Omission of Pre-Procedure Planning Scan During CT-Guided Bone Marrow Biopsy Reduces Patient Radiation Dose Without Sacrificing Procedure Success or Duration

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Abstract

The purpose of this study is to evaluate the impact of eliminating a planning computed tomography (CT) during CT-guide bone marrow biopsy on the technical aspects of the procedure including patient dose, sample quality, procedure time, and CT fluoroscopy usage. Retrospective analysis of 40 patients from 2018-2019 was performed. Patients were grouped based on whether or not they received a planning CT scan. Relative radiation exposure was measured using dose-length product (DLP). Secondary metrics included number of CT fluoroscopic acquisitions until target localization, total number of CT fluoroscopic acquisitions, biopsy diagnostic yield, and procedure time. A total of 13 bone marrow biopsies with planning CT scans (Group 1) and 27 bone marrow biopsies without planning CT scans (Group 2) were performed. The average total DLP for Group 1 and Group 2 was 381.99 mGy*cm and 61.53 mGy*cm, respectively. The mean radiation dose reduction between the groups was 84% ($p < 0.0001$). Significantly more CT fluoroscopy acquisitions were needed for needle localization in Group 2 than Group 1 ($p < 0.0001$). Total number of CT fluoroscopy acquisitions was 8.85 for Group 1 and 9.63 for Group 2 ($p = 0.04$). There was no significant difference between the groups in procedure time or diagnostic yield. Patients without a planning CT scan received more fluoroscopic CT acquisitions but were exposed to significantly less radiation without increased procedure time or decreased diagnostic yield.

Background

The use of computed tomography (CT) for patient biopsies was first performed in 1975 [1]. A year later, CT was widely regarded as the most accurate method of guiding biopsy procedures [2]. CT has become an important image-guidance modality for many types of tissue sampling, including bone marrow biopsy and aspiration. Several recent studies have shown that radiologists are performing more of these procedures for a variety of reasons including patient body mass index (BMI), prior failed bedside attempt, and sedation requirements among other causes [3,4]. However, there is no standardized protocol for the use of CT while performing a bone marrow biopsy. Depending on user preference, a planning CT scan may be obtained for localization purposes followed by limited CT fluoroscopy to guide needle placement.

Radiologists should endeavor to reduce unnecessary radiation exposure while performing CT guided procedures. Previous research with respect to CT-guided procedures has focused on methods to reduce radiation exposure during the planning and post-procedural scans. According to Sarti et al, more than 90% of the patient's absorbed dose is administered during the planning CT [5]. If a planning CT is deemed necessary by the radiologist, methods to limit radiation exposure include reducing the craniocaudal scan length (z-axis), increasing the pitch, decreasing the photon fluence (mA), and/or decreasing the beam energy (kVp) [4].

To our knowledge, the utility of a dedicated planning CT for bone marrow biopsies has not been described. The purpose of this study is to evaluate the impact of eliminating the dedicated planning CT on various technical aspects of the procedure including total dose, use of CT fluoroscopy, procedure time, and biopsy quality.

Materials and Methods

This retrospective HIPAA-compliant study was approved by the Institutional Review Board. Procedure codes from departmental PACS were searched to find all patients who underwent a CT-guided bone marrow biopsy performed at a single regional hospital at our institution by a single musculoskeletal attending radiologist from June 1, 2018 to December 31, 2019. Patients were included in the study if they underwent a CT-guided bone marrow biopsy in a prone position that included both dose reporting information and stored procedural images within our departmental PACS. A total of 44 CT-guided bone marrow biopsies were performed. All procedures were performed on the same CT scanner (GE Optima 660). Four patients were excluded from the study, as these patients did not have procedural images stored in PACS.

Our hospital adopted a CT-guided marrow biopsy protocol that excluded the planning CT in Fall 2018. All patients prior to adoption of this protocol received a planning CT during marrow biopsy, while patients subsequent to this time did not receive a planning CT. Patients that received a planning CT scan were assigned to Group 1 and patients who did not receive a planning scan were assigned to Group 2. For patients in Group 2, the posterior superior iliac spine was palpated and marked by the radiologist before obtaining the first set of CT fluoroscopy images. The images obtained during each procedure were stored in our departmental PACS. For each case, dose length product (DLP), number of CT fluoroscopy acquisitions until localization of the targeted posterior ilium entry site, total number of CT fluoroscopy acquisitions, skin to bone distance, and procedure time were recorded. Relative radiation exposure to the patient was approximated using DLP. Localization of the target site was determined as the first image in which a needle was visualized within the subcutaneous soft tissues. Each CT fluoroscopy acquisition produced three contiguous axial CT images with 2.5 mm thickness at a fixed DLP of 6.37 mGy*cm. Starting procedural time for patients in Group 1 was obtained by the time of the planning CT scan. Starting time of the patients in Group 2 was obtained by the time of the first spot fluoroscopic image. Ending procedural time for both Group 1 and Group 2 was determined by the time of the final CT fluoroscopy image. Retrospective chart analysis was performed with regard to pertinent data including body mass index and gender, as well as pathology results to ensure a proper sample was obtained.

For the statistical analysis, continuous variables were described using the median and interquartile range. Discrete variables were described using frequency (n) and percentages (%). Differences between groups were computed using Mann-Whiney U-Test (WMW) and $\chi 2$ or Fisher's exact tests for discrete variables. P-value less than alpha <.05 is considered statistically significant. All analyses were conducted using SAS 9.4 (SAS Inc., Cary, N.C., USA).

