Reduction of guide needle streak artifact at CT-guided biopsy.

Abstract

Purpose

CT-guided core needle biopsy (CNB) can potentially be impacted by streak artifact obscuring visualization of the needle tip. This study was undertaken to investigate factors which influence the occurrence and severity of streak artifact during CNB.

Materials and Methods

Eight coaxial guide-needles of two sizes from two manufacturers with and without stylets were imaged in a CT phantom using CT reconstructed with Adaptive Statistical Iterative reconstruction(ASiR) and Filtered Back Projection(FBP). CNB-related streak artifact was quantified with profile-analysis using Image J (Version 1.33, NIH, Washington, DC). Differences between maximum Hounsfield Unit (HU) at the needle tip and minimum HU in the streak artifact beyond were compared for each variable. Diagnostic acceptability and streak artifact were subjectively assessed on each phantom image and on 40 clinical CNB procedures, by three independent blinded reviewers following training case review. Statistical analysis (Mann-Whitney U-test, Kappa and T-tests) was performed using SPSS V.19.

Results

Artifact was significantly less with central stylet removed compared with images acquired with central stylet in-situ(median 1145HU versus 3390HU, $p<0.001$) for all needles and for 19G needles when compared with 17G needles(median 1334HU versus 2780HU, respectively; $p=0.006$). There was no difference based on manufacturer ($p=0.906$), or reconstruction algorithm ($p=0.524$). Qualitative assessment of phantom images confirmed reduced streak

artifact and improved needle visualization with central stylet removed with substantial(*0.875-1.0*) and fair to substantial(*0.231-0.711)* agreement, respectively between readers.

Conclusion

Streak artifact can be reduced and needle tip visualization can be improved by confirming final biopsy needle position with central stylet removed at CT.

Introduction

Percutaneous computed tomography (CT)-guided core needle biopsy (CNB) is frequently performed to obtain tissue for histological diagnosis. The technique entails stepwise placement of a guiding needle containing a central stylet (Fig. 1) into the periphery of a subject lesion, confirmation of satisfactory guide needle position, removal of the central stylet, deployment and confirmation of biopsy needle placement across the subject lesion and subsequent tissue sampling[1]. This technique has been shown to be highly effective, safe, and accurate[1]. Optimal biopsy technique requires adequate depiction of the subject lesion as well as the tip of the guide needle[2]. Unfortunately, with CNB, unwanted streak artifact can obscure the subject lesion and impair needle tip visualization[3]. Streak artifact on CT is caused by inconsistent measurement of attenuation by detectors in the setting of low numbers of detected photons. Streak artifact is a significant disadavantage of performing needle biopsy under CT guidance; it is secondary to the biopsy needle's attenuation of a substantial portion of the x-ray beam along the needle's length resulting in photon starvation. Streak artifact potentially limits optimal guide needle placement and accurate estimation of distance from the tip of the guide needle to the far side of the lesion and therefore the maximum desired biopsy needle throw distance.

The aim of this paper was to find a simple method to reduce unwanted streak artifact during confirmation of guide needle tip position at CT-guided core needle biopsy.

Materials and Methods

There were two components to this study: quantitative analysis of streak artifact observed during a phantom-based experiment, and qualitative analysis of the phantom images and secondly a similar investigation of streak artifact in clinical images acquired during CNB. Institutional review board approval was obtained for the clinical component of this study, which was undertaken in compliance with the Health Insurance Portability and Accountability Act.

Four factors potentially affecting the quantity of streak artifact during needle core biopsy were quantitatively studied using a cylindrical acrylic water-bath phantom (Positron emission tomography/CT Phantom source Tank, Oprax Medical, Ca, USA): 1) presence or absence of central stylet ; 2) needle size; 3) image reconstruction algorithm; and 4) needle manufacturer. A total of eight core-biopsy needles of similar lengths were placed in the phantom (Fig. 2) and imaged in-plane using 64-slice CT (VCT Xte General Electric Health Case, WI, USA). The biopy needles imaged included a total of eight needles, which comprised two sets of four needles each set produced by a different manufacturer (Temno needle guide, McGraw Park, Ill, USA and Bauer Med Inc., Clearwater, Fl, USA (M1), and Bard needle guide, Bard Inc, Covington, GA USA (M2)), in two different gauge sizes (17 and 19 gauge) imaged with and without the central stylets in place. Data were reconstructed using filtered back-projection (FBP) and prospective adaptive statistical iterative reconstruction (ASIR). CT imaging parameters were; 120kVp, 250mA, 0.8s (200mAs), 2.5mm + 2.5mm spacing. Quantitative profile analysis of streak artifact was performed using Image J (Version 1.33, National Institute of Health, Washington, DC) and Microsoft Excel (Microsoft, Redmond, WA, USA).

Hounsfield unit (HU) differences between the maximum HU at the needle tip (A) and the minimum HU in the streak artifact beyond (B) were compared for each variable (Fig. 3).

