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CT-Guided Percutaneous Spine Biopsy Specimen Adequacy, Pathology Concordance, and Negative Predictive Value with Battery-Powered Drill and Manual Approaches

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A B S T R A C T

Objective: Determine computed tomography-guided percutaneous spine biopsy specimen adequacy, pathology-imaging concordance, and negative predictive value with battery-powered drill vs manual approach.

Materials and Methods: One-hundred-fourteen consecutive computed tomography-guided percutaneous spine biopsies in 109 patients (age: 61.1 ± 15.4 years; range: 17-90 years; males: 55, 50.5%; females: 54, 49.5%) performed at a single institution from September 2013 through January 2017 were retrospectively reviewed. Specimen adequacy was recorded. Imaging-pathology concordance was assessed. Chi-square tests compared specimen adequacy and imaging-pathology concordance obtained with a battery-powered drill vs manual approach. Negative predictive values were calculated.

Results: Battery-powered drill yielded slightly better, but not statistically significant, specimen adequacy (96% vs 90% overall, $P = 0.270$; 96% vs 89% for suspected neoplasm, $P = 0.278$; 95% vs 90% for suspected infection, $P = 0.514$), pathology-imaging concordance (82% vs 74% overall, $P = 0.301$; 92% vs 77% for suspected neoplasm, $P = 0.107$; 71% vs 65% for suspected infection, $P = 0.602$), and negative predictive value (65% vs 41% overall; 75% vs 33% for suspected neoplasm; 58% vs 33% for suspected infection). Four battery-powered drill procedures were technically unsuccessful.

Conclusions: Use of a battery-powered drill appears to yield similar to slightly better spine biopsy specimens than a manual approach, but also appears to carry a greater risk of technical failure. The battery-powered drill may be particularly helpful for procedures with complex approaches, but trajectory planning remains of paramount importance.

Introduction

Traversing cortical and medullary bone when performing a computed tomography (CT)-guided biopsy of suspected infectious or neoplastic spine lesions can be performed with a manual method, generally either with a manual drill kit or a hammering technique, or with a battery-powered electronic drill. This study directly compares the results obtained with the manual and power drill methods.

The Arrow OnControl battery-powered bone drill (Teleflex Incorporated, Morrisville, NC) has been primarily compared to manual biopsy methods for bone marrow biopsies performed by hematologists. Although the battery-powered drill tends to yield larger bone marrow core specimens and faster procedure times,[1,2] the results of specimen adequacy are slightly mixed but overall similar with the battery-powered drill and manual methods.[1−5] The same battery-powered drill has been shown to reduce bone lesion biopsy procedure time and radiation dose relative to manual biopsy methods.[6] It has also been successfully used to obtain access for radiofrequency ablation and cryoablation of benign and malignant spine tumors.[7−9] In addition, it has been demonstrated to be safe and effective for spine biopsies.[10−12]

A higher diagnostic yield for sclerotic bone lesions has been obtained with the battery-powered drill compared to manual methods.[13] However, only a portion of the biopsied lesions in that study were located in the spine. Moreover, sclerotic lesions account for only a portion of all presumed neoplastic spine lesions. The battery-powered drill and manual methods have generated similar microbiology yields in cases of suspected infectious spondylodiscitis.[14] While these studies and the bone marrow biopsy studies have evaluated the yield of positive results, they have not reported pathology-imaging concordance or the yield of results reported as definitively negative.

The purpose of this study was to determine specimen adequacy, pathology-imaging concordance, and negative predictive value achieved during CT-guided percutaneous spine biopsies performed with a battery-powered drill vs those performed with a manual approach.

Materials and Methods

This retrospective study was approved by our institutional review board and performed in compliance with Health Insurance Portability and Accountability Act. Informed consent was waived.

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Data Collection

All consecutive patients who underwent CT-guided percutaneous spine biopsy from September 2013 through January 2017 were identified by searching our institution's picture archival and communication system (PACS). The cutoff date of September 2013 was chosen due to a change in procedure coding in our PACS system at that time. The PACS procedure coding prior to September 2013 makes it difficult to search for and confidently isolate records related to specific procedure types.

The relevant imaging and charts of the identified patients were then reviewed. The following data were recorded: patient age; patient gender; indication for biopsy (suspected neoplasm, infection, or both); location of lesion; use of manual approach vs battery-powered drill; biopsy needle gauge; procedure technical success (yes/no); procedure complications (yes/no); specimen adequacy; histopathology results; microbiology results; pathology concordance with imaging features; true negative result (yes/no); antibiotic administration (no, yes prior to biopsy, yes after biopsy); treatment; follow-up results; and primary malignancy if previously known.