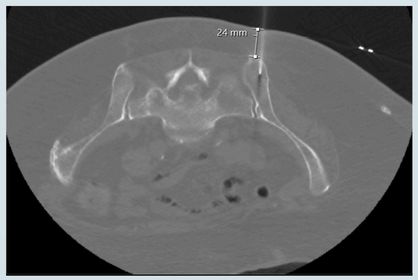

Figure 1. Single axial CT fluoroscopic acquisition in bone window demonstrating the calculation of skin to bone distance of a patient undergoing bone marrow biopsy in prone position

Results

The median age of our sample was 67.55 (IQR: 52.72, 82.38) years old. 52.5% (n=23) of the patients were male and the median BMI was 31.3 kg/m^2 (IQR: 21.09, 41.51). The median skin-to-bone measurement was 3.7 cm (IQR: 0.7, 6.62), the total median number of acquisitions was 9 (IQR: 3, 15), and the median procedure time was 19.6 minutes (IQR: 13, 26). A total of 13 patients received a planning CT and 27 patients did not receive a planning CT. All bone marrow biopsies yielded diagnostic samples. There were no statistically significant differences in patient BMI, patient age, procedure time, or skin to bone distance.

Median DLP in Group 1 was 381.99 (IQR: 132.84, 631.14) and in Group 2 was 61.53 (IQR: 36.94, 86.12) ($p < 0.0001$). Median number of CT fluoroscopy acquisitions to localization in Group 1 was 1 (IQR: 1, 1) and in Group 2 was 3 (IQR: 2, 5) ($p < 0.0001$). Median total number of CT fluoroscopy acquisitions in Group 1 was 9 (IQR: 1, 18) and in Group 2 was 9 (IQR: 6, 14) ($p = 0.04$). The results of the study are summarized below in Table 1.

	All Participants (n=40)	Group 1 Scout CT (n=13)	Group 2 No Scout CT (n=27)	
Patient Characteristics	Mean ± SD / Frequency (%)	Mean ± SD / Frequency (%)	Mean ± SD / Frequency (%)	p-value
Age (years)	67.55 ± 14.83	71.15 ± 17.85	65.81 ± 13.16	0.1
Female Gender	17 (42.5)	8 (61.54)	9 (33.33)	0.41
BMI (kg/m^2)	31.3 ± 10.21	34.13 ± 13.74	29.94 ± 7.95	0.75
Skin to Bone Distance (cm)	3.68 ± 2.94	4.78 ± 4.3	3.14 ± 1.87	0.66
DLP Total	168.93 ± 209.94	381.99 ± 249.15	61.53 ± 24.59	**<.0001**
Total number of fluoroscopic acquisitions	9.38 ± 6.1	8.85 ± 9.35	9.63 ± 3.89	**0.04**
Number of CT fluoroscopic acquisitions to localization	2.55 ± 1.69	1.08 ± 0.28	3.26 ± 1.63	**<.0001**
Procedure Time (min)	19.58 ± 6.76	22.54 ± 7.89	18.15 ± 5.77	0.12

Table 1. Characteristics of Bone Marrow Biopsy Patients

Conclusion

Our results demonstrated an average decrease in radiation dose of 84% with the elimination of the planning CT. Since identifying the optimal access site is largely performed on physical examination, Group 2 required about three CT fluoroscopy acquisitions on average compared to one for Group 1. Our CT fluoroscopy acquisitions are obtained via a foot pedal within the procedure room behind a moveable, radiation-shielded wall. Radiologists radiation exposure was not directly measured and the increased number of CT fluoroscopy acquisitions could potentially increase scatter dose to the radiologist.

Conclusion (continued)

There were no complications in either group and all obtained samples yielded diagnostic results, suggesting procedure efficacy and safety were not compromised by forgoing the planning CT. There was significantly more CT fluoroscopy acquisitions used to localize the target site as well as for the entire procedure for patients that did not receive a planning CT. Since each CT fluoroscopy acquisition on our CT unit exposed the patient to a relatively small dose of 6.37 mGy*cm, total radiation dose to the patient was still markedly lower in Group 2 despite additional fluoroscopy acquisitions.

Our study has several limitations. First, all procedures were performed by a single MSK radiologist at a single community hospital, which may limit the generalizability. Second, all of the patients were in the prone position, and our findings may not apply to CT guided marrow biopsies performed with atypical or different patient positioning. Third, we did not use a CT topogram to aid identification of the target site for Group 2; use of a planning topogram could potentially minimize the amount of CT fluoroscopy acquisitions needed to identify an ideal target site even when not performing a dedicated planning CT scan. Finally, in this study DLP was used as a surrogate for radiation dose, which presents several limitations. DLP is a measurement of radiation output from the scanner (and energy imparted to the patient), and it varies based on the selected scan length, which is often a subjective assessment by the technologist. DLP does not account for patient size, although in our sample there were no significant differences in BMI between the groups, suggesting that imparted energy for the two groups would show the same trend as absorbed dose and effective dose. The same anatomical region was scanned in all subjects, so the same radiosensitive organs and tissues were exposed. Although DLP does not provide accurate absolute radiation dosimetry, it was used as a readily-available, sufficient surrogate to compare the subject groups since the relative difference in exposure was the parameter of interest.

Elimination of a planning CT scan prior to bone marrow biopsy significantly reduced the patient's radiation dose without any significant negative impact on the technical aspects of the procedure or decreasing sample quality. Employing this change in routine practice is compatible with the patient radiation protection principles of justification and limitation of doses and thus, in the appropriate patient population, the radiologist should consider performing bone marrow biopsies without a planning CT.

References

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