The subjective impact of central stylet removal at CT-guided biopsy was qualitatively assessed on the phantom imaging and also on a set of 40 abdominal CT-guided biopsy procedures depicting final guide needle tip position. The clinical cases consisted of percutaneous hepatic, renal and lymph node biopsies and lesion size was not standardized. Three radiologists (x, y z with 10, 19 and 25 years interventional radiology experience, respectively) graded the phantom and clinical images following review of 11 training cases, which demonstrated varying levels of artifact. The central stylet was removed in half of the 40 examinations which were analyzed. The reviewers were blinded as to whether the central needle stylet was in situ or removed at the time the biopsy images were acquired; this was accomplished by obscuring the needle hub on the images reviewed.

Diagnostic acceptability of imaging of the lesions being biopsied and adjacent anatomic structures was subjectively assessed. The presence of streak artifact was graded using a three-point scale (1, streak artifact present and interfering with needle tip visualization; 2, streak artifact present but not interfering with needle tip visualization; 3, No streak artifact) [4]. The acceptability of needle tip visualization was graded on a five-point scale (1,unacceptable; 2, minimally acceptable; 3, acceptable; 4, highly acceptable; 5, excellent). Statistical analysis (Mann-Whitney U-test for non-parametric quantitative data, T-tests for quantitative phantom data and kappa analysis for interobserver variation) was performed with SPSS V.19 (IBM, Amonk, USA) with a p-value of less than 0.05 considered statistically significant.

Results

Quantitative analysis of phantom images using imageJ demonstrated that the median tip-to-trough distance, a proxy for streak artifact, was significantly less with central stylet removed than with the central stylet in place (median 1145HU versus 3390HU, respectively; $p<0.001$) for all needles. The amount of streak artifact was also less for 19G needles compared with 17G needles (median 1334HU versus 2780HU, respectively; $p=0.006$) (Fig. 4). There was no statistical difference in the quantity of streak artifact between needles of the same gauge made by different manufacturers ($p=0.906$), or when reconstructed with ASiR vs FBP($p=0.524$) used (Fig. 4 and 5).

Cohen's kappa agreement of the 3 reader independent quantitative assessment was almost perfect for phantom streak artifact analysis (κ range 0.875-1.0) and fair to substantial for phantom needle tip visualization (κ range 0.231-0.711). The presence of streak artifact was significantly reduced when the central stylet was removed (2±0 vs. 3±0, $p<0.001$). There was no significant difference with regard to gauge, manufacturer or image reconstruction method (Table 1). Qualitative needle tip visualization analysis of the phantom images by the independent readers demonstrated that the needle tip position was best visualized in cases where the stylet was removed (4±1 vs. 1±0, $p<0.001$). As with streak artifact, other factors did not significantly alter needle tip visualization (Table 2).

The three reviewers also qualitatively assessed forty CT-guided biopsies in an independent manner. Cohen's kappa agreement of the 3 readers was moderate to substantial for streak artifact analysis (κ range 0.577-0.763) and fair to moderate for needle tip visualization (κ range 0.341-0.502). Similar to the phantom images, these results showed that the presence of streak artifact (2±1 vs. 1±1) and visualization of the needle tip (4±2 vs. 2±1) were significantly improved with the central stylet removed (Table 3). When all images from both the phantom and clinical images were examined together, removal of the stylet resulted in superior images in terms of both streak artifact (2±0 vs. 1±1, p<0.001) and needle tip visualization (4±3 vs. 2±2, p<0.001) (Table 3).

Discussion

CT guidance is an important tool for safe and effective image-guided biopsy. Accurate needle visualization and positioning is required in order to avoid complications and to obtain a diagnostic tissue sample[5]. All cause mortality at liver biopsy is two per 1000 patients; one patient per 500 develops mild to moderate hemorrhage, one patient per 2500 develops severe hemorrhage, and organ perforation has an incidence of 1.7 in 1000 cases[6]. A prior study documented the occurrence and effect of streak artifact due to the guide needle during CT-guided biopsy; 10.5% of hepatic lesions were poorly visible at the beginning of the procedure and this increased to 44.7% prior to biopsy[7]. Poor visualization due to streak artifact was associated with a 12.8% increased incidence of false negative biopsy. The purpose of the present study was to investigate factors implicated in the creation of streak artifact during CT-guided needle core biopsy in order to identify a simple strategy to limit streak artifact. This is based on the premise that streak artifact interferes with needle tip visualization, reduces the accuracy of needle placement, potentially diagnostic yield, number of biopsies required and development of complications.