A procedure was considered technically successful, if specimen tissue was obtained, when the biopsy needle was confirmed by imaging to be within the lesion. The quality of tissue obtained was not factored into whether the procedure was considered technically successful. Specimen adequacy was indicated within the pathology report by the interpreting pathologist. Pathology-imaging concordance was assessed independently by 2 radiology residents. Findings were considered concordant if the final pathology report yielded a result consistent with the original imaging report and imaging features. Disagreements or uncertainties about concordance were resolved by a neuroradiology attending with 10 years of dedicated neuroradiology experience. A negative result was considered a true negative when the pathology specimen was adequate, there was no microbiology or histopathology evidence of infection or malignancy, and follow-up clinical symptoms, follow-up imaging, and/or subsequent surgical pathology supported the initial negative pathology result.

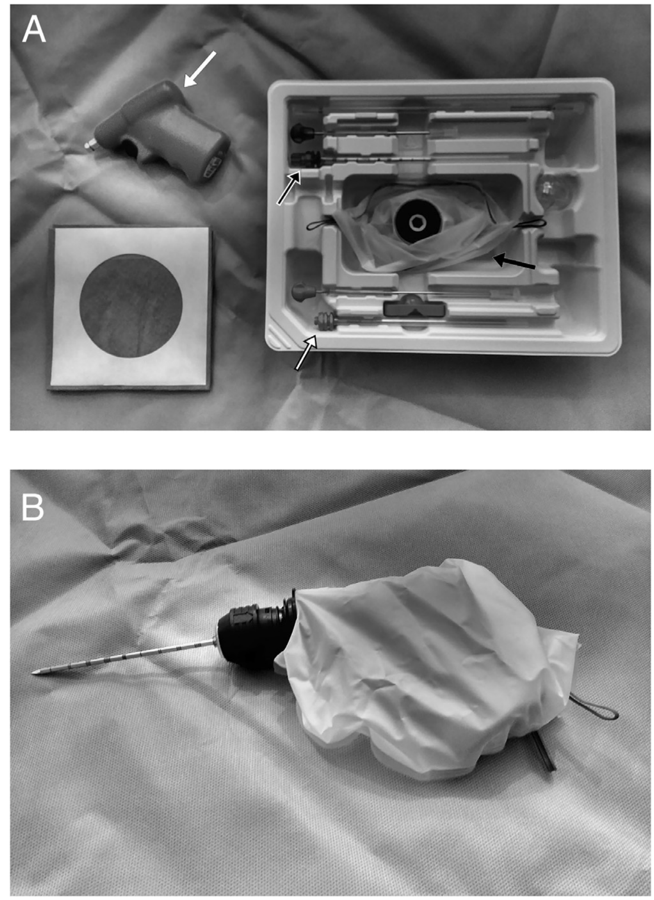

FIG 1. (A) Photograph of the OnControl reusable drill (white arrow) and drill kit, which includes a sterile bag (black arrow) to hold the drill, a drill bit within an 11 gauge introducer needle (black arrow with white border), and a 13 gauge biopsy needle (white arrow with black border) that fits within the introducer needle. (B) Photograph of the reusable drill within the sterile bag with the introducer needle and drill bit attached.

Subjects

A total of 120 consecutive procedures were identified in 111 patients. One procedure was excluded because the specimen was for research purposes and the specimen adequacy and concordance could not be appropriately assessed. One procedure was excluded because the pathology demonstrated chronic osteomyelitis but all other care was provided outside our system and therefore no notes were available to assess whether this pathology was concordant with the clinical concern or with prior imaging features. Four procedures, all performed with the power drill, were not technically successful. Procedures that were not technically successful were excluded because the primary aim of this study was to assess the quality of the samples given to pathology. All 4 of the technically unsuccessful procedures were repeated. A total of 114 procedures in 109 patients (overall age: 61.1 ± 15.4 years; range: 17-90 years; males: 55 total, age: 62.2 ± 15.7 years; females: 54 total, age: 60.0 ± 15.2 years) were thus evaluated.

