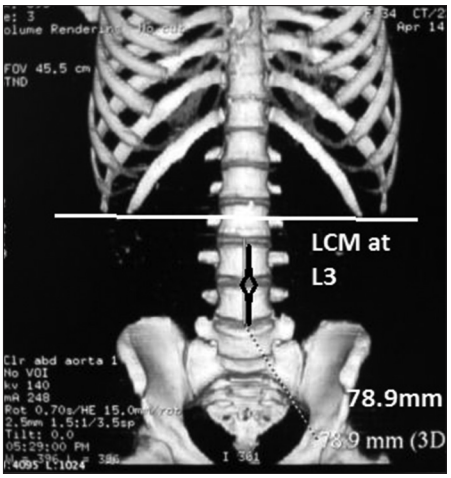

Figure 2: Three-dimensional computed tomography image of the bony borders of the abdomen; the horizontal line transverses the vertebra at the level of the lower costal margin (L3) on full inspiration

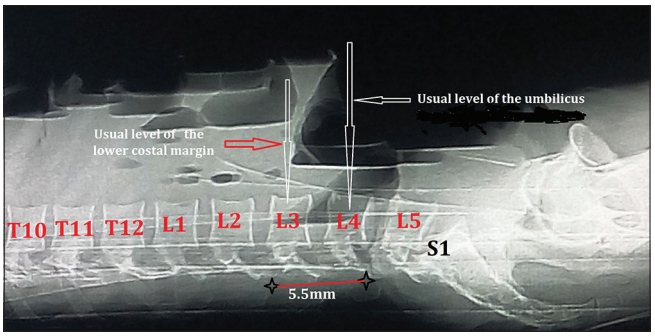

Figure 3: An abdominal computed tomography image showing neutralized natural lumbar lordosis; the vertebra distance was calculated using on-screen calipers. The distance between L3 and L4 vertebrae is approximately 5.5 cm

angle cutoff. From CT assessment, 5.5 cm represents two vertebrae distance and coincides with the inferior border of L2 vertebra in many subjects. The maximum distance between the most inferior costophrenic angle and the inferior collimation border was determined [Figure 2].

Metrics for central tendency and dispersion from the Statistical Packages for Social Sciences, version 17.0 (SPSS Incorporated, Chicago, Illinois, USA) was used to analyze the data.

Results

The radiographs of 222 male and 216 female (n = 438) comprising 375 asymptomatic and 63 symptomatic cases were analyzed [Table 1]. When collimation was done at 5.5 cm superior to the umbilicus in cases with different body habitus, it coincided with L2 to T11 [Table 2] with 61% of subjects having costophrenic angles at T12 while only 3.7% had it high up at T10. No incidence of costophrenic angle cutoff was observed. The gender difference in the level of collimation is summarized in Table 3.

Table 1: Subjects involved in the study

Variable	Gender		
	Male	Female	Total
Preresearch assessment			
Asymptomatic	141	125	266
Symptomatic	40	23	63
Postresearch assessment			
Asymptomatic	41	68	109
Symptomatic	0	0	0
Total (%)	222 (50.7)	216 (49.3)	438

Table 2: Costophrenic angle excursion

Costophrenic angle level	Collimation level				Frequency	Percentage
	L2	L1	T12	T11		
T10	0	2	1	1	4	3.7
T11	8	12	5	0	25	22.9
T12	23	42	2*	0	67	61.4
L1	7	6*	0	0	13	12.0
Total	38	61	9	1	109	100

*Costophrenic angle and collimation level at same vertebra

Table 3: Gender difference in collimation levels

Gender	Collimation level				Total
	L2	L1	T12	T11	
Male	12	25	4	0	41
Female	33	29	5	1	68
Total	45	54	9	1	109

Discussion

Effective X-ray beam collimation is one of a number of ways to reduce radiation dose. By limiting the field size of the beam, less tissue is interacting with the primary beam, thus reducing the likelihood of secondary scatter radiation arising from beam interactions within and outside of the patient.[11] The documented evidence that accuracy in beam collimation is a serious challenge to radiographers in the subregion,[6,9] was the inspiration for the work. The aim was to find clues to collimation errors.

We hypothesized that emphasis be diverted from centering point to inferior collimation border because the problem being tackled had not been addressed by many decades of centering. In our procedure, we determined the average height of a lumbar vertebra using CT [Figure 1], noted the maximum excursion of the costophrenic angles, palpated the umbilicus, and measured 5.5 cm superiorly from that point.

Our findings show that both symptomatic and asymtomatic cases [Table 1] have comparable costophrenic angle excursion from T10 to L1 [Table 2]. That presupposes that the silver line of collimation found at L2 (2.75 cm from L1) or at L3 (5.5 cm from L1) is adequate. A further descent

Figure 4: Computed tomography image showing the anatomical location of the umbilicus; the usual location of the umbilicus is shown (L4)

to L4 (8.25 cm from L1) would be unnecessary abdominal irradiation. Hopefully, this vertebrae level easy to locate since the palpable umbilicus is at L4 [Figures 3 and 4]. Our observation is in tandem with a previous work where it was suggested that the lower collimation border should be 2.5–5 cm inferior to the costophrenic angle.[10]

When our formula was investigated using cases with different body habitus, the silver line ranged from L2 to T11 with no single cutoff of the costophrenic angles [Table 3]. This further confirms that the most inferior level of the costophrenic angle does not get to L3, and that the silver line on the film should not be inferior to L3. Other workers, however, considered collimation adequate if a minimum of 3 silver lines were seen, if 80% of the film surface was covered by image,[6] or if the lung bases were included in the image.[12] This is, however, fraught with limitations as a large chunk of the abdomen could still constitute a part of the image despite the preceding criteria.

In conclusion, inferior collimation for chest X-ray in Nigerian adults is adequate at an axial plane 5.5 cm superior to the umbilicus along the xipho-umbilical line on a patient without pendulous abdomen or bulbous umbilicus. This point is a constant landmark while the centering point could be variable.

Limitation

The radiographers who agreed to test out the new collimation technique were not consistent in examining a wide range of patients.

Recommendation

The work should be replicated with different ethnic and clinically heterogeneous populations to determine if there are exceptions to our findings that the costophrenic excursion ranges between T10 to L1.

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Conflicts of interest

There are no conflicts of interest.

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