Streak artifact tends to occur at interfaces between substances of markedly different attenuations and can be caused by beam hardening or photon starvation[8]. Beam hardening occurs when lower energy photons are absorbed by highly attenuating objects and the remaining beam strength has disproportionately higher energy creating inaccuracies of CT reconstruction and artifact. This can inhibit proper visualization of the surrounding tissues and lead to errors[9]. Extreme attenuation of an X-ray beam leads to photon starvation whereby there is insufficient useful signal for image generation and a surplus of image noise. Streak artifact from metal can be reduced using several methods. Filtration of lower energy photons using metal or bow tie filters can be used to create a more homogenous beam although this reduces signal data and can create noise when radiation exposure is not increased. Extension of the upper limit of the HU scale from 4,000HU (standard) to 40,000HU compensates for the attenuation of metal (8,000-20,000HU) that can reduce streak artifact provided thin section imaging is performed[10 11]. Metal deletion techniques have been developed which show promise but long reconstruction times can be prohibitive for procedure guidance[9]. Our study however, focused on assessing the influence that a number of practical time efficient actions, which can easily be taken during CTB, may have on streak artifact reduction and needle tip visualization.

There are many patient-determined variables which affect the accuracy of CT-guided core needle biopsy. Factors such as patient habitus, lesion size and location, lesion conspicuity on unenhanced CT images, lesion contents, biopsy route, operator experience, technique, and tissue sample handling all potentially influence successful outcome [8 12 13]. It is difficult to standardize for so many variables as part of research, especially in a clinical setting. Phantom-based analysis of streak artifact allowed four important factors to be assessed while standardizing all other variables including body attenuation (simulated by Perspex phantom) and radiation beam. It was possible to perfectly position needle guides in the imaging plane that ensured accurate measurement of streak artifact both over the length of the needle and beyond its tip. In-plane imaging of the guide needle is one of our technical objectives during biopsy performance. The phantom component of this paper clearly established that the amount of streak artifact created during CT guided biopsy is significantly less when the central stylet is removed from the guide needle for all needle types and sizes ($P < 0.001$) and that there was less artifact from smaller 19G needles compared with 17G needles ($P < 0.001$). No differences were observed based on manufacturer ($p=0.906$), or reconstruction algorithm ($p=0.524$).

Images from 40 CT-guided abdominal biopsies using 17G guide needles were reviewed in a blinded manner by three experienced interventional radiologists in order to assess if observations made during the phantom experiment held true in the clinical setting. This component of the study confirmed a statistically significant decrease in the amount of streak artifact observed ($P < 0.001$) and improved needle tip visualization ($P < 0.001$) when the central stylet was removed. There was substantial and moderate interobserver agreement regarding the presence of streak artifact and adequacy of needle tip visualization, respectively. The clinical cases consisted of percutaneous hepatic, renal and lymph node biopsies and lesion size was not standardized.

Although we have demonstrated that smaller (19G) gauge needle guides produce less artifact, they potentially do so in exchange for higher rates of sampling error [5]. It is normal practice in our departments to perform percutaneous abdominal and pelvic biopsies using coaxial systems with 17 gauge guide needles and 18 gauge cutting needles. Therefore 19 gauge guide needles were not assessed during the clinical component of the study. Larger guide needles likely increase the chances of air embolism even though this is a rare occurrence at the time of biopsy. Confirmation of guide needle position with the stylet removed has the potential to introduce air. We therefore recommend occlusion of the guide needle hub using a bung at the time of procedure when the stylet is removed or alternatively partial withdrawal of the stylet prior to position confirmation. It is our practice to confirm final guide needle position prior to biopsy, using a short spiral CT rather than using CT fluoroscopy. It is likely that the present results are also applicable to images acquired on CT fluoroscopy but this has not been formally assessed in the present paper.

Further research is required concerning this aspect of the study. Correlation of histological - tissue yield, procedure time and development of complications following adoption of central stylet removal technique would be required for final validation. It is also possible that central stylet removal would most benefit biopsy of small lesions, since these lesions potentially have the highest chance of non–diagnostic tissue sampling, or lesions located in difficult to access areas where precise needle placement is vital to avoid injury to an adjacent structure.

In conclusion, this present paper confirms that streak artifact can be reduced and needle tip visualization improved if guide needle position is confirmed with the central stylet removed when performing CT at the time of a biopsy procedure.

Figure legends

Figure 1. Coaxial needle biopsy guiding system. The stylet (A) is placed inside the biopsy needle guide in order to separate tissues during needle passage. The stylet may be removed when adequate needle guide position is obtained in order to introduce the biopsy needle and obtain samples.

Figure 2. Picture of water filled cylindrical acrylic phantom within the CT gantry. Needles were positioned so that the CT laser guide was parallel with the long axis of the needle guide (arrow).

Figure 3. Quantitative Profile analysis of streak artifact using Image J. Attenuation values along the shaft of the needle and the streak artifact were determined in order to assess the maximum attenuation of the streak artifact at the needle tip (A) and minimum attenuation within the streak artifact (B).

Figure 4. Averaged needle tip profiles for both manufacturers (M1 and M2) and needle size (19G and 17G) with both the stylet in (S+) and the stylet out (S-). There was significantly more streak artifact with the stylet in situ.

Figure 5. Averaged needle tip profiles for both manufacturers (M1 and M2), sizes (19G and 17G), and stylet positions reconstructed with FBP and ASIR. There was significantly more streak artifact extending from the tip of the 17 gauge needle compared with the 19 gauge needle.

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