Procedure Details

In all cases in which a battery-powered drill was used, the drill device was the Arrow OnControl Powered Bone Access System (Teleflex Incorporated, Morrisville, NC; Fig 1). Several different devices were used for manually obtained biopsies including the Bonopty coaxial bone biopsy system (AprioMed AB, Uppsala, Sweden). For all procedures, conscious sedation was administered. Lidocaine was

TABLE 1
CT-guided biopsy specimen adequacy and pathology-imaging concordance

	Number of procedures	Power drill total	Manual total	Power drill specimen adequate	Manual specimen adequate	Adequacy P value	Power Drill Pathology-Imaging Concordant	Manual Pathology-Imaging Concordant	Concordance P value
Total cohort	114	45	69	43 (96%)	62 (90%)	0.270	37 (82%)	51 (74%)	0.301
Neoplasm*	70	26	44	25 (96%)	39 (89%)	0.278	24 (92%)	34 (77%)	0.107
Infection*	52	21	31	20 (95%)	28 (90%)	0.514	15 (71%)	20 (65%)	0.602
Prior antibiotics	24	13	11	12 (92%)	11 (100%)	0.347	7 (54%)	6 (55%)	0.973
No prior antibiotics	28	8	20	8 (100%)	17 (85%)	0.246	8 (100%)	14 (70%)	0.081

*Neoplasm and Infection categories each include subjects for whom the concern was both neoplasm and infection, resulting in category overlap.

TABLE 2
CT-guided biopsy negative predictive value

	Power drill true negatives	Manual true negatives	Power drill true negatives to inadequate specimens	Manual true negatives to inadequate specimens	Power drill negative predictive value	Manual negative predictive value
Total cohort	13 (41%)	12 (17%)	13:2	12:7	65%	41%
Neoplasm*	6 (29%)	5 (11%)	6:1	5:5	75%	33%
Infection*	7 (33%)	7 (23%)	7:1	7:3	58%	33%
Prior antibiotics	3 (23%)	3 (27%)	3:1	3:0	38%	38%
No Prior antibiotics	4 (50%)	4 (20%)	4:0	4:3	100%	44%

*Neoplasm and Infection categories each include subjects for whom the concern was both neoplasm and infection, resulting in category overlap.

administered for superficial and deep soft tissue local anesthesia. The introducer needle was inserted under sterile conditions and advanced to the bone surface until purchase in the cortex was obtained. For manual procedures, the needle was then advanced to the lesion edge either with twisting motions or with hammering of the needle with a mallet. For battery-powered drill procedures, the needle was advanced to the lesion edge using the drill. Intermittent CT was performed to evaluate the position of the needle in all cases. Once the needle was confirmed at the edge of the lesion, the inner stylet was removed and the biopsy needle was advanced into the lesion, the positioning was confirmed with CT, and core biopsy samples were obtained. The needle system was removed and the patient was observed for at least 1 hour prior to discharge or was returned to the inpatient unit.

Statistical Analysis

All statistical analysis was performed in R 3.2.3.[15] Significance was set at $P \leq 0.05$. Logistic regressions were performed to ascertain if there was a confounding effect of needle size on the discrete dependent variables specimen adequacy and pathology-imaging concordance. Chi-square tests were calculated to examine, whether there was a significant difference between power drill and manual biopsy specimen adequacy and pathology-imaging concordance. Negative predictive values were calculated.

Results

Needle Gauge as a Potential Confounding Factor

Biopsy needle gauge did not significantly affect either specimen adequacy (odds ratio [OR] = 0.892, 95% confidence interval [CI] = 0.714-1.116) or pathology-imaging concordance (OR = 1.114, 95% CI = 0.912-1.362).

Specimen Adequacy and Pathology-Imaging Concordance

Battery-powered drill specimen adequacy was slightly, but not significantly, better than manually obtained specimen adequacy (Table 1). Similarly, pathology-imaging concordance was slightly, but not significantly, better for specimens obtained with the power drill compared to those obtained manually (Table 1). Pathology-imaging concordance almost reached statistical significance in favor of the power drill for biopsies of neoplasms (X^2 (1, N = 70) = 2.601, P = 0.107) and for biopsies of infection, when antibiotics had not been previously administered (X^2 (1, N = 28) = 3.055, P = 0.081). A total of 47 of the 70 suspected neoplasm cases, 67%, yielded positive histology. A total of 23 of the 52 suspected infection cases, 44%, yielded either positive microbiology or positive histology.

Negative Predictive Value

The ratio of true negatives to inadequate samples trended better with the battery-powered drill than with manual biopsy (Table 2).

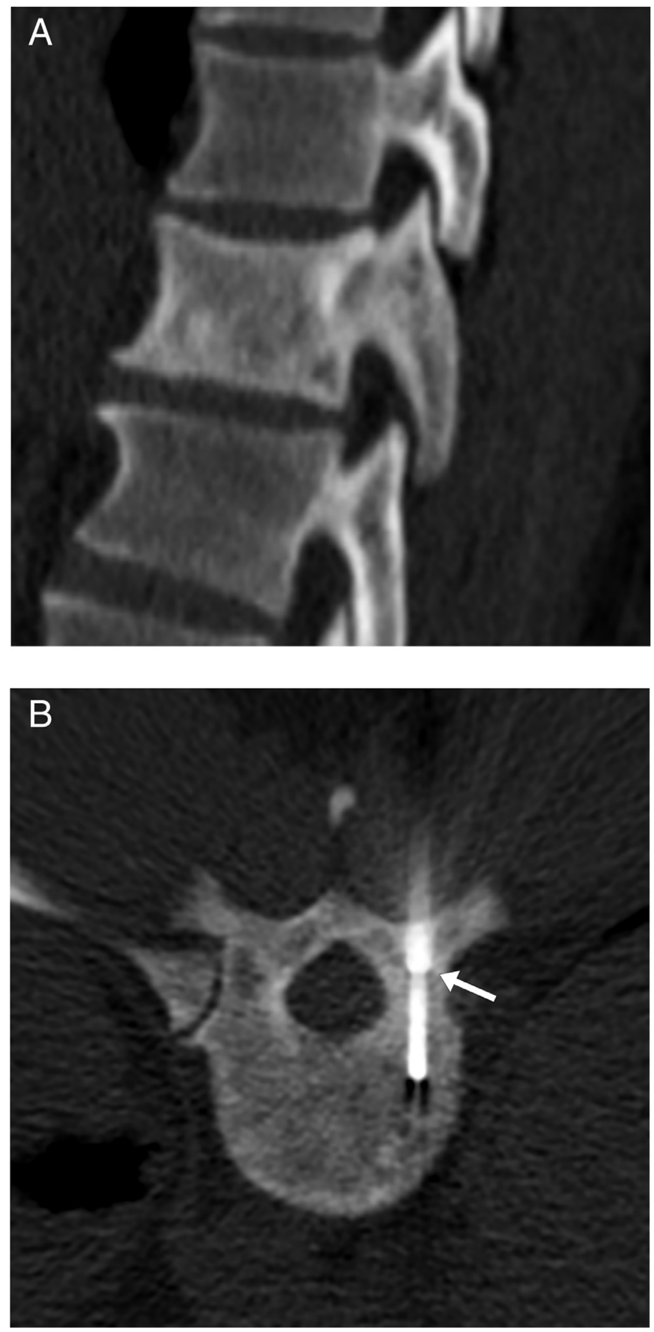

FIG 2. Forty-nine-year old male with an incidental T11 lesion. (A) Sagittal CT image in bone windows shows diffuse sclerosis and slight volume loss of the T11 vertebral body. (B) Axial intraprocedural CT image in bone windows shows the OnControl 11 gauge introducer needle terminating (arrow) in the proximal aspect of the pedicle while the OnControl 13 gauge biopsy needle traverses the pedicle and dorsal aspect of the sclerotic vertebral body. Two core biopsy specimens were obtained and the pathology report indicated reactive bone with no malignancy, suggestive of Paget's disease.

FIG 3. Twenty-six-year-old male with history of intravenous drug use presenting with lumbar back pain and history of recently treated pseudomonas infectious spondylodiscitis at L4-L5. (A) Sagittal CT image in bone windows shows erosion of the endplates at L4-L5 with surrounding sclerosis and associated intervertebral disk height loss. (B) Sagittal STIR MR image shows high signal throughout the L4-L5 vertebral bodies with high signal traversing the endplates and disk in the region of erosion. Given that these findings could be seen either with recently treated infection or ongoing/new infection, a biopsy was requested. (C) Sagittal-oblique reformatted intraprocedural CT image in bone windows shows the OnControl 11 gauge introducer needle terminating (arrow) just proximal to the L5 endplate while an 18 gauge biopsy needle inserted through the introducer needle traverses the expected location of both endplates and the L4-L5 intervertebral disk. Multiple core biopsies were obtained and the pathology report indicated minimal chronic inflammation with no acute inflammation and no diagnostic features of acute or chronic osteomyelitis.

Similarly, the negative predictive value trended better with the battery-powered drill (range: 38%-100%) than with manual biopsy (range: 33%-44%; Table 2).

Discussion

In this study, spine biopsy specimens obtained with a battery-powered drill trended toward being more adequate for pathology interpretation and trended toward better pathology-imaging concordance than specimens obtained without the drill, but neither of these findings reached statistical significance. Similarly, the negative predictive value of specimens obtained with the battery-powered drill was somewhat better than that achieved without the drill. On the other hand, 4 procedures performed with the battery-powered drill were technically unsuccessful and had to be repeated.

To place this study in perspective, our biopsy specimen adequacy (as reported by the reporting pathologist) of 89%-96%, when sampling suspected neoplasms is similar to the 77%-95% reported in prior studies.[16–18] Similarly, our biopsy specimen yield (as defined by positive gram stain and/or cultures) of 44% for infection is also similar to previously reported yields of 25%-41%.[17–20] We note that biopsy specimen adequacy, pathology-imaging concordance, and negative predictive value were superior in the setting of suspected infection in this study when antibiotics had not been previously administered.

This study raises 3 important considerations when choosing between a battery-powered drill vs manual spine biopsy approach. First, in our practice, we may convert to the battery-powered drill after beginning with a potentially unsuccessful manual approach. For example, sometimes thick cortical bone in the middle of a pedicle deflects the needle tip superolaterally, away from small biopsy targets that are located in the medial or inferior vertebral body. In such cases, after anchoring the needle in the pedicle using a manual approach, we may switch to the battery-powered drill to navigate through the cortical bone to stay on trajectory. As such, it may be that the drill confers an advantage in biopsies with similarly complex trajectories.

Second, all 4 technically unsuccessful procedures in this study occurred with the battery-powered drill. It is quite easy to inadvertently drill a centimeter or more at a time, especially through soft bone, between the serial CT imaging checks. However, once a tract is created through bone with the battery-powered drill, it is very difficult to adjust the tract if the trajectory is not accurate within 1 or 2 mm. As such, we advocate CT imaging for position confirmation after every 5 mm of needle advancement. In addition, we stress that meticulous trajectory planning is essential prior to entering the cortex, even with the battery-powered drill.

Third, in our experience, the OnControl drill can occasionally fail with very sclerotic lesions (eg, anecdotally, over 1000 Hounsfield units). In such cases, the drill stops turning when power is applied and we may switch to a manual drill, such as the Bonopty manual drill. While the procedure takes longer and is more physically difficult with the manual drill, we generally have no difficulty obtaining specimens even in extremely dense sclerotic lesions (Fig 2), such as dense prostate metastases. Thus, sometimes, the optimal approach may involve using the battery-powered OnControl drill to reach the lesion and then using a different manual device to biopsy the lesion.

Another very strong consideration should be that, in this study, a better negative predictive value was achieved when performing biopsy with the battery-powered drill (Fig 3). In other words, the pathologists at our institution were more inclined to report adequate specimens with a definitively and accurately negative result when specimens were obtained with the battery-powered drill. However, there are 2 major confounding factors: first, some operators prefer one method over the other and yield may be related to operator or trainee; second, the clinical pathologists varied from specimen to specimen and there may be an inherent reporting bias among the interpreting pathologists.

The primary limitations of this study are its retrospective nature and lack of randomization. Operator preference, lesion location, and biopsy difficulty often influenced the choice of whether to use the battery-powered drill. Similarly, technical success with either approach is likely improved with more operator experience and thus an inability to account for trainee experience makes a standardized analysis difficult. In addition, the procedures were performed by a mix of attending neuroradiologists, attending musculoskeletal radiologists, neuroradiology fellows, and musculoskeletal radiology fellows with varied experience.

Conclusions

Use of a battery-powered drill appears to yield similar to slightly better spine biopsy specimens than a manual approach, but also appears to carry a greater risk of technical failure. The battery-powered drill may be particularly helpful for procedures with complex approaches, but trajectory planning remains of paramount importance. More focused research on biopsy tract planning and considerations that would favor use of either approach would help advance this field of diagnostic image-guided interventions.

Conflict of Interest

The authors declare that they have no conflict of interest